NONRESIDENT
TRAINING
COURSE

February 1998

Construction Mechanic Basic, Volume 1

NAVEDTRA 14264

Although the words "he," "him," and "his" are used sparingly in this course to enhance communication, they are not intended to be gender driven or to affront or discriminate against anyone.

PREFACE

By enrolling in this self-study course, you have demonstrated a desire to improve yourself and the Navy. Remember, however, this self-study course is only one part of the total Navy training program. Practical experience, schools, selected reading, and your desire to succeed are also necessary to successfully round out a fully meaningful training program.

THE COURSE: This self-study course is organized into subject matter areas, each containing learning objectives to help you determine what you should learn along with text and illustrations to help you understand the information. The subject matter reflects day-to-day requirements and experiences of personnel in the rating or skill area. It also reflects guidance provided by Enlisted Community Managers (ECMs) and other senior personnel, technical references, instructions, etc., and either the occupational or naval standards, which are listed in the *Manual of Navy Enlisted Manpower Personnel Classifications and Occupational Standards*, NAVPERS 18068.

THE QUESTIONS: The questions that appear in this course are designed to help you understand the material in the text.

VALUE: In completing this course, you will improve your military and professional knowledge. Importantly, it can also help you study for the Navy-wide advancement in rate examination. If you are studying and discover a reference in the text to another publication for further information, look it up.

1998 Edition Prepared by
CMC(SCW) Charles Lathan

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Sailor's Creed

"I am a United States Sailor.

I will support and defend the Constitution of the United States of America and I will obey the orders of those appointed over me.

I represent the fighting spirit of the Navy and those who have gone before me to defend freedom and democracy around the world.

I proudly serve my country's Navy combat team with honor, courage and commitment.

I am committed to excellence and the fair treatment of all."

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SUMMARY OF CONSTRUCTION MECHANIC BASIC

VOLUME 1

Construction Mechanic Basic, Volume 1, NAVEDTRA 14264, consists of chapters on Technical Adminstration; Principles of an Internal Combustion Engine; Construction of an Internal Combustion Engine; Gasoline Fuel Systems; Fuel Diesel Fuel Systems; and Cooling and Lubricating Systems.

VOLUME 2

Construction Mechanic Basic, Volume 2, NAVEDTRA 14273, consists of chapters on Basic Automotive Electricity; Automotive Electrical Circuits and Wiring; Hydraulic and Pneumatics Systems; Automotive Clutches and Transmissions; Drive Lines, Differentials, Axles, and Power Train Accessories; Construction Equipment Power Trains; Brakes; and Automotive Chassis and Body.

INSTRUCTIONS FOR TAKING THE COURSE

ASSIGNMENTS

The text pages that you are to study are listed at the beginning of each assignment. Study these pages carefully before attempting to answer the questions. Pay close attention to tables and illustrations and read the learning objectives. The learning objectives state what you should be able to do after studying the material. Answering the questions correctly helps you accomplish the objectives.

SELECTING YOUR ANSWERS

Read each question carefully, then select the BEST answer. You may refer freely to the text. The answers must be the result of your own work and decisions. You are prohibited from referring to or copying the answers of others and from giving answers to anyone else taking the course.

SUBMITTING YOUR ASSIGNMENTS

To have your assignments graded, you must be enrolled in the course with the Nonresident Training Course Administration Branch at the Naval Education and Training Professional Development and Technology Center (NETPDTC). Following enrollment, there are two ways of having your assignments graded: (1) use the Internet to submit your assignments as you complete them, or (2) send all the assignments at one time by mail to NETPDTC.

Grading on the Internet: Advantages to Internet grading are:

- you may submit your answers as soon as you complete an assignment, and
- you get your results faster; usually by the next working day (approximately 24 hours).

In addition to receiving grade results for each assignment, you will receive course completion confirmation once you have completed all the assignments. To submit your assignment answers via the Internet, go to:

http://courses.cnet.navy.mil

Grading by Mail: When you submit answer sheets by mail, send all of your assignments at one time. Do NOT submit individual answer sheets for grading. Mail all of your assignments in an envelope, which you either provide yourself or obtain from your nearest Educational Services Officer (ESO). Submit answer sheets to:

COMMANDING OFFICER
NETPDTC N331
6490 SAUFLEY FIELD ROAD
PENSACOLA FL 32559-5000

Answer Sheets: All courses include one "scannable" answer sheet for each assignment. These answer sheets are preprinted with your SSN, name, assignment number, and course number. Explanations for completing the answer sheets are on the answer sheet.

Do not use answer sheet reproductions: Use only the original answer sheets that we provide—reproductions will not work with our scanning equipment and cannot be processed.

Follow the instructions for marking your answers on the answer sheet. Be sure that blocks 1, 2, and 3 are filled in correctly. This information is necessary for your course to be properly processed and for you to receive credit for your work.

COMPLETION TIME

Courses must be completed within 12 months from the date of enrollment. This includes time required to resubmit failed assignments.

PASS/FAIL ASSIGNMENT PROCEDURES

If your overall course score is 3.2 or higher, you will pass the course and will not be required to resubmit assignments. Once your assignments have been graded you will receive course completion confirmation.

If you receive less than a 3.2 on any assignment and your overall course score is below 3.2, you will be given the opportunity to resubmit failed assignments. **You may resubmit failed assignments only once**. Internet students will receive notification when they have failed an assignment--they may then resubmit failed assignments on the web site. Internet students may view and print results for failed assignments from the web site. Students who submit by mail will receive a failing result letter and a new answer sheet for resubmission of each failed assignment.

COMPLETION CONFIRMATION

After successfully completing this course, you will receive a letter of completion.

ERRATA

Errata are used to correct minor errors or delete obsolete information in a course. Errata may also be used to provide instructions to the student. If a course has an errata, it will be included as the first page(s) after the front cover. Errata for all courses can be accessed and viewed/downloaded at:

http://www.advancement.cnet.navy.mil

STUDENT FEEDBACK QUESTIONS

We value your suggestions, questions, and criticisms on our courses. If you would like to communicate with us regarding this course, we encourage you, if possible, to use e-mail. If you write or fax, please use a copy of the Student Comment form that follows this page.

For subject matter questions:

E-mail: n314.products@cnet.navy.mil
Phone: Comm: (850) 452-1001, Ext. 1826
DSN: 922-1001, Ext. 1826
FAX: (850) 452-1370
(Do not fax answer sheets.)
Address: COMMANDING OFFICER
NETPDTC (CODE 314)
6490 SAUFLEY FIELD ROAD
PENSACOLA FL 32509-5237

For enrollment, shipping, grading, or completion letter questions

E-mail: fleetservices@cnet.navy.mil
Phone: Toll Free: 877-264-8583
Comm: (850) 452-1511/1181/1859
DSN: 922-1511/1181/1859
FAX: (850) 452-1370
(Do not fax answer sheets.)
Address: COMMANDING OFFICER
NETPDTC (CODE N331)
6490 SAUFLEY FIELD ROAD
PENSACOLA FL 32559-5000

NAVAL RESERVE RETIREMENT CREDIT

If you are a member of the Naval Reserve, you will receive retirement points if you are authorized to receive them under current directives governing retirement of Naval Reserve personnel. For Naval Reserve retirement, this course is evaluated at 8 points. (Refer to *Administrative Procedures for Naval Reservists on Inactive Duty*, BUPERSINST 1001.39, for more information about retirement points.)

COURSE OBJECTIVES

In completing this nonresident training course, you will demonstrate a knowledge of the subject matter by correctly answering questions on the following subjects: Technical Administration; Principles of an Internal Combustion Engine; Construction of an Internal Combustion Engine; Gasoline Fuel Systems; Diesel Fuel Systems; and Cooling and Lubricating Systems.

Student Comments

Course Title: *Construction Mechanic Basic, Volume 1*

NAVEDTRA: 14264 **Date**: ______________________

We need some information about you:

Rate/Rank and Name: ______________________ SSN: _____________ Command/Unit ___________________

Street Address: ___________________________ City: _____________ State/FPO: _________ Zip ________

Your comments, suggestions, etc.:

Privacy Act Statement: Under authority of Title 5, USC 301, information regarding your military status is requested in processing your comments and in preparing a reply. This information will not be divulged without written authorization to anyone other than those within DOD for official use in determining performance.

NETPDTC 1550/41 (Rev 4-00)

CHAPTER 1

TECHNICAL ADMINISTRATION

LEARNING OBJECTIVE: *Identify personnel, their functions, and requited paper work to administer a Battalion Equipment Maintenance Program; recognize maintenance support requirements for a Civil Engineering Support Equipment (CESE) maintenance program.*

The higher you ascend on the enlisted ladder, the more valuable you are to the Navy. Advancement brings both increased rewards and responsibilities. You must be able to perform various administrative duties within the Construction Mechanic rating, such as opening and closing of equipment repair orders, maintaining history jackets, updating preventive maintenance record cards, and ordering direct turnover (DTO) or repair parts. The type of activity to which you are attached will determine the way you should carry out your administrative responsibilities.

In this chapter, technical administration as it relates to the Naval Construction Force is discussed. It is primarily concerned with maintenance administration and maintenance support.

MAINTENANCE ADMINISTRATION

LEARNING OBJECTIVE: *Recognize the principles and techniques of administering the Civil Engineering Support Equipment (CESE) maintenance program.*

Administrative guidelines concerning Civil Engineering Support Equipment (CESE) maintenance are contained *in* NAVFAC P-300, *Management of Civil Engineering Support Equipment* and *COMSECONDNCB/COMTHIRDNCBINST 11200.1.*

MAINTENANCE ORGANIZATION

The organization of an equipment maintenance section varies depending upon several factors: number and type of assigned equipment, number and experience of personnel, working hours, number of shifts, environmental conditions, and the mission of the activity. The organization discussed in this chapter is based upon the operation of a typical Naval Mobile Construction Battalion (NMCB). The functions discussed are also applicable to small activities where one person may be required to perform several functions.

Maintenance Supervisor

The maintenance supervisor is the senior mechanic assigned to an activity, usually a senior chief. This supervisor is responsible for the maintenance program for all assigned Civil Engineer Support Equipment (CESE) and all personnel involved. The maintenance supervisor directly supervises the inspectors, the shop supervisors, the preventive maintenance and cost control clerks, the technical librarian, and the toolroom and parts expediters.

Some of the maintenance supervisors responsibilities are to enforce all established maintenance policies, approve all repair actions before accomplishment, approve requisitions for procurement of Not-In-Stock (NIS) and Not-Carried (NC) materials, maintain shop work load files, make all decisions concerning deadline CESE, control transfer and disposal of CESE, supervise the preventive maintenance (PM) program, and control shop tools and kits. The maintenance supervisor also initiates action when, during maintenance procedures, equipment abuse or misuse is suspected

Shop Supervisor

The typical NMCB maintenance organization is divided into three shops: the heavy shop, the light shop, and the support shop. Each shop is supervised by a shop supervisor. This position is held by a chief or senior first class petty officer, who is responsible for the quality of maintenance and repairs performed by personnel within the shop. The shop supervisor is also responsible for ensuring that the equipment repair order (ERO) is complete with length of time, initials, materials list, and any required requisitions.

Crew Leader

The crew leader is a second or senior third class petty officer.. This person is responsible for ensuring the job gets done. When assigned a job, the crew leader must determine what member of the crew is to do what work, what tools and repair parts are required, identify special safety precautions to be observed, and what priority the job has. A crew may be assigned more than one job at a time. Once the job is assigned, it is the crew leader's "baby." The crew leader is also responsible for ensuring that crew time is reported, that all materials used on the job are recorded, and that any unscheduled repairs are reported to the shop supervisor.

Inspector

Inspectors examine equipment for needed repairs and services. They work directly for and are responsible to the maintenance supervisor. Inspectors should be first class or senior second class petty officers. They must be knowledgeable and proficient in their rating, and they should be able to describe each repair action on the ERO clearly.

Before the initial inspection is performed, an inspector should review the equipment history jacket. The inspector is responsible for reviewing previous EROs for follow-up adjustments from previous repairs and maintenance schedule and lubrication charts to initiate hourly/mileage repairs or adjustments. He also reviews the DTO file for parts recieved to perform deferred repairs. Inspectors may perform minor work that pertains to inspection procedures only. Inspectors should inform the maintenance supervisor of suspected equipment abuse or misuse and recurring component failures immediately.

Each piece of equipment is inspected after repairs are completed to ensure that the work was done correctly. Thorough final inspection increases reliability and reduces the mechanic's work load.

Cost Control Supervisor

The cost control supervisor is usually a first class petty officer who is responsible for adminstrative control of the equipment maintenance program. The cost control supervisor works directly for and responsible to the maintenance supervisor. The cost control supervisor directly supervises the PM clerk, the DTO clerk, the tool custodian, and the technical librarian.

Some of the cost control supervisor's responsibilities are to draft all maintenance related correspondence such as monthly CESE reports, receipt messages and letters, disposal letters, 1348s and material-handling equipment (MHE) reports. The cost control supervisor also, completes EROs, forwards downloads to 3rd NCB equipment office, tracks daily and weekly equipment availability, maintains the deadline equipment file, and NORS/ANORS status board.

Preventive Maintenance Clerk

The preventive maintenance clerk controls the PM program directed by the maintenance supervisor. The PM clerk places all CESE into PM groups, prepares the PM schedule, and maintains the PM record cards with the preventive maintenance history of each vehicle. The PM clerk is responsible for controlling EROs. maintaining the ERO log, maintaining and updating equipment history jackets, and updating equipment status boards in the maintenance office. The PM clerk also summarizes the total cost of repairs and of labor expended and makes appropriate entries on the ERO.

Direct Turnover Clerk

The direct turnover (DTO) clerk maintains the maintenance shop's repair parts status and accountability records and is a liaison between the supply office and the shop. All requisitions for Not-in-Stock (NIS) and Not-Carried (NC) material must pass through the DTO clerk who maintains the DTO log and repair parts summary sheets. The DTO clerk also maintains the deadline file and deadline status board.

Technical Librarian

Technical librarians are responsible for the prepacked library that contains operational, maintenance, and parts manuals. They establish and enforce check-out procedures for the manuals and initiate parts requisitions (NAVSUP 1250s and DD Form 1348s). The task of researching and preparing the requisitions is handled by the technical librarian, so the floor mechanics can perform maintenance functions.

MAINTENANCE CATEGORIES

The goal of maintenance is to maintain equipment in a safe and serviceable condition at all times at a reasonable cost and to detect minor deficiencies before they develop into costly repairs. The CESE maintenance system of the NCF is predicated on three categories or levels of maintenance as prescribed in NAVFAC P-300 and CONSECONDNCB/ COMTHIRDNCBINST 11200.1. These three levels are as follows: ORGANIZATIONAL, INTERMEDIATE, and DEPOT. The category of repairs performed are determined by the nature of the repair; level of repair parts, support, tools, equipment and time available; personnel capabilities; and the tactical situation. An activity's range of repair parts support is keyed to the authorized level of maintenance.

Organizational Maintenance

Organizational maintenance is the responsibility of and performed by the equipment operator; scheduled preventive maintenance services are performed by trained personnel. Operational maintenance consists of proper equipment operation, safety and serviceability inspections, lubrication, and minor adjustments and services. Organizational maintenance is divided into operator maintenance and preventive maintenance as specified below.

1. Operator Maintenance. Each operator is required to perform work needed. to maintain their vehicle in a clean, safe, and serviceable condition. This includes the daily inspections before, during, and after operation. It also includes periodic lubrication and adjustments recommended by the equipment manufacturer. Operator maintenance is performed to ensure early detection of deficiencies.

2. Preventive Maintenance. Preventive maintenance (PM) is scheduled for the purpose of maximizing equipment availability and minimizing repair costs. PM consists of safety and mechanical inspections, fluid and filter changes, lubrication, and services and adjustments beyond an operator's responsibility. Operators assist with the work unless directed otherwise.

Intermediate Maintenance

Intermediate maintenance is the responsibility of and performed by a designated maintenance shop. The extent of intermediate maintenance encompasses the removal, replacement, repair, alteration, calibration, modification, and the rebuilding and overhauling of individual components, assemblies, and subassemblies. Although the rebuilding and overhauling of major assemblies are included, only essential repairs must be accomplished to ensure safe and serviceable equipment. Intermediate maintenance requires a higher degree of skill than organizational maintenance. There is a larger assortment of repair parts, more precision tools, and other types of test equipment involved.

Equipment that requires extensive repairs or numerous assembly rebuilds must NOT be repaired without prior approval of higher authority. Field units must request authority from COMSECONDNCB Equipment Det, Gulfport, Mississippi, or COMTHIRDNCB Equipment Det, Port Hueneme, California, before purchasing component parts in excess of $2,500.

Depot Maintenance

Depot maintenance is performed on equipment requiring major overhaul or comprehensive restoration to return an item of equipment to a "like-new" condition. Depot level maintenance uses production line and assembly line methods whenever practical.

At this point, you should only be concerned with organizational and intermediate maintenance. Most depot maintenance is performed by overhaul facilities located at Port Hueneme, California, and Gulfport, Mississippi.

MAINTENANCE SCHEDULING

The only type of maintenance that can be performed on a regular basis is preventive maintenance. A dynamic PM program reduces equipment downtime and prevents unexpected equipment failure. PM scheduling provides a balanced shop work load, thus reducing the size of the work force required. Once the PM schedule of an activity has been established, only the maintenance supervisor can authorize deviations. The PM scheduling system used in the NCF is the only system discussed here. The standard interval between PMs is 40 working days.

PM Groups

PM groups are scheduling units into which all of the equipment of an activity is distributed evenly. Each item of CESE must be assigned to at least one PM group. The equipment should be distributed evenly throughout the 40 PM groups, so only a minimum number of similar pieces of equipment are out of service at any one time. The normal grouping works like this: If there are ten dump trucks within the inventory, one should be assigned to every fourth PM group; if there are four water distributors, assign one to every tenth PM

SAMPLE PM SCHEDULE

ACTIVITY ______________________

YEAR ______________

PM SCHED. GROUP	MONTH AND DAY SCHEDULE											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	21		19		14		11		6		1	
2	22		20		15		12		9		4	
3	23		21		16		15		10		5	
4	24		22		17		16		11		6	
5	25		25		20		17		12		7	
6	28		26		21		18		13		8	
7	29		27		22		19		16		12	
8	30		28		23		22		17		13	
9	31		29		24		23		18		14	
10		1		1	27		24		19		15	
11		4		2	28		25		20		18	
12		5		3	29		26		23		20	
13		6		4	31		29		24		21	
14		7		5		3	30		25		22	
15		8		8		4	31		26		25	
16		11		9		5		1	27		26	
17		12		10		6		2	30		27	
18		13		11		7		5		1	29	
19		14		12		10		6		2		2
20		15		15		11		7		3		3
21		18		16		12		8		4		4
22		19		17		13		9		7		5
23		20		18		14		12		8		6
24		21		19		17		13		9		9
25		25		22		18		14		10		10
26		26		23		19		15		11		11
27		27		24		20		16		14		12
28	2	28		25		21		19		15		13
29	3		1	26		24		20		16		16
30	4		4	29		25		21		17		17
31	7		5	30		26		23		18		18
32	8		6		1	27		26		221		19
33	9		7		2	28		27		22		20
34	10		8		3		1	28		23		21
35	11		11		6		2	29		24		24
36	14		12		7		3	30		25		26
37	15		13		8		5			28		27
38	16		14		9		8		3	29		30
39	17		15		10		9		4	30		31
40	18		18		13		10		5	31		

CMB10001

Figure 1-1.—Sample preventive maintenance inspection schedule.

group and so on. The equipment should be grouped so a unit that works together is scheduled for the same PM group; for example, semitrailers with truck tractors, scrapers with tractors, and so on. Activities should assign each piece of equipment to one PM group initially. After the system is established and operating, the maintenance supervisor should review its effectiveness and REDUCE the intervals for high mileage/hour items of equipment, if necessary. The time interval is NEVER INCREASED beyond 40 working days.

Preventive Maintenance

A preventive maintenance inspection schedule, such as the one shown in figure l-l, should be established annually. A new schedule is required each year, as the schedules are based on the workdays in each calendar year. The workdays on the schedule must correspond to the actual workdays of the unit; for example, if you work a 5-day week, enter 5 days; omit holidays. The PM groups are numbered vertically down the first column. Figure 1-1 shows the standard 40 PM group concept arranged for a 5-day workweek. The dates of the workdays of January are then listed consecutively in the January column. After the last workday in January is entered, continue with workdays in the February column and so forth. After completion, the schedule indicates the workdays that each PM group is due for inspection. For example, figure 1-1 shows PM group 5 is due on January 8, March 6, May 1, June 27, August 23, October 23, and December 19.

OPERATOR'S INSPECTION GUIDE AND TROUBLE REPORT

REGISTRATION NO.	ODOMETER READING
94-75111	7581

Use this form as a guide when performing before and after operation inspection. Check (✓) items that require servicing by maintenance personnel.

	1. DAMAGE (Exterior, Interior, Missing Components)
✓	2. LEAKS (Oil, Gas, Water)
	3. TIRES (Check Inflation, abnormal wear)
	4. FUEL, OIL, WATER SUPPLY (Antifreeze in season)
	5. BATTERY (Check water level, cables, etc.)
	6. HORN
	7. LIGHTS/REFLECTORS/MIRRORS/TURN SIGNALS
	8. INSTRUMENTS (Oil, Air, Temperature, etc.)
	9. WINDSHIELD WIPER
	10. CLEAN WINDSHIELD/VEHICLE INTERIOR
	11. CARGO, MOUNTED EQUIPMENT
	12. STEERING
	13. SAFETY DEVICES (Seatbelts, flares, etc.)
	14. DRIVE BELTS/PULLEYS
	15. BRAKES (Drain air tank when equipped)
	16. OTHER (Specify in "Remarks")

DATE	OPERATOR'S SIGNATURE
01 Jul 1997	Jim Seabee

REMARKS

OIL LEAK BOTTOM OF OIL PAN

NAVFAC 9-11240 13 (12-89)
Supersedes DD Form 1358
*U.S. Government Printing Office: 1983 683-006-1060
S/N 0105-LF-004-1195

CMB10002

Figure 1-2.—Operator's Inspection Guide and Trouble Report, NAVFAC 9-11240/13.

MAINTENANCE INSPECTIONS

The object of a maintenance inspection is to detect minor deficiencies before they develop into costly major repairs. This is done daily by the operator and regularly scheduled preventive maintenance.

Operator

The first sign of vehicle trouble is usually detected by the operator during one of the three daily inspections: before, during, and after operation.

The BEFORE OPERATION (prestart) inspection consists of an operator inspecting the items listed on the Operator's Inspection Guide and Trouble Report, NAVFAC 9-11240/13 (fig. 1-2). If a defect is discovered, the equipment **SHOULD NOT BE OPERATED.** The defect must be reported to the dispatcher who, in turn, will report it to the maintenance section.

The DURING OPERATION inspection consists of an operator using the sense of smell, sight, and touch to detect improper operation. When a defect is discovered during operation, the equipment should be secured and the problem reported to either the supervisor or the dispatcher.

The AFTER OPERATION (post operation) inspection consists of an operator looking over the equipment while performing established shutdown procedures and reporting defects to the dispatcher.

Preventive Maintenance

Preventive maintenance inspections consist primarily of safety and serviceability inspections and are performed by using the *Automotive and Construction Preventive Maintenance Guides* listed in the COMSECONDNCB/COMTHIRDNCBINST

11200.1. The type of PM inspection is determined and controlled as follows:

- Type "A" (01)—At intervals of 40 working days. It is performed on each scheduled PM due date until a vehicle qualifies for a type "B" PM.
- Type "B" (02)—PMs are based on the equipment manufacturer's recommendations/ specifications for milage/hours usage required to initiate a "B" (02) for fluid and filter change, major adjustments or scheduled maintenance as required. For example, a 5-ton dump truck could undergo three or four "A" (01) PMs before accumulating the required milage/hours for a "B" (02) PM.
- Type "C" (03)—Annual safety inspection (ASI), as per manufacturer's recommendations/ specifications.

Deadline Vehicle

Deadline inspections are particularly critical to ensure equipment does not deteriorate. Deadline inspections are performed at each regularly scheduled PM. An 01 level PM is accomplished on all deadline CESE. The equipment is inspected to ensure the following:

- All openings are covered and weathertight.
- All machined surfaces are preserved.
- All disassembled components are tagged, covered, and stored.
- No cannibalization has taken place since the last inspection (controlled parts interchange is not approved as a normal procedure; however, the maintenance supervisor only may authorize it to meet operational commitments).
- Parts removed from deadline equipment should be replaced with non-serviceable items, and the maintenance supervisor must ensure that replacement parts are ordered "Not Operationally Ready for Supply (NORS)." This should be done using a priority applicable to mission accomplishment.
- All replacement parts, costs, and labor hours related to the interchange should be charged against the item of equipment on which the part failed. When the replacement parts are received and installed, only the labor involved should be charged to the piece of equipment from which the interchange part was taken.

Whenever possible, deadline inspections should include cycling (checking components for proper operation). For example, if a truck is deadlined for an axle, you can still start the engine and ensure that it runs properly. When cycling is accomplished, make sure that all required preservation is accomplished. Equipment is considered deadlined when it does not perform as designed or when it is in need of parts that are not on hand.

Accident

Accident safety inspections "12" ERO are initiated on all CESE involved in a mishap, regardless of damage and is commonly used for estimates. This inspection ensures that a vehicle is in safe condition before being released for operation Any repairs and parts required must be charged against this Equipment Repair Order (ERO). No preventive maintenance should be performed. When preventive maintenance is required, the type "12" ERO should be closed and another ERO opened for the maintenance required.

PM RECORD CARDS

A Vehicle/Construction Equipment Preventive Maintenance Record Card, NAVFAC 11240/6 (fig. 1-3) must be accurately maintained for each item of assigned equipment and attachments to assist the PM clerk in preparing an ERO. PM record cards are maintained by PM groups in a tickler file, and the following information is to be recorded from the completed preventive maintenance EROs:

- Type of PM service performed
- Date performed
- Cumulative mileage/hours
- Oil change or filter change (indicated by O/C or F/C)
- Fuel filter change (indicated by FF/C)
- Hydraulic filter change (indicated by HF/C)

CESE with assigned attachments are identified on the PM record card by a colored tab to ensure attachments are given PM inspections with the assigned equipment, and each attachment and attachment code are listed on the back of the PM record card. The PM

ASSIGNED TO	PHONE	TYPE OF ASSIGNMENT	EQUIP. CODE	CE NO.	PM GROUP
NMCB ______		______	423001	______	13
MAKE	**MODEL**	**TYPE**	**YEAR**	**EST. ANNUAL MI/HRS**	**USN REG. NO.**
BUCYRUS ERIE	30B	D	82	______	42-03317

TYPE PM	DATE	CUMULATIVE MILEAGE OR HRS. OPN.	MILES (OR HRS) SINCE LAST PM	MILES (OR HRS) REPORTED FOR 6 MO. PERIOD	TYPE PM	DATE	CUMULATIVE MILEAGE OR HRS. OPN.	MILES (OR HRS) SINCE LAST PM	MILES (OR HRS) REPORTED FOR 6 MO. PERIOD
LAST A	2-4-88	1945	ENTRIES TRANSFERRED FROM PRIOR RECORD						
LAST B	6-5-88	2259							
LAST C	4-1-88	2060							
07	6-1-88	2100	SFL,LC,SB,	SAC					
01	7-26-88	2156	SFL,LC,SB,	SAC					
01	9-21-88	2340	SFL,LC,SB,	SAC					
02	11-16-88	2510	COF,CFF,OC	LC,SFL					

VEHICLE/CONSTRUCTION EQUIPMENT PM RECORD NAVFAC 11240/6 (2 78)

(Front)

TYPE PM	DATE	CUMULATIVE MILEAGE OR HRS. OPN.	MILES (OR HRS) SINCE LAST PM	MILES (OR HRS) REPORTED FOR 6 MO. PERIOD	TYPE PM	DATE	CUMULATIVE MILEAGE OR HRS. OPN.	MILES (OR HRS) SINCE LAST PM	MILES (OR HRS) REPORTED FOR 6 MO. PERIOD
					A14000		FAIRLEAD	1	
					A04000		BOOM TIP	1	
					A03500		BOOM JIB	1	
					A02500		BOOM BUTT	1	
					A11500		CRANE HOOK	1	
					A03000		BOOM EXT	3	
					A23500		TAGLINE	1	

NAVFAC 11240/6 (2-78) BACK

U.S. GOVERNMENT PRINTING OFFICE: 1980-603-

(Back)

CMB10003

Figure 1-3.—Vehicle/Construction Equipment PM Record Card, NAVFAC Form 11240/6.

record cards are returned to the equipment history jacket whenever CESE is transferred or the card is full.

REPAIR ORDERS

The Navy uses repair orders to specify, authorize, and control repairs on all USN-numbered equipment. The repair orders also serve as a reporting document from which information can be extracted to provide an activity with a complete picture of how their maintenance program is doing. They also provide complete historical cost and utilization information for each piece of CESE; therefore, the information contained on the repair orders must be neat, complete, and accurate. This cannot be overemphasized.

Shop Repair

The Shop Repair Order (SRO) and its Continuation Sheet (figs. 1-4 and 1-5) are used mainly in Public Works activities. The SRO is a three-part snap out set. It is required each time labor exceeds 0.3 of an hour, or material is expended on a piece of USN-numbered equipment. Instructions for using an SRO are contained in the NAVFAC P-300 manual.

Equipment Repair

The Equipment Repair Order (ERO), NAVFAC Form 11200/41 (figs. 1-6 and 1-7). wasdesigned for use by all Naval Construction Force units to record types of repairs and the total time a piece of equipment is out of service. Accumulation of such data provides reliable information to plan the budget, to determine

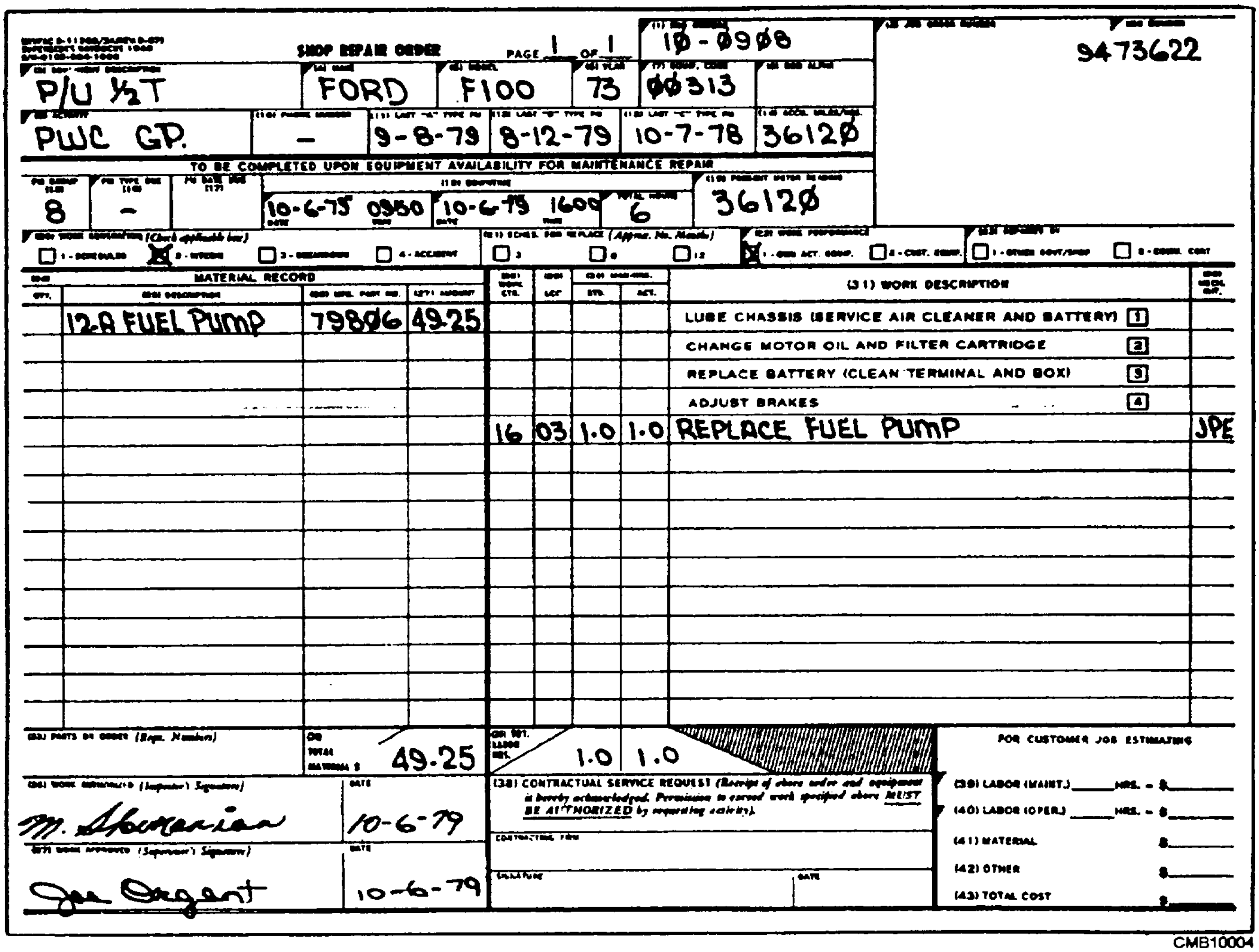
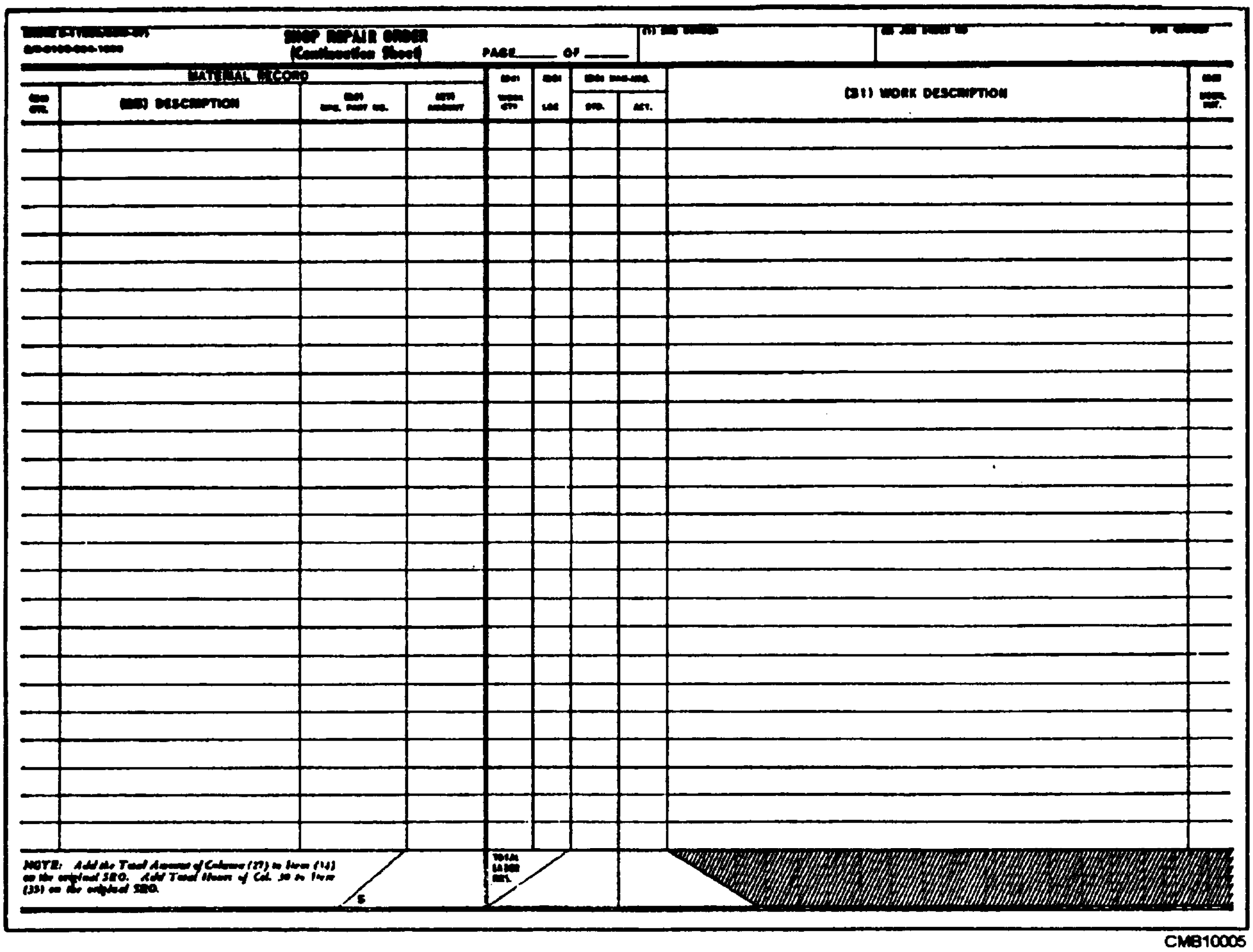

SHOP REPAIR ORDER PAGE 1 OF 1
10-0908
9473622
P/U ½T | FORD | F100 | 73 | 00313
PWC GP. | – | 9-8-79 | 8-12-79 | 10-7-78 | 36120
TO BE COMPLETED UPON EQUIPMENT AVAILABILITY FOR MAINTENANCE REPAIR
8 | – | 10-6-79 0950 | 10-6-79 1600 | 6 | 36120
MATERIAL RECORD
12-A FUEL PUMP | 79806 | 49.25
(31) WORK DESCRIPTION
LUBE CHASSIS (SERVICE AIR CLEANER AND BATTERY) 1
CHANGE MOTOR OIL AND FILTER CARTRIDGE 2
REPLACE BATTERY (CLEAN TERMINAL AND BOX) 3
ADJUST BRAKES 4
16 | 03 | 1.0 | 1.0 | REPLACE FUEL PUMP | JPE
TOTAL MATERIAL $ 49.25 | 1.0 | 1.0
FOR CUSTOMER JOB ESTIMATING
(38) CONTRACTUAL SERVICE REQUEST
(39) LABOR (MAINT.) ____ HRS. - $____
(40) LABOR (OPER.) ____ HRS. - $____
(41) MATERIAL $____
(42) OTHER $____
(43) TOTAL COST $____
10-6-79
10-6-79
CMB10004

Figure 1-4.—Shop Repair Order (SRO).


SHOP REPAIR ORDER
(Continuation Sheet)
PAGE ____ OF ____

MATERIAL RECORD

(25) DESCRIPTION

(31) WORK DESCRIPTION

NOTE: Add the Total Amount of Column (27) to Item (14) on the original SRO. Add Total Hours of Col. 30 to Item (35) on the original SRO.

CMB10005

Figure 1-5.—Shop Repair Order Continuation Sheet.

economical life expectancies, and to predict future equipment and training requirements. The Equipment Repair Order Continuation Sheet, NAVFAC Form 11200/41A (fig. 1-8), is used with the ERO when the number of repair items exceeds the spaces provided on the ERO. An Equipment Repair Order Work Sheet, NAVFAC 11200/41B (fig. 1-9), should be used to record repair parts use and be filed with the completed ERO in the equipment history jacket. The ERO and the ERO Continuation Sheet are five part, multicolored (white, blue, green, yellow, and pink) snap sets. The green copy is the mechanic's working copy.

The ERO is the sole authority to perform work on CESE in the following categories, regardless of the location of the equipment, in the field or in the shop:

- Scheduled maintenance (PM)
- Field repairs
- Accident repair
- Interim repairs that exceed 1.0 man-hour or require repair parts
- Modernization or alteration of equipment
- Deadline cycling or preservation of equipment

Control of each ERO is required to prevent having two or three EROs open for the same piece of

EQUIPMENT REPAIR ORDER (ERO)
NAVFAC 11200/41 (Rev. 10 75)

USN ID NUMBER	COST CODE	ACTIVITY UIC	JOB ORDER NUMBER	LOCATION ALLOWANCE	TYPE REPAIR	HOURMETER READING	MILE METER READING	ERO NUMBER
4813Ø87	485ØØ1	N55ØØØ	PMG1	CB400	Ø2	2617		AAØØØØØ1

	A. DIRECT LABOR	B. INSPECTION	C. INDIRECT LABOR	D. MATERIAL	E. TOTALS
ESTIMATED HOURS					
ACTUAL HOURS	12.2	1.Ø	.2		ØØØØ14
ESTIMATED COST					
ACTUAL COST (WHOLE $)				188	

	TIME	JULIAN DATE
A. EQPT AVAILABLE	11ØØ	833Ø8
B. INSPECTION START	1315	833Ø8
C. SHOP START	1415	83308
D. STOP FOR PARTS	Ø93Ø	8331Ø
E. PARTS AVAILABLE	1ØØØ	83321
F. STOP FOR PARTS		
G. PARTS AVAILABLE		
H. COMPLETED	Ø83Ø	83322

WORK PERFORMED: [X] SHOP [ ] CONTRACTED [ ] OTHER

MAKE	MODEL
IHC	TD2Ø B
ENGINE MFG	ENGINE MODEL
IHC	DT429

ENGINE SERIAL NUMBER: TD20BPM510
YR / LAST PM DATE: 79 B3150
DESCRIPTION: TRACTOR CRAWLER
CHASSIS SERIAL NUMBER: TD20BP4001

W/C	FUNCTION CODE	WORK DESCRIPTION (MECHANIC NOTIFY SUPERVISOR OF ALL ADDITIONAL WORK)	PRI/SEC	MANHOURS ACTUAL	MANHOURS ESTIMATE	ESTIMATED MAT'L COST	MECH INITIALS
	12 X	Steam Clean		4.0			
	23 X	Change Oil and Filters		1.0			
	Ø1 X	Lube Complete		1.0			
	Ø4 X	Change Fuel Filters		.5			
	11 X	Clean and Service Batteries		.6			
	1Ø X	Service Air Cleaners		.3			
		Replace Rain Cap			on order		
	F5 5	Replace #6 Fuel Injector		1.8			
	N9 4	Adjust R/H Steering Brake		3.0			
		SUB TOTALS		12.2			

RECEIPT OF ABOVE ORDER AND EQUIPMENT IS HEREBY ACKNOWLEDGED

PERMISSION TO EXCEED WORK ON ERO MUST BE AUTHORIZED BY REQUESTING ACTIVITY

CMB10006

Figure 1-6.—Equipment Repair Order (ERO), NAVFAC 11200/41.

TYPE REPAIR (BLICK 6)

01 A PM
02 B PM
03 C PM
04 Interim Repair
05 Overhaul
06 Breakdown (Field Repair)
07 Acceptance
08 Repair for Stock
09 Preservation and Storage Maintenance
10 Warranty
11 Rework
12 Accident
13 Shipping Inspection (CED)
14 Surveillance Inspection (CED)
15 Operational Test (CED)

FUNCTIONAL CODES (BLOCK 45)
SERVICES

01x Lubrication
20x Drain & Refill Engine Oil
03x Engine Oil Filter
23x Change Oil & Filters (Both 20x and 03x)
04x Fuel Filters and Screens
50x Drain & Refill Transmission
06x Transmission Filters
56x Change Oil & Filters (Both 50x and 06x)
70x Drain & Refill Hydraulic Oil
08x Hydraulic Filters & Screens
78x Change Oil & Filters (Both 70x and 08x)
09x Drain & Refill Differential/ Final Drive Oil/Filters
10x Air Cleaner/Filter
11x Battery Service/Recharge
12x Cleaning
13x Preservation
14x Other

ATTACHMENTS

A01 Winch/PCU
A02 Backhoe
A03 Boom
A04 Buckets/Blades/Edges
A05 Sheeves/Pulleys/Wire Rope
A06 Augers
A07 Other

BRAKES

809 Linings/Disks/Plates/Bands
810 Drums/Rotors
811 Backing Plate/Cams/Calipers
812 Hoses/Lines/Pipes/Fittings
813 Master/Wheel Cylinder
814 Chambers/Diaphragms
815 Hydrovac/Vacuum Pump
816 Valves, Governors, Tank
817 Parking/Hand Brake
818 Other

SUSPENSION

C20 Springs
C21 Shock Absorbers
C22 Bars/Rods
C23 Other

DRIVE TRAIN

D25 Clutch, Main Drive
D26 Clutch, Control/Drum
D27 Manual Transmission
D28 Auto/Power Shift Transmission
D29 Auxiliary Transmission
D30 Transfer Cases/Power Dividers
D31 Drive Shafts/U-Joints
D32 Differentials
D33 Drive Axles
D34 Final Drive/Planetaries
D35 Power Take-off
D36 Drive Belts/Chains
D37 Torque Converter
D38 Other

ENGINE

E40 Engine Assy, Gas
E41 Engine Assy, Diesel
E42 Engine Assy, Aux
E43 Air Intake System
E44 Blowers/Superchargers/TurboChargers
E45 Exhaust System
E46 Emission Control System
E49 Cooling System
E50 Other

FUEL

F52 Fuel System
F53 Fuel Transfer Pump
F54 Fuel Injection Pump
F55 Injectors/Nozzles
F56 Carburetor
F57 Gov/Throttle Controls
F58 Other

HYDRAULIC

H60 Pump
H61 Pressure Control Valves
H62 Operating Valves
H63 Cylinders
H64 Motors
H65 Hoses/Lines/Pipes/Fittings
H66 Accumulators/Tanks
H67 Other

ELECTRICAL

J69 Replace Battery
J70 Replace Speedometer/Hourmeter
J71 Charging System
J72 Cranking System
J73 Lighting/Wiring System
J74 Electrical Controls/Panels
J75 Ignition System
J76 Instruments/Gauges
J77 Generators, Power/Welding
J78 Electric Drive Motors
J79 Electronic Circuits
J80 Other

BODY AND FRAME

K82 Cab/Sheet Metal
K83 Body/Bed
K84 Cushions/Seats/Canvas/Bows/Sideracks
K85 Painting/Marking
K86 Frame/Mast
K87 Bumper/Guard/Lifting Device
K88 Fifth Wheel/Trlr Hitch/Towing Hook
K89 Outriggers/Landing Gear
K90 Other

STEERING SYSTEM

N92 Adjustments/Wheel/Alignment
N93 Steering Wheel/Box
N94 Steering Brakes/Clutches
N95 Linkages/Tie Rods/Etc.
N96 Ball Joints/King Pins
N97 Power Steering Pump/Belt
N98 Steering Cylinder/Hoses
N99 Other

PNEUMATIC

P01 Cylinders
P02 Separators/Filters
P03 Separators/Filters
P04 Drifters
P05 Motors
P06 Hoses/Lines/Pipes/Fittings
P07 Controls
P08 Receivers/Oilers
P09 Other

SAFETY EQUIPMENT

S11 Fire Extinguisher
S12 Mirrors/Reflectors
S13 Windshield Wipers
S14 Mud Flaps/Guards/Shields
S15 Glass/Windshield
S16 Horn
S17 Other

PRODUCT TRANSFER

T19 Asphalt Pump
T20 Water/Mud Pump
T21 Refueling Pump
T22 Concrete Pump
T23 Conveyor Belt/Bucket/Screw
T24 Other

HEATER/VENTILATING SYSTEM

V26 Asphalt/Tank Heater
V27 Water Heater/Defroster
V28 Aggregate Heater
V29 Screed Heater
V30 Air Conditioning
V31 Other

WHEELS/TRACKS

W33 Wheels/Rims
W34 Tires/Tubes
W35 Bearings/Seals/Packings
W36 Hub Assy/Studs/Nuts
W37 Rollers/Idlers/Sprockets
W38 Track Frame/Guards
W39 Rails/Pins/Grousers
W40 Track Adjuster/Accumulator
W41 Other

PRODUCTION EQUIPMENT

Z43 Jaws/Hammer Mills
Z44 Rolls/Liners/Concaves
Z45 Screens
Z46 Mixers
Z47 Dryers
Z48 Screed
Z49 Scales/Meters
Z50 Collector
Z51 Other

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CMB10007

Figure 1-7.—Equipment Repair Order (ERO) Block Codes, NAVFAC 11200/41.

EQUIPMENT REPAIR ORDER (ERO)
CONTINUATION SHEET
NAVFAC 11200/41A (10-75) S/N 0105-LF-012-0210

★ U.S. GOVERNMENT PRINTING OFFICE 1977—737-585

1. USN ID NUMBER	2. EQPT COST CODE	3. ACTIVITY UIC	4. JOB ORDER NUMBER	ERO NUMBER

62. W/C	45. FUNCTION CODE	63. WORK DESCRIPTION MECHANIC: NOTIFY SUPERVISOR OF ALL ADDITIONAL WORK	64. PRI/SEC	65. MANHOURS ACT.	EST.	66. ESTIMATED MAT'L COST	67. MECH INITIALS
		SUB TOTALS		83.	84.	86.	

71. INSP CODE	72. INITIAL INSPECTOR (SIGNATURE)	73. DATE	82. PAGE OF

CMB10008

Figure 1-8.—Equipment Repair Order (ERO) Continuation Sheet, NAVFAC 11200/41A.

EQUIPMENT REPAIR ORDER (ERO) WORKSHEET
NAVFAC 1120041B (4-79)

PAGE ______ OF ______

1. USN/ID NUMBER	2. EQPT COST CODE	3. ACTIVITY UIC	4. JOB ORDER NUMBER	5. LOCATION/ALLOWANCE	6. TYPE REPAIR	7. HR METER READING	8. MILE METER READING	9. ERO NUMBER
10. CUSTOMER	11. WORK CENTER	12. DESCRIPTION	13. YEAR	14. MAKE	15. MODEL	16. APL NUMBER		
17. ENGINE MANUFACTURER	18. ENGINE MODEL	19. ENGINE SERIAL NUMBER	20. CHASSIS SERIAL NUMBER					

21. NSN	22. FSCM	23. MANUFACTURER PART NUMBER	24. DESCRIPTION	25. QTY	26. U/I	27. UNIT COST	28. DOCUMENT NUMBER (LAST 8 DIGITS)	29. RCVD

30. APPROVED BY (SIGNATURE)	31. DATE

CMB10009

Figure 1-9.—Equipment Repair Order (ERO) Work Sheet, NAVFAC 11200/41B.

EQUIPMENT REPAIR ORDER (ERO)
CONTINUATION SHEET
NAVFAC 11200/41A (10-75) S/N 0105-LF-012-0210

*U. S. GOVERNMENT PRINTING OFFICE: 1977—737-685

1. USN/ID NUMBER	2. EQPT COST CODE	3. ACTIVITY UIC	4. JOB ORDER NUMBER	ERO NUMBER

62. W/C	45. FUNCTION CODE	63. WORK DESCRIPTION MECHANIC: NOTIFY SUPERVISOR OF ALL ADDITIONAL WORK	64. PRI/SEC	65. MANHOURS ACT.	EST.	66. ESTIMATED MAT'L COST	67. MECH INITIALS
			SUB TOTALS	83.	84.	85.	

71. INSP CODE	72. INITAL INSPECTOR (SIGNATURE)	73. DATE	82. PAGE OF

CMB10010

Figure 1-10.—Equipment Repair Order (ERO) Log.

equipment. Figure 1-10 shows a sample Equipment Repair Order Log. The types of information generally called for are the following:

- ERO number (assigned eight-digit number). (The first four digits are two alpha characters and two numeric, such as AA00. The last four digits are numeric and constitute a Job Sequence Number (JSN) which is assigned locally. This JSN runs continuously from 0001 through 9999. At such time as 9999 is used, a new series starts 0001.)
- Equipment code (six-digit code, as shown on the PM record card).
- USN number (seven digit equipment registration number).
- Type of repair (type of maintenance performed, such as 01, 02, or 03).
- Date in (date ERO forwarded to inspector).
- Date out (date equipment is returned to dispatch).
- PM group.
- Hard card number (number issued by dispatch from the hard card log).
- Remarks (date deadlined, and so on).

The EROs and the ERO log are maintained by the PM clerk. Complete instructions on the use of EROs are located in the *Management of Civil Engineering Support Equipment*, P-300, and the COMSECONDNCB/COMTHIRDNCBINST 11200.1.

EQUIPMENT HISTORY JACKETS

An equipment history jacket is maintained for each USN-numbered piece of CESE. The history jacket contains the pertinent descriptive data and maintenance history of the vehicle. The descriptive data includes the appropriate DoD Property Record, DD Form 1342 (fig. 1-11), and Equipment Attachment Registration Record, NAVFAC 6-11200/45 (fig. 1-12), if applicable. The maintenance history jacket also includes the completed PM record cards and blue copies of completed EROs.

When a vehicle is transferred, the PM record card is removed from the PM group file and returned to the history jacket. The jacket is then either hand carried or forwarded by mail to the receiving custodian. When the vehicle is to be transferred to a Defense Reutilization Marketing Office (DRMO), the history jacket must accompany it.

LABOR REPORTING

In battalions and at shore-based activites, your duties involve posting of working hours on time cards for military personnel; therefore, you should know the type of information required in labor reporting. You should note that the labor reporting system used primarily in Naval Mobile Construction Battalions (NMCBs) and the system used at a shore-based activity are similar.

A labor accounting system is mandatory for you to record and measure the number of man-hours that a unit spends on various functions. In this system, labor usage data is collected daily in sufficient detail and in a way that enables the Operations Department to compile the data readily and prepare reports for higher authority.

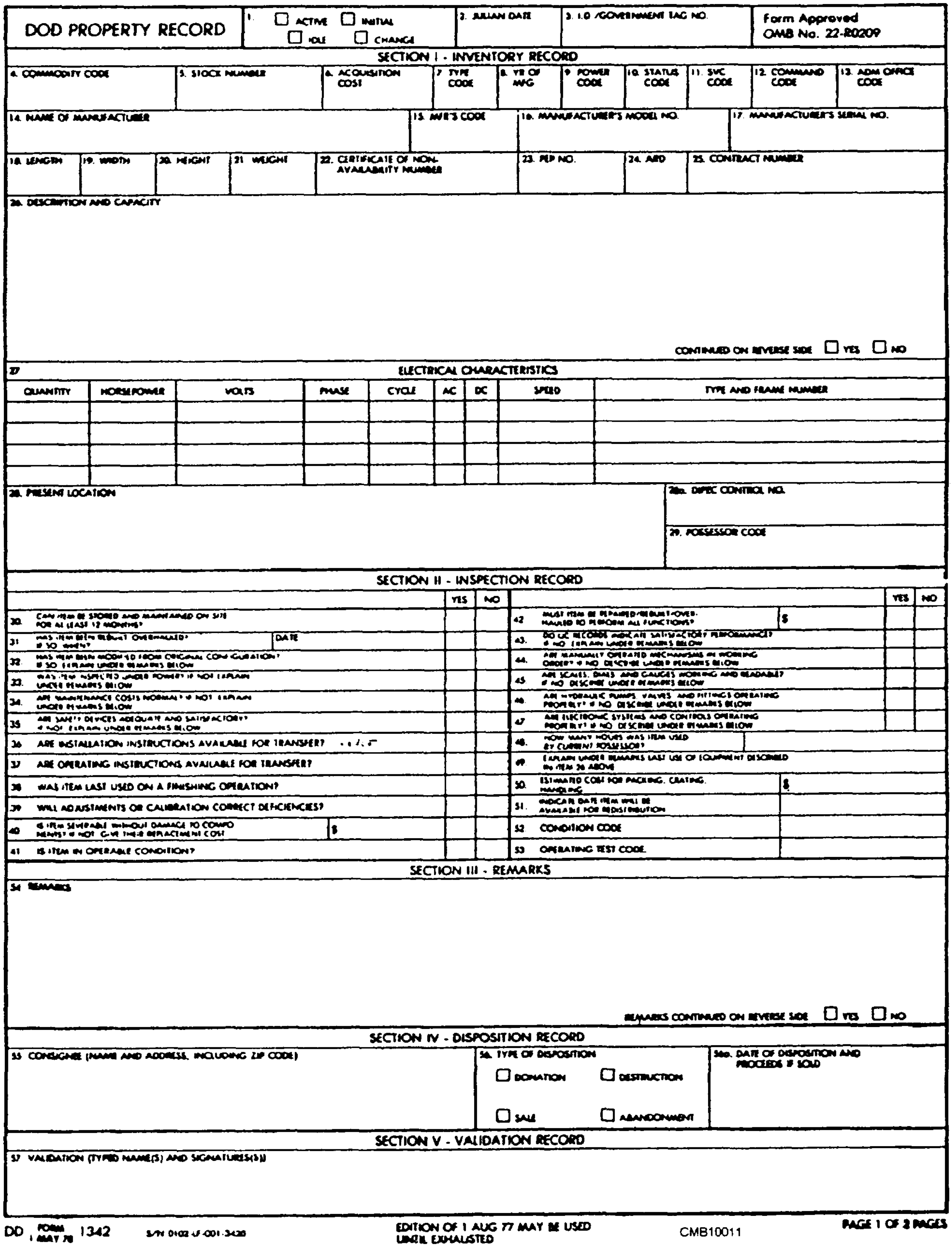
Although labor accounting systems vary slightly from one command to another, the system described here can be tailored to record labor at any command.

A unit must account for all the labor used to carry out its assignment. Labor costs are figured and actual man-hours are compared with previous estimates based on jobs of a similar nature. When completed, this information is used by unit managers and higher commands to develop planning standards.

The labor accounting system covered in this section is based upon the procedure and guidelines established by both Naval Construction Brigades (NCBs) for NMCB use.

Time cards (fig. 1-13) are the basis for your situation report (SITREP) input. Therefore, it is imperative that time cards be filled out correctly and accurately. COMSECONDNCB/COMTHRIDNCBINST5312.1 is the instruction that governs timekeeping procedures. Man-hours should be recorded under a specific code in one of three labor categories. The categories are listed below.

1. DIRECT LABOR is man-days expended directly on assigned construction activity, either in the field or in the shop, and labor that contributes directly to the completion of an end product. Tasked projects are assigned a project number. Labor expended on a specific project should be reported under that project number. Record direct labor by construction activity number. Included under direct labor (besides construction) arc such tasks as the following:



DOD PROPERTY RECORD

1. ☐ ACTIVE ☐ INITIAL ☐ IDLE ☐ CHANGE | 2. JULIAN DATE | 3. I.D./GOVERNMENT TAG NO. | Form Approved OMB No. 22-R0209

SECTION I - INVENTORY RECORD

4. COMMODITY CODE | 5. STOCK NUMBER | 6. ACQUISITION COST | 7. TYPE CODE | 8. YR OF MFG | 9. POWER CODE | 10. STATUS CODE | 11. SVC CODE | 12. COMMAND CODE | 13. ADM OFFICE CODE

14. NAME OF MANUFACTURER | 15. MFR'S CODE | 16. MANUFACTURER'S MODEL NO. | 17. MANUFACTURER'S SERIAL NO.

18. LENGTH | 19. WIDTH | 20. HEIGHT | 21. WEIGHT | 22. CERTIFICATE OF NON-AVAILABILITY NUMBER | 23. PEP NO. | 24. ARD | 25. CONTRACT NUMBER

26. DESCRIPTION AND CAPACITY

CONTINUED ON REVERSE SIDE ☐ YES ☐ NO

27 ELECTRICAL CHARACTERISTICS

QUANTITY	HORSEPOWER	VOLTS	PHASE	CYCLE	AC	DC	SPEED	TYPE AND FRAME NUMBER

28. PRESENT LOCATION | 28a. DIPEC CONTROL NO. | 29. POSSESSOR CODE

SECTION II - INSPECTION RECORD

		YES	NO			YES	NO
30	CAN ITEM BE STORED AND MAINTAINED ON SITE FOR AT LEAST 12 MONTHS?			42	MUST ITEM BE REPAIRED/REBUILT/OVERHAULED TO PERFORM ALL FUNCTIONS? $		
31	HAS ITEM BEEN REBUILT OVERHAULED? IF SO WHEN? DATE			43.	DO UC RECORDS INDICATE SATISFACTORY PERFORMANCE? IF NO EXPLAIN UNDER REMARKS BELOW		
32	HAS ITEM BEEN MODIFIED FROM ORIGINAL CONFIGURATION? IF SO EXPLAIN UNDER REMARKS BELOW			44.	ARE MANUALLY OPERATED MECHANISMS IN WORKING ORDER? IF NO DESCRIBE UNDER REMARKS BELOW		
33.	WAS ITEM INSPECTED UNDER POWER? IF NOT EXPLAIN UNDER REMARKS BELOW			45.	ARE SCALES, DIALS AND GAUGES WORKING AND READABLE? IF NO DESCRIBE UNDER REMARKS BELOW		
34.	ARE MAINTENANCE COSTS NORMAL? IF NOT EXPLAIN UNDER REMARKS BELOW			46.	ARE HYDRAULIC PUMPS, VALVES AND FITTINGS OPERATING PROPERLY? IF NO DESCRIBE UNDER REMARKS BELOW		
35	ARE SAFETY DEVICES ADEQUATE AND SATISFACTORY? IF NOT EXPLAIN UNDER REMARKS BELOW			47	ARE ELECTRONIC SYSTEMS AND CONTROLS OPERATING PROPERLY? IF NO DESCRIBE UNDER REMARKS BELOW		
36	ARE INSTALLATION INSTRUCTIONS AVAILABLE FOR TRANSFER?			48.	HOW MANY HOURS WAS ITEM USED BY CURRENT POSSESSOR?		
37	ARE OPERATING INSTRUCTIONS AVAILABLE FOR TRANSFER?			49.	EXPLAIN UNDER REMARKS LAST USE OF EQUIPMENT DESCRIBED IN ITEM 26 ABOVE		
38	WAS ITEM LAST USED ON A FINISHING OPERATION?			50.	ESTIMATED COST FOR PACKING, CRATING, HANDLING $		
39	WILL ADJUSTMENTS OR CALIBRATION CORRECT DEFICIENCIES?			51.	INDICATE DATE ITEM WILL BE AVAILABLE FOR REDISTRIBUTION		
40	IS ITEM SEVERABLE WITHOUT DAMAGE TO COMPONENTS? IF NOT GIVE THEIR REPLACEMENT COST $			52	CONDITION CODE		
41	IS ITEM IN OPERABLE CONDITION?			53	OPERATING TEST CODE		

SECTION III - REMARKS

54 REMARKS

REMARKS CONTINUED ON REVERSE SIDE ☐ YES ☐ NO

SECTION IV - DISPOSITION RECORD

55 CONSIGNEE (NAME AND ADDRESS, INCLUDING ZIP CODE) | 56. TYPE OF DISPOSITION ☐ DONATION ☐ DESTRUCTION ☐ SALE ☐ ABANDONMENT | 56a. DATE OF DISPOSITION AND PROCEEDS IF SOLD

SECTION V - VALIDATION RECORD

57 VALIDATION (TYPED NAME(S) AND SIGNATURE(S))

DD FORM 1 MAY 78 1342 S/N 0102-LF-001-3420 EDITION OF 1 AUG 77 MAY BE USED UNTIL EXHAUSTED CMB10011 PAGE 1 OF 2 PAGES

Figure 1-11.—DoD Property Record, DD Form 1342.

EQUIPMENT ATTACHMENT REGISTRATION RECORD NAVFAC 6-11200/45 (1-70) S/N 0105-002-0405				22. NAVFAC ID NO.	
1. ATTACHMENT CODE	2. TYPE ATTACHMENT			3. MODEL NO.	4. SERIAL NUMBER
5. LENGTH *(Inches)*	6. WIDTH *(Inches)*	7. HEIGHT *(Inches)*	8. CUBES *(Cubic Feet)*	9. SIZE/CAPACITY	
10. MANUFACTURER *(Name and Address)*				11. WEIGHT *(Lb)*	12. FSN
13. SHORT DESCRIPTION PECULIAR TO:		14. MAKE	15. MODEL		16. YEAR
17. ACCESSORIES					
18. ASSIGNED TO	19. DATE RECEIVED	20. ACQUISITION COST $	21. JULIAN DATE REGISTERED	22. NAVFAC ID NO.	

CMB10012

Figure 1-12.—Equipment Attachment Registration Record, NAVFAC 6-11200/45.

TIME CARD

Crewleader:	Signature:	Company:	Crew Size:	Transfers This Date:
Project Number:	Project Title:			Date:

Crew Member's Rate/Name	Direct Labor by Construction Activity Number									Indirect					Readiness and Training				
									Total					Total					Total
Totals																			

CMB10013

Figure 1-13.—Time card.

- Project and site surveying.
- Shop work that contributes directly to the completion of a project. For example, prefabrication of components.
- Camp maintenance when accomplished as part of the battalion direct labor tasking.
- Mineral product operations for either a tasked project or as a specific tasked project.
- Construction equipment operation when assigned to a tasked project.

2. INDIRECT LABOR is man-days expended to support construction operations. but does not produce an end product itself; therefore, this time is not repotted/recorded under a project number; it is recorded under an indirect labor code. The codes are as follows:

XO1—Equipment, Repair and Records

XO2—Project and Camp Maintenance

XO3—Project Management

XO4—Location Moving

XO5—Project Travel

XO6—Material Support

XO7—Tools

XO8—Adminstration and Personnel

XO9—Last Time

X10—Other

3. READINESS and TRAINING are comprised of functions related to preparation for and execution of military exercises, disaster preparedness, mobility, and technical training. Training includes attendance at service schools, factory and industrial training courses, fleet-type training, special Seabee training courses, safety training, military training, and any other organized training conducted within a battalion. Report/record these man-hours under a specific name.

Your report should be submitted on a typical daily time card form, similar to the one shown in figure 1-13. The form provides a breakdown by man-hours of the activities in the various labor codes for each crew member for each day on any given project. This form is reviewed at the company level by the staff and platoon commander, then it is initialed by the company commander before it is forwarded to the Operations Department. It is tabulated by the management division of the Operations Department with the daily labor distribution reports received from each company and department in the unit. This report is a means by which the operations office can analyze the distribution of manpower resources each day. It also serves as feeder information for preparation of the monthly OPS/SITREP reports and other source reports required of the unit. This information must be accurate and timely. Each level in the company organization should review the report to analyze its own internal construction management and performance.

Q1. What person is responsible for the maintenance program in a Naval Mobile Construction Battalion?

Q2. What is the standard interval between PMs?

Q3. What NAVFAC manual provides instructions for using a Shop Repair Order?

Q4. Interim repairs that exceed what number of man-hours require an ERO?

Q5. Equipment maintenance is what type of labor?

MAINTENANCE SUPPORT

LEARNING OBJECTIVE: *Describe key items of maintenance support required for the Civil Engineering Support Equipment (CESE) maintenance program.*

The tools, consumables, and spare parts needed to support the equipment allowance of the unit are portions of maintenance support. The Supply Department is responsible for providing these items.

In a battalion, the Supply Dpartment is under the control of the supply officer, who is assisted by a chief Storekeeper. The supply section (S-4) is responsible for general supply, ship's service, material control, and delivery. The material control section is responsible for ordering, receiving, and controlling tools, materials, and repair parts. As you can see, S-4 has a big job. Keep this in mind when you become impatient with the Storekeepers.

REPAIR PARTS SUPPORT

Mechanics expect repair parts to be available when needed—and rightly so. It is the job of supply to provide the parts you need; however, supply cannot satisfactorily perform its support mission without the help of maintenance personnel. Mechanics must understand how the repair parts supply system works and make sure that supply knows what you need and when you need it. Telling supply you need a "whatchamacallit" for a jeep does not help, but provide them the proper nomenclature and a part number and they can obtain it for you. Normally at least one mechanic is assigned to the repair parts storeroom for technical information and assistance. The DTO clerk provides liaison with supply for checking requisition status. The maintenance supervisor assists supply in determining additional repair parts requirements. The NCF initial outfitting of repair parts is designed to support new or like-new CESE for the first 1,200 construction hours. It is based on two 10-hour shifts, 7 days per week, for the first 60 days of deployment.

Levels

There are four different levels of repair parts support (O, G, H, or D) that can be assigned to a unit, depending upon its mission, location, maintenance capabilities, and so on.

1. "O" LEVEL support is designed for Seabee teams, Construction Battalion Units (CBUs), Reserve battalions, and outlying NMCBs that perform only organizational level maintenance. It is the lowest level of support.
2. "G" LEVEL support is designed for NMCB/PHIBCB major detachments that perform intermediate level maintenance.
3. "H" LEVEL support is designed for the main body of an NMCB/PHIBCB that performs intermediate level maintenance.
4. "D" LEVEL support is designed for major shops (CBCs) that perform depot level maintenance.

Each level of support includes all lower level items; for example, "H" level includes all "O" and "G" level items.

Categories of Repair Parts

Repair parts can be divided into two categories: parts peculiar and parts common.

REPAIR PARTS PECULIAR is composed of parts that only fit a specific make and model piece of equipment. When a unit requests support for an allowance of equipment, the Civil Engineering Support Office (CESO) identifies the applicable Allowance Parts List (APL) for each make and model of equipment in the allowance. Using the APLs that are identified by CESO, the Ships Parts Control Center (SPCC) consolidates these APLs into a tailored repair parts list. This list is referred to as a Consolidated Seabee Allowance List (COSAL) or a NAVSUP Modifier Code 98 (MOD 98 kit). CESO provides copies of the COSAL to both the requesting unit and the Construction Battalion Center (CBC) that supports it. The CBC is then responsible for drawing the required items from stock or initiating procurement action and shipping the parts to the unit requesting the allowance.

REPAIR PARTS COMMON is composed of common and consumable supplies for use on numerous types of equipment. These items have been separated into common assemblies (MOD 97 kit) to reduce redundancy and overstocking of these items. Presently the MOD 97 kit consists of 29 individual kits, such as hydraulic hose and fittings, nuts and bolts, electrical terminals and wire, O rings, and so on. The MOD 97 kit is designed to supplement a MOD 98 kit for the first 60 days of a contingency operation. Note that these MOD 97 kits are not designed to support a unit for a full deployment. MOD 96 provided the same support for smaller units such as details and air detachments.

COSAL Arrangement

Each COSAL is arranged and divided into three separate parts.

PART I consists of a cross-reference list to determine what APL applies to what USN number. PART I is composed of three separate cross-reference lists, each containing the same information, but sorted and printed in a different sequence.

- Section A is printed in USN-number sequence.
- Section B is in Equipment Code (EC) sequence.
- Section C is in APL-number sequence.

PART II consists of APLs arranged by identification number. The APL identification number is listed in both the upper- and lower-right corner of each APL page and consists of nine digits, such as 950004121. The PART II MAJOR SEQUENCE is based on the last four digits (95000**4121**) of the APL identification number (low to high). This is commonly referred to as the APL number. Exceptions are vehicles, such as truck-mounted water distributors (one APL for the truck, another APL for the distributor) and mobile cranes (one APL for the carrier, another for the crane.) The PART II MINOR SEQUENCE is based on the preceding three digits, such as 95**006**4121 for the fuel system group items. A listing of groups covered in each APL is displayed on the first page of each APL, such as

950004121. The first two digits of the APL number (950004121) are consistent in the Naval Construction Force COSALs because they identify the APL as NCF versus shipboard Within each APL, the parts are arranged by component identification groups (CIDs). Figure 1-14 shows the CID groups presently being used by the NCF. The first CID group is always the allowance application group. The second CID group is the technical manual group that lists all the applicable operating, maintenance, and parts manuals. The remainder of the AFXs contain actual parts listings.

CID	Group Name	CID	Group Name
000	Allowance Application Group (Gp)	043	Grader Gp
OTM	Technical Manual Gp	044	Dozer Gp
001	Engine Gp	045	Ditcher or Trencher Gp
002	Truck Engine Gp	046	Road Roller Gp
003	Starting Engine Gp	047	Earth Auger Truck Mounted Gp
004	Auxiliary Engine Gp	048	Conveying Equipment Gp
005	Clutch Gp	049	Crushing Equipment Gp
006	Fuel System Gp	050	Screening/Washing Equip. Gp
007	Exhaust System Gp	051	Fire Fighting Equipment Gp
008	Cooling System Gp	052	Refrigeration/Acng Gp
009	Electrical System Gp	053	MMK Gp
010	Transmission Gp	054	Separator Gp
011	Auxiliary Transmission Gp	055	Running Gear Gp
012	Power Transfer Gp	056	Manifold Gp
013	Propeller Shaft Gp	057	Tank Gp
014	Front Axle Gp	058	Trailer Gp
015	Rear Axle Gp	059	Flood Light Gp
016	Brakes Gp	060	Filter or Strainer Gp
017	Wheels Gp	061	Chlorine Control Gp
018	Tracks Gp	062	Evaporating Gp
019	Steering Gp	063	Water Fording Gp
020	Frame Gp	064	Machinery Gp
021	Springs/Shock Absorbers Gp	065	Laundry Equipment Gp
022	Body, Cab, Hood, Hull Gp	066	Winterization Gp
023	Hoists Gp	067	Bobsled Gp
024	Power Control Unit Gp	068	Dolly Gp
025	Power Take Off Gp	069	Generator Lox & Nitrogen Gp
026	Miscellaneous Body Gp	070	Steam Cleaning Gp
027	Elevator Gp	071	Spraying Equipment Gp
028	Electric Motors Gp	072	Saw Gp
029	Electric Generators Gp	073	Distillation Equipment Gp
030	Electrical Equipment Gp	074	Heater Gp (Gas or Fuel)
031	Hydraulic Systems Gp	075	Blower Gp
032	Air and Vacuum Systems Gp	076	Boiler Gp
033	Gage and Measuring Devices Gp	077	Pile Driver Gp
034	Pneumatic Equipment Gp	078	Water Purification Gp
035	Pump Gp	079	Reel Gp
036	Burner Gp	080	Scraper Gp
037	Mach Tools/Related Equip Gp	081	Ripper Gp
038	Snow Removal Equipment Gp	082	Outboard Drive Gp
039	Mowing/Sweeping Equipment Gp	083	Rotary Tiller Soil Stabilizer Gp
040	Servicing Equipment Gp	085	Drill Equipment (Pneu) Gp
041	Concrete/Asphalt Equipment Gp	086	Dehydrator Gp
042	Crane/and/or Shovel Gp	087	Remote Control Gp

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Figure 1-14.—Component identification group numbers (CIDs).

PART III consists of a Stock Number Sequence List (SNSL) and two repair parts cross lists. The SNSL lists the repair parts, arranged in National Item Identification Number (NIIN) sequence, that were provided in the COSAL to support the assigned level of support The SNSL also lists all the APL numbers each part is stocked for, the unit price, and the total COSAL quantity. The first list crosses a manufacturer's part number to a National Stock Number (NSN). The second list crosses an NSN, in NIIN sequence, to a part number. Part III is NOT a master cross reference; if the number you are researching is not included in the COSAL, it is not in these lists.

Technical Manuals

One key to effective equipment maintenance is the availability of authoritative technical data and guides for each unique item of equipment. Within the NCF, this information is supplied through the appropriate operator manuals, lubrication charts, parts manuals, and shop repair manuals. There are two types of technical manuals: manufacturer's manuals and specialized technical mantis. It is important for you to understand the difference.

- **Manufacturer's manuals** are published by the various equipment manufacturers (Ford, General Motors, and so on). Also called factory manuals, each book covers equipment produced by that company, usually for a l-year period.

- **Specialized technical manuals** cover only specific repair areas. They usually come in several volumes, each covering one specific section (Engine, Transmission, Hydraulics, and so forth).

A technical manual is divided into sections, such as general information, engine, transmission, and electrical. The **general information section** of a technical manual helps you with the vehicle identification, basic maintenance, lubrication, and other general subjects. The vehicle identification (ID) number contains a code that is used when ordering parts. The ID number identifies the type of engine, the type of transmission, and other useful information The repair sections of a technical manual cover the major systems of a vehicle. These sections explain how to diagnose problems, inspect, test, and repair each system. To use a technical manual, follow these basic steps:

- Locate the right technical manual. Some manuals come in sets or volumes that cover different repair areas.

- Turn to the table of contents or index. This will help you locate the information. **NEVER** thumb through a manual looking for a subject.

- Use the page listings given at the beginning of each repair section. Most manuals have a small table of contents at the beginning of each section

- Read the procedures carefully. A technical manual provides detailed instructions. **DO NOT** overlook any step or the repair may fail.

- Study the manual illustrations closely; they contain essential information. They cover special tools, procedures, torque specifications, and other data essential to the repair.

The technical manuals (TMs) are included in the parts peculiar COSAL of each unit. The quantity of TMs is determined in the same way as repair parts. In general, this results in the following number of TMs being provided to the unit: one copy for each piece of equipment of the same make and model; two copies for two to four pieces of the same make and model; three copies for five to eight pieces of the same make and model; and four copies for more than eight pieces of the same make and model.

Regardless of the type of manual, all NCF units are responsible for maintaining, in good condition and in the proper quantities, all TMs listed in the COSAL. It is important for units to maintain inventory control of TMs through the use of periodic inventories, check-out procedures, and so on, because replacement mantis are difficult to obtain. Manuals in excess of COSAL quantities must be returned to M3 stock at CBC, Port Hueneme, California. TMs that are lost, damaged, worn out, or otherwise unserviceable, may be replaced by submitting funded requisitions to the appropriate CBC.

REQUESTING SPARE PARTS

NAVSUP Forms 1250-1 and 1250-2 are shown in figures 1-15 and 1-16. These forms are used as authorization for drawing parts and requesting requisition of items Not In Stock (NIS) or Not Carried (NC) by supply. It is not a purchase document and does not leave the command. The form must be filled out with either a ball-point pen or typed. Confusion between the number zero and the letter *O* can be avoided by using the communication symbol(∅) for zero. NAVSUP Form 1250 must be signed by the maintenance supervisor or a designated representative when requesting spare parts. It is your responsibility to ensure that the right part is ordered. So, provide the correct information on NAVSUP Form 1250. Instructions on how to fill out this form are located in NAVFAV P-300 and COMSECONDNCB/ COMTHRIDNCBINST 11200.1.

After signature, the form is submitted to the repair parts storeroom. The person receiving the part signs NAVSUP Form 1250-1. The national stock number (NSN), quantity, and price are then documented on the ERO work sheet.

The request for NIS/NC repair parts should be attached to the ERO and returned to the cost control office for review by the maintenance supervisor. The maintenance supervisor then assigns an Urgency-of-Need Designator. The ERO is then passed to the cost control clerk for verification and/or closing. The 1120-1/-2 is then sent to the DTO clerk who records the information in the DTO log and DTO summary sheet. The yellow copy of the ERO is pulled and filed with the DTO summary sheet. Request for repair parts with an Urgency-of-Need-Designator of "A" (NORS) requires the approval signature of the commaning officer who may delegate authority to the company commander (A-6); an Urgency-of Need-Designator of "B" (ANORS) requires the approval signature maintenance supervisor.

USING PART NUMBERS

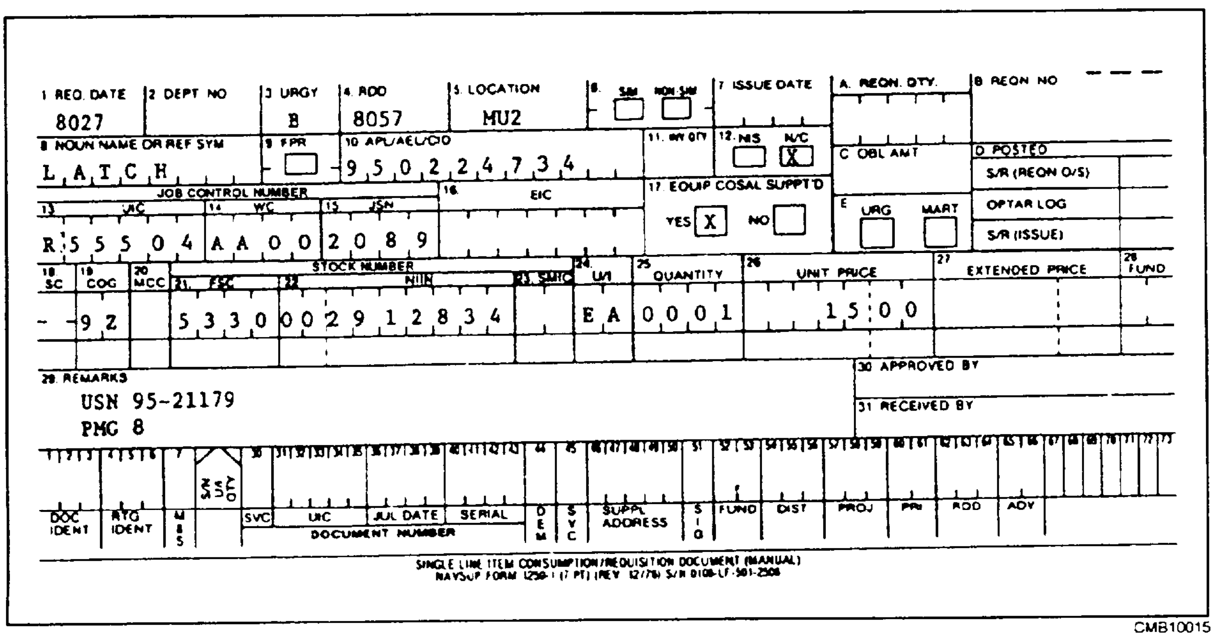
To identify the part you need, you must use part numbers. There are two types of part numbers: manufacturer's part numbers and national stock numbers.

Manufacturer's Part Numbers

Manufacturer's part numbers are those used by the manufacturer of a piece of equipment to identify each part on that piece of equipment. These part numbers are usually a combination of letters and numbers or all numbers.

National Stock Numbers

Effective September 1974, the United States agreed to replace its federal numbering system with a new 13 digit system that conforms to the NATO stock numbering format. This system is known as the NATIONAL STOCK NUMBER (NSN) system. The 13 digit NSN is broken down into four major groups. The first 4 digits on the NSN is the Federal Supply


1 REQ. DATE 8027 | 2 DEPT NO | 3 URGY B | 4 RDD 8057 | 5 LOCATION MU2 | 6 SM NON SM | 7 ISSUE DATE | A. REQN. QTY. | 8 REQN NO

8 NOUN NAME OR REF SYM: LATCH | 9 FPR | 10 APL/AEL/CID: 9502247 34 | 11. MY QTY | 12. NIS N/C [X] | C OBL AMT | D POSTED | S/R (REQN O/S)

JOB CONTROL NUMBER: 13 UIC R55504 | 14 WC AA00 | 15 JSN 2089 | 16 EIC | 17 EQUIP COSAL SUPPT'D YES [X] NO | E URG MART | OPTAR LOG | S/R (ISSUE)

18 SC | 19 COG 9Z | 20 MCC | STOCK NUMBER: 21 FSC 5330 | 22 NIIN 00291 2834 | 23 SMIC | 24 U/I EA | 25 QUANTITY 0001 | 26 UNIT PRICE 15.00 | 27 EXTENDED PRICE | 28 FUND

29 REMARKS USN 95-21179 PMC 8 | 30 APPROVED BY | 31 RECEIVED BY

DOC IDENT | RTG IDENT | M & S | SVC | UIC | JUL DATE | SERIAL (DOCUMENT NUMBER) | D E M | S Y C | SUPPL ADDRESS | S I G | FUND | DIST | PROJ | PRI | RDD | ADV

SINGLE LINE ITEM CONSUMPTION/REQUISITION DOCUMENT (MANUAL)
NAVSUP FORM 1250-1 (7 PT) (REV. 12/76) S/N 0108-LF-501-2506

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Figure 1-15.—Single Line Item Consumption/Requisition Document, NAVSUP Form 1250-1.

NON-NSN REQUISITION (4491)

A. REQ. DATE	8027
B. DEPT NO	
C. URGY	B
D. RDD	8057
E. LOCATION	MU2
F. SIM / NON-SIM	
G. ISSUE DATE	
H. REQN QTY	
I. REQN NO	
J. NOUN NAME OR REF SYM	LATCH
K. SPR	
L. APL/AEL/CID	950224734
M. INV QTY	
N. NIS / NC	NC: X
O. OBL AMT	
P. POSTED	
S/R (REQN O/S)	
OPTAR LOG	
S/R (ISSUE)	
JOB CONTROL NUMBER — Q. UIC	R 55504
R. WC	AA00
S. JSN	2089
T. EIC	
U. EQUIP COSAL SUPP'D (YES / NO)	YES: X
V. URG / MART	

DOCUMENT IDENTIFIER (1-3)	ROUTING IDENTIFIER (4-6)	M & S (7)	NAVY ITEM CONTROL NUMBER (NICN) OR P-NICN (8-22)	UNIT OF ISSUE (23-24)	QUANTITY (25-29)	DOCUMENT NUMBER: REQUISITIONER (30-35)	DATE (36-39)	SERIAL (40-43)	SC (W)
				EA	00001				

D (44)	SUPPLEMENTARY ADDRESS (45-50)	S (51)	FUND CODE (52-53)	DISTRIBUTION CODE (54-56)	PROJECT CODE (57-59)	PRIORITY (60-61)	REQUIRED DELIVERY DATE (62-64)	ADV (65-66)	BLANK (67-69)	(70-80)	REJECT CODE (FOR USE BY SUPPLY SOURCE ONLY) 65	66

IDENTIFICATION DATA

AA. MANUFACTURER'S CODE AND PART NO.
83179

BB. MANUFACTURER'S NAME, ADDRESS AND POINT OF CONTACT (POC)
Joy Manufacturing Co., Air Power Group
900 Woodland Avenue
Michigan City, IN 46360-5672
Phone: (412) 562-4711

CC. SHIP'S POC
NAME ____
RATE ____
DIVISION ____
PHONE ( ) ____

DD. TECH MANUAL NO./BLUEPRINT NO.
7610 LL L7A 6251

EE. END ITEM APPLICATION

FF. MANUFACTURER'S CATALOG IDENTIFICATION
Joy Portable Air Compressor MODD125S

GG. CATALOG DATE

HH. TECHNICAL ORDER NO.

II. NAME OF ITEM REQUESTED/CIRCUIT SYMBOL NO.
LATCH DOOR

JJ. DESCRIPTION OF ITEM REQUESTED/COMPLETE NAMEPLATE DATA FROM EXISTING UNIT
ILLUSTRATION PAGE 5-4, FIGURE 2
ITEM 15

DESCRIPTION PAGE 5-15
ITEM 15

MAKE	MODEL NO.
JOY	D125S
SERIES	**SERIAL NO.**
1977	135186
COLOR	**SIZE**

KK. SOURCE OF SUPPLY (Incl phone and POC if avail)

LL. ACCOUNTING DATA

MM. REQUISITIONER (Clear text name and address)

NN. APPROVED BY: (Supply/Contracting/Ordering Officer)
NAME ____ RANK ____
SIGNATURE ____

NAVSUP FORM 1250-2 (7-87) (2-84) S/N 0108-LF-501-2530

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Figure 1-16.—Non-NSN Requisition, NAVSUP Form 1250-2.

Classification (FSC) that groups similar items into classes. The last 9 digits of the NSN is the National Item Identification Number (NIIN). The first 2 digits of the NIIN identifies the NATO country that cataloged the item, and the last 7 digits identifies the item.

As pointed out above, NSN numbers provide you with the federal class of the item (first 4 digits), what country cataloged the item (digits 5 and 6). and the item identification number (last 7 digits).

Part III of the COSAL is the section used to cross-reference manufacturer's part numbers to NSNs.

REPAIR PARTS CONTROL

Each maintenance department is required to maintain control over repair parts. One of the biggest problems in some maintenance programs is the control of direct turnover (DTO) repair parts. DTO parts are those ordered for direct turnover to the user.

For DTO parts to be complete and accurate, all NAVSUP Form 1250s for NIS and NC repair parts must pass through the cost control clerk and the DTO clerk before being submitted to the supply office. The supply office maintains current procurement and shipping status for items on order. When requesting the status of a requisition from supply, DTO clerks must be able to identify, by requisition number, the procurement document they are interested in. Accurate DTO parts records accomplish this and allow the cost control clerk to identify the USN-number of the equipment each part was ordered for. The DTO repair parts status keeping system provides excellent accountability with minimum effort. This system consists of two separate records designed to be used together: the DTO log and the repair parts summary sheets.

DTO Log

The DTO log (fig. 1-17) is a sequential record and proof of order for all NAVSUP Form 1250-1/-2 requests for NIS/NC/Non-NSN requirements submitted to the repair parts storeroom. It is maintained in such a way that the last NAVSUP Form 1250 entered is the last parts request submitted to the supply office. This tells the DTO clerk when the requisition was submitted to supply. Normally, supply should order priority "A" (NORS) requisitions within 24 hours and priority "B" and "C" requisitions within 7 days. After accomplishing all ordering actions and issuing a procurement document, supply enters the requisition number in block "B" of a NAVSUP Form 1250-1 or block "I" of a NAVSUP Form 1250-2. The pink copy is returned to the repair parts storeroom where outstanding requisition data is posted to stock record cards for NIS items. The yellow copy is returned to the cost control office to log the requisition number in the DTO log. The yellow copy of NAVSUP Form 1250 is retained as proof of order and maintained with the repair parts summary sheet in the DTO files. The DTO log provides a cross-index between the requisition number, the department order number, and the USN number. This cross-reference allows the DTO clerk to determine the appropriate USN number for which the part was ordered. This is invaluable for follow-up actions in the event of lost or misfiled requisitions, lost or missing shipping documents, partial or duplicate parts shipments, and so forth. The columns required to maintain an effective DTO log are listed and explained below.

- DATE—The date NAVSUP Form 1250 was submitted to supply. It is indicated by the Julian date: For example, December 12, 1996, is written 6347.
- DEPARTMENT ORDER NUMBER—Internal control number assigned to each NAVSUP Form 1250 submitted to supply, numbered in sequence starting with 0001.
- PM GROUP—The PM group that the appropriate USN-number equipment is assigned.
- USN NUMBER—Identifies the vehicle for which the part was ordered.
- NSN/PART NUMBER—The NSN or part number of the ordered item.
- ITEM—Nomenclature or noun name of the item ordered.
- UNIT PRICE—The price of a single item.
- QUANTITY—Total number of items ordered.
- PRIORITY—Urgency-of-need Designator (A, B, or C).
- NC/NIS—Provides ready information on whether an item is Not Carried or Not In Stock.
- REQUISITION NUMBER—Entered when the yellow copy is returned from supply. All supply office documents are tiled by this number.

CBPAC (31) - 4408/2 REV (9-82)

DIRECT TURNOVER LOG (DTO)

DATE	DEPT.	PMG	USN NUMBER	NSN-P/N	ITEM	UNIT PRICE	QTY	PRI	NC/ NIS	REQ. NO.	FOLLOW-UP	REC'D	ISSUED & INITIAL

Figure 1-17.—DTO Log.

- FOLLOW-UP STATUS—Status furnished by supply. Intervals for follow-ups should not exceed 7 days for NORS/ANORS, 14 days for priority "B," and 30 days for priority "C" requisitions.
- RECEIVED DATE—Date indicating when the document ordering the items was processed.
- ISSUED DATE—Date item was issued to the shop for installation.

Repair Parts Summary Sheet

The repair parts summary sheet (fig. 1- 18) shows all parts on order for each vehicle. One sheet is maintained for each USN number; the summary sheets are filed in PM group order. This is for the convenience of the DTO clerk, because the DTO parts bins and the PM EROs are arranged in the same order. All EROs pass through the DTO clerk to preclude the accidental reordering of items. This also allows the DTO clerk to attach a DTO Information Sheet (fig. 1-19) to the ERO that parts have been received and are in the DTO bin. Summary sheets provide ready reference for determining the quantity of parts received from a multiple order; for example, parts for an engine overhaul, deadline equipment, and so forth. When equipment is transferred or disposed of, the summary sheet is used to identify outstanding requisitions, so they may be canceled. The heading on each summary sheet must show the EC and the USN number. The columns required on a repair parts summary sheet are listed and explained below.

- DATE—Julian date the NAVSUP Form 1250 was submitted to supply.
- DEPARTMENT NUMBER—This number serves as a cross reference between the DTO log and the summary sheets.
- UND—Urgency-of-Need Designation (Priority A, B, or C).
- REQUISITION NUMBER—Entered when the yellow copy of NAVSUP Form 1250 is returned from supply with the requisition number entered.
- NOMENCLATURE—Description of the item ordered.
- FOLLOW-UP—Dates that the DTO clerk requested the status from supply.
- RECEIVED-Date indicating when the document ordering the items was processed.

REPAIR PARTS SUMMARY SHEET

PM Group 23
Code 485001 USN 48-00123

Date	Dept. No	UND	Req No.	Nomenclature	Follow-up	Rec'd
8018	A009	B	8021-2211	Gasket Set	1/31	2/28
8229	A161	B	8230-2713	Injector	8/28 9/15 10/2	10/11
8246	A218	B		Raincap		

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Figure 1-18.—Repair Parts Summary Sheet

DTO INFORMATION SHEET

ECC ______________ PMG ______________ USN ______________

PARTS RECEIVED	PARTS ON ORDER/DESCRIPTION
1 ______________	1 ______________
2 ______________	2 ______________
3 ______________	3 ______________
4 ______________	4 ______________
5 ______________	5 ______________
6 ______________	6 ______________
7 ______________	7 ______________
8 ______________	8 ______________

WORK DEFERRED FROM PREVIOUS ERO

ITEMS

1 ______________

____

2 ______________

____

3 ______________

____

CMB10019

Figure 1-19.—DTO Information Sheet.

Once a part is received, supply forwards a copy of DD Form 1348-1 (fig. 1-20) with the part to the DTO clerk. Because this form does not contain the USN number, the DTO clerk must match the requisition number with the DTO log to determine the USN number for which the part was ordered. It must then be determined whether the part is still required. Questionable items should be discussed with the maintenance supervisor. Parts that are no longer required should not be stored in the DTO bins; they should be returned to supply for return to stock, return to CBC L3 stock, or disposal according to supply regulations. The DTO clerk tags each required part with the correct USN number, PM group, and the yellow copy of NAVSUP Form 1250. The DTO clerk ensures the DTO log and the summary sheet are dated, showing the item received. The part is stored in the DTO bin awaiting installation. The summary sheet can then be used as a record showing what parts are stored in the DTO bins.

When a part is issued, the DTO log is initialed by the receiving individual and a line is drawn through the received date with a yellow marker showing the part is no longer in the bin. If the received part is for a deadline piece of equipment, the maintenance supervisor is notified and determines whether enough parts are on hand to restart work on the vehicle.

Each time an ERO is issued, the DTO clerk checks the repair parts summary sheets to determine whether parts are stored in the DTO bin for the USN number concerned. If so, the DTO information sheet is attached to the ERO to alert the shop supervisor and the inspectors. The shop supervisors ensure that the parts are either used or returned to supply. The DTO bin that was worked through the shop yesterday should be empty today, as all parts should have been used or returned to supply. The only exception is when all required parts have not been received.

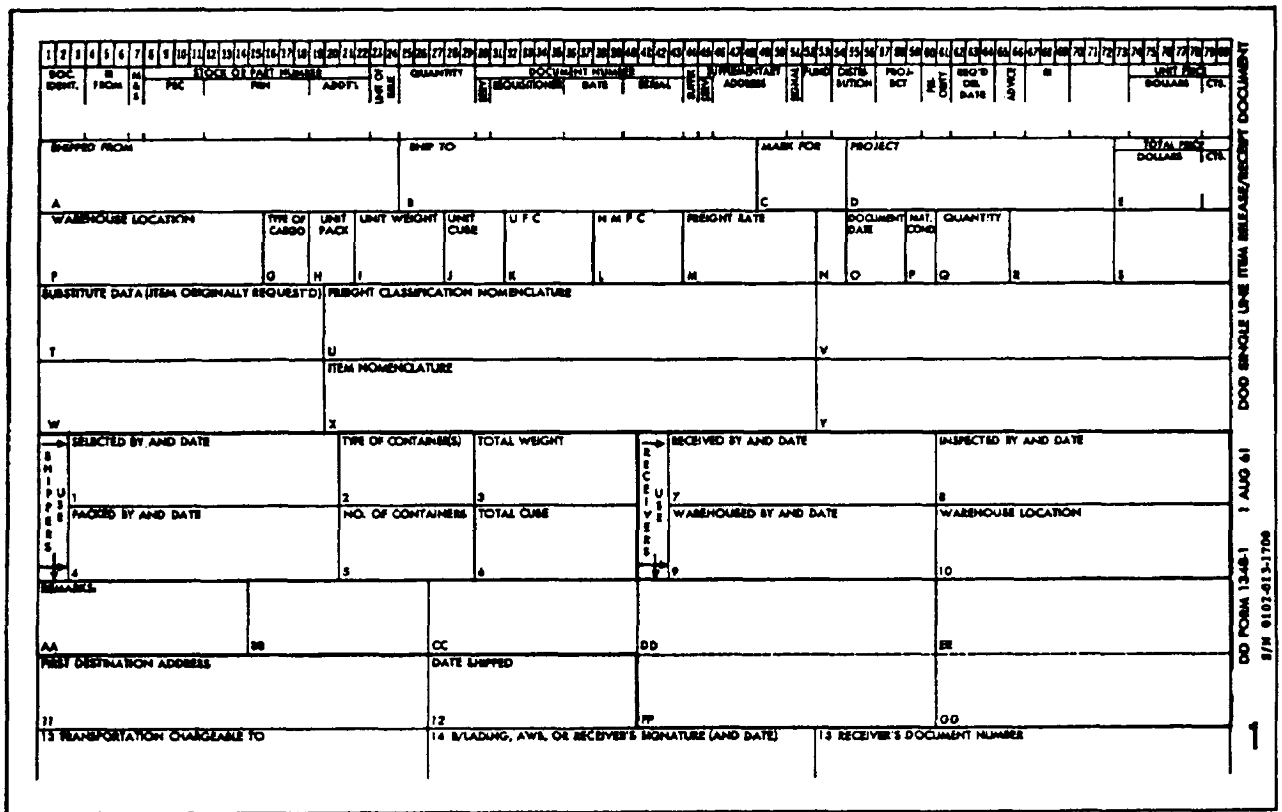
Q6. What level of repair parts support does an NMCB main body receive?

Q7. What NAVSUP form is used for requistioning NON-NSN repair parts?

Q8. Upon receipt of a NAVSUP Form 1250, supply should order priority "A" requisitions within how many hours?

Q9. Repair parts summary sheets are filed in what manner?

Q10. What person determines whether enough DTO parts are on hand to restart work on a deadline vehicle?


SHIPPED FROM
SHIP TO
MARK FOR
PROJECT
TOTAL PRICE DOLLARS CTS
WAREHOUSE LOCATION
TYPE OF CARGO
UNIT PACK
UNIT WEIGHT
UNIT CUBE
U F C
N M F C
FREIGHT RATE
DOCUMENT DATE
MAT. COND
QUANTITY
SUBSTITUTE DATA (ITEM ORIGINALLY REQUEST'D)
FREIGHT CLASSIFICATION NOMENCLATURE
ITEM NOMENCLATURE
SELECTED BY AND DATE
TYPE OF CONTAINER(S)
TOTAL WEIGHT
RECEIVED BY AND DATE
INSPECTED BY AND DATE
PACKED BY AND DATE
NO. OF CONTAINERS
TOTAL CUBE
WAREHOUSED BY AND DATE
WAREHOUSE LOCATION
REMARKS
FIRST DESTINATION ADDRESS
DATE SHIPPED
13 TRANSPORTATION CHARGEABLE TO
14 B/LADING, AWB, OR RECEIVER'S SIGNATURE (AND DATE)
15 RECEIVER'S DOCUMENT NUMBER
DD FORM 1348-1 1 AUG 61 DOD SINGLE LINE ITEM RELEASE/RECEIPT DOCUMENT
S/N 0102-013-1700

CMB10020

Figure 1-20.—DD Form 1348-1.

CHAPTER 2

PRINCIPLES OF AN INTERNAL COMBUSTION ENGINE

LEARNING OBJECTIVE: *Explain the principles of operation, the different classifications, and the measurements and performance standards of an internal combustion engine.*

As a Construction Mechanic, you are concerned with repairing and replacing worn or broken parts, making various adjustments to vehicles and equipment, and ensuring that they are serviced properly and inspected regularly. To perform these duties intelligently, you must fully understand the operation and function of the various components of an internal combustion engine. This makes your job of diagnosing and correcting troubles much easier. This, in turn, saves time, effort, and money.

This topic discusses the theory and operation of an internal combustion engine. You also need to become familiar with the terms being used.

INTERNAL COMBUSTION ENGINE

LEARNING OBJECTIVE: *Identify the series of events, as they occur, in both a gasoline engine and a diesel engine. Describe the differences between a four-stroke cycle engine and a two-stroke cycle engine.*

Combustion is the act or process of burning. An "external" or "internal" combustion engine is defined simply as a machine that converts heat energy into mechanical energy. Figure 2-1 shows, in simplified form, an external and an internal combustion engine.

In the internal combustion engine, combustion takes place inside the cylinder and is directly responsible for forcing the piston to move down. With an external combustion engine, such as a steam engine, combustion takes place outside the engine. The external combustion engine requires a boiler to which heat is applied. This combustion causes water to boil to produce steam. The steam passes into the cylinder under pressure and forces the piston to move downward.

The transformation of **HEAT ENERGY** to **MECHANICAL ENERGY** by the engine is based on the fundamental law of physics which states that gas expands when heated. The law also states that when gas is compressed, the temperature of the gas increases. if the gas is confined with no outlet for expansion, then the pressure of the gas increases when heat is applied. In the internal combustion engine, the burning of fuel within an enclosed cylinder results in an expansion of gases. This expansion creates pressure on top of the piston, causing it to move downward. In an internal combustion engine, the piston moves up and down

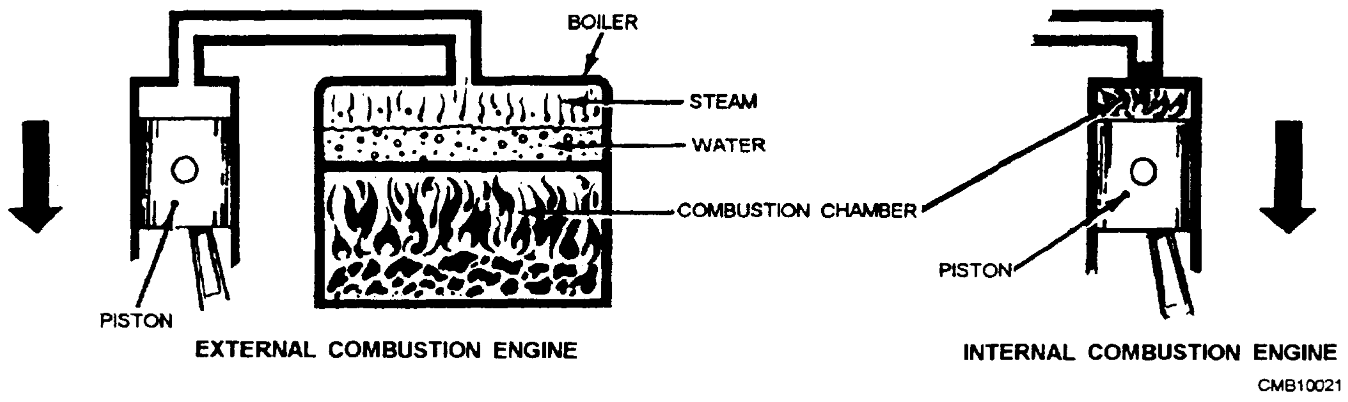


Figure 2-1.—Simple external and internal combustion engines.

within the cylinder. The relationship between volume, pressure, and temperature within a cylinder of the engine is explained in the chart below and shown in figure 2-2. Note the changes within the cylinder while the temperature outside remains a constant 70°F.

View	Description
A and B	The piston moves upward, compressing the air in the cylinder.
B and C	As **volume** decreases, **pressure** increases, and **temperature** rises. These changing conditions continue, as the piston moves upward.
D	As the piston nears TDC, **volume is still decreasing.** Because of compression within the cylinder, both **pressure and temperature of the air are now greater** than at the beginning.

This up-and-down motion is known as **RECIPROCATING MOTION.** This motion (straight-line motion) must be changed into **ROTARY MOTION** (turning motion) to turn the wheels of a vehicle. A crankshaft and a connecting rod change their reciprocating motion to rotary motion.

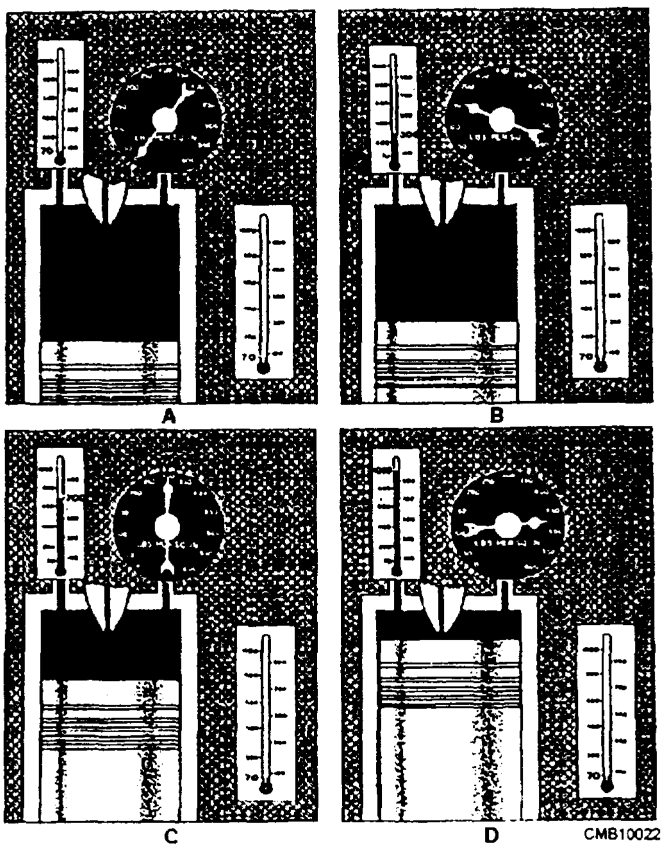


Figure 2-2.—Volume, pressure, and temperature relationships.

All internal combustion engines, whether gasoline or diesel, are basically the same. We can best demonstrate this by saying they all rely on three **things—FUEL, AIR,** and **IGNITION.**

FUEL contains potential energy for operating the engine; **AIR** contains the oxygen necessary for combustion; and **IGNITION** starts combustion. Each one is fundamental, and an engine cannot operate without them. Any discussion of engines must be based on these three factors and the steps and mechanisms involved in delivering them to the combustion chamber at the proper time.

DEVELOPMENT OF POWER

The power of an internal combustion engine comes from burning a mixture of fuel and air in a small, enclosed space. When this mixture bums, it expands greatly, and the push or pressure created is used to move the piston, thereby rotating the crankshaft. This motion is eventually sent to the wheels that move the vehicle.

Since similar action occurs in each cylinder of an engine, let's use one cylinder to describe the steps in the development of power. The one-cylinder engine consists of four basic parts, as shown in figure 2-3.

First, we must have a CYLINDER that is closed at one end; this cylinder is similar to a tall metal can that is stationary within the engine block.

Inside this cylinder is the PISTON—a movable plug. It fits snugly into the cylinder but can still slide up and down easily. This piston movement is caused by fuel burning in the cylinder and results in production of reciprocating motion.

You have already learned that the up-and-down movement of the piston is called reciprocating motion. This motion must be changed into rotary motion, so the wheels or tracks of a vehicle can rotate. This change is accomplished by a throw on the CRANKSHAFT and the CONNECTING ROD which connects the piston and crankshaft throw.

The throw is an offset section of the crankshaft that scribes a circle, as the shaft rotates. The top end of the connecting rod is connected to the piston and must therefore go up and down. The lower end of the connecting rod is attached to the Crankshaft. The lower end of the connecting rod also, moves up and down but,

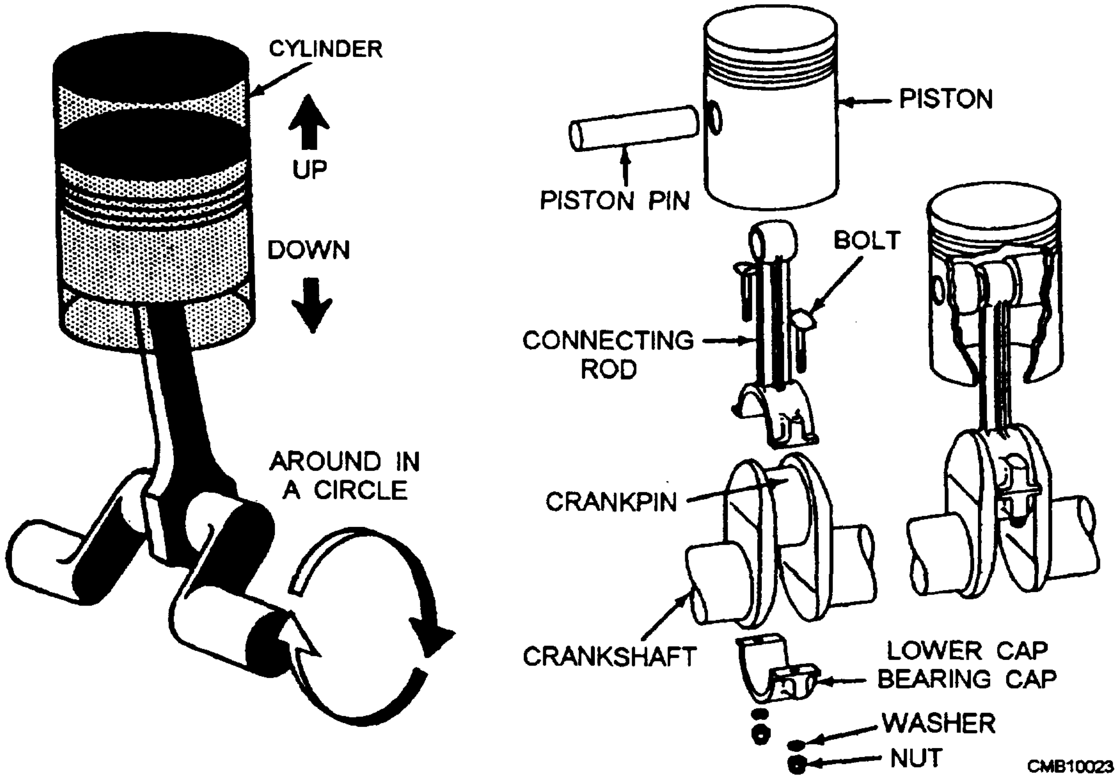


Figure 2-3.—Cylinder, piston, connecting rod, and crankshaft for a one-cylinder engine.

because it is attached to the crankshaft, it must also move in a circle.

When the piston of the engine slides downward because of the pressure of the expanding gases in the cylinder, the upper end of the connecting rod moves downward with the piston in a straight line. The lower end of the connecting rod moves down and in a circular motion at the same time. This moves the throw and, in turn, the throw rotates the crankshaft; this rotation is the desired result. So remember, the crankshaft and connecting rod combination is a mechanism for the purpose of changing straight line, or reciprocating motion to circular, or rotary motion.

FOUR-STROKE-CYCLE ENGINE

Each movement of the piston from top to bottom or from bottom to top is called a stroke. The piston takes two strokes (an up stroke and a down stroke), as the crankshaft makes one complete revolution Figure 2-4

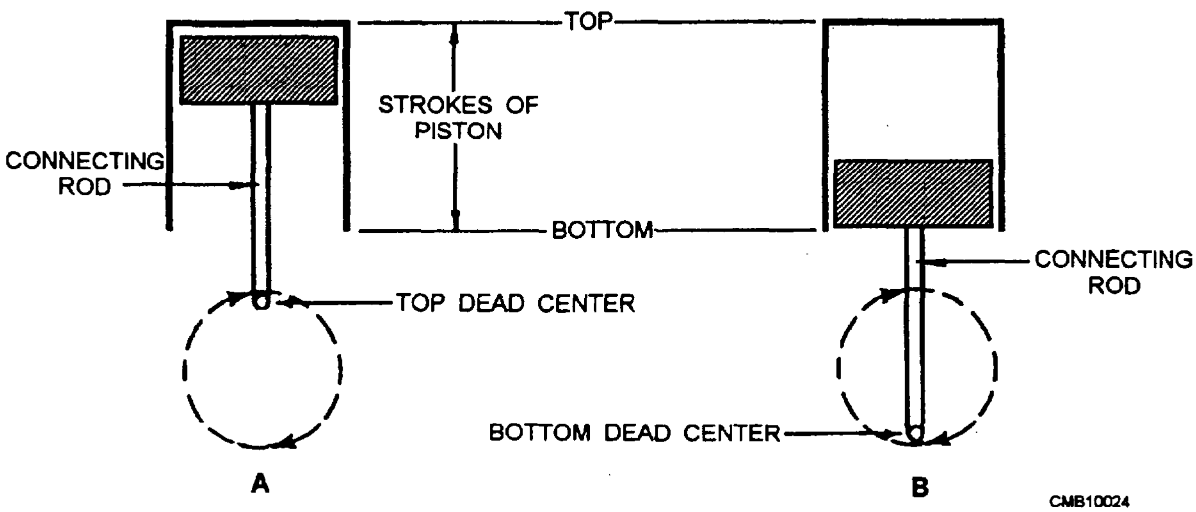


Figure 2-4.—Piston stroke technology.

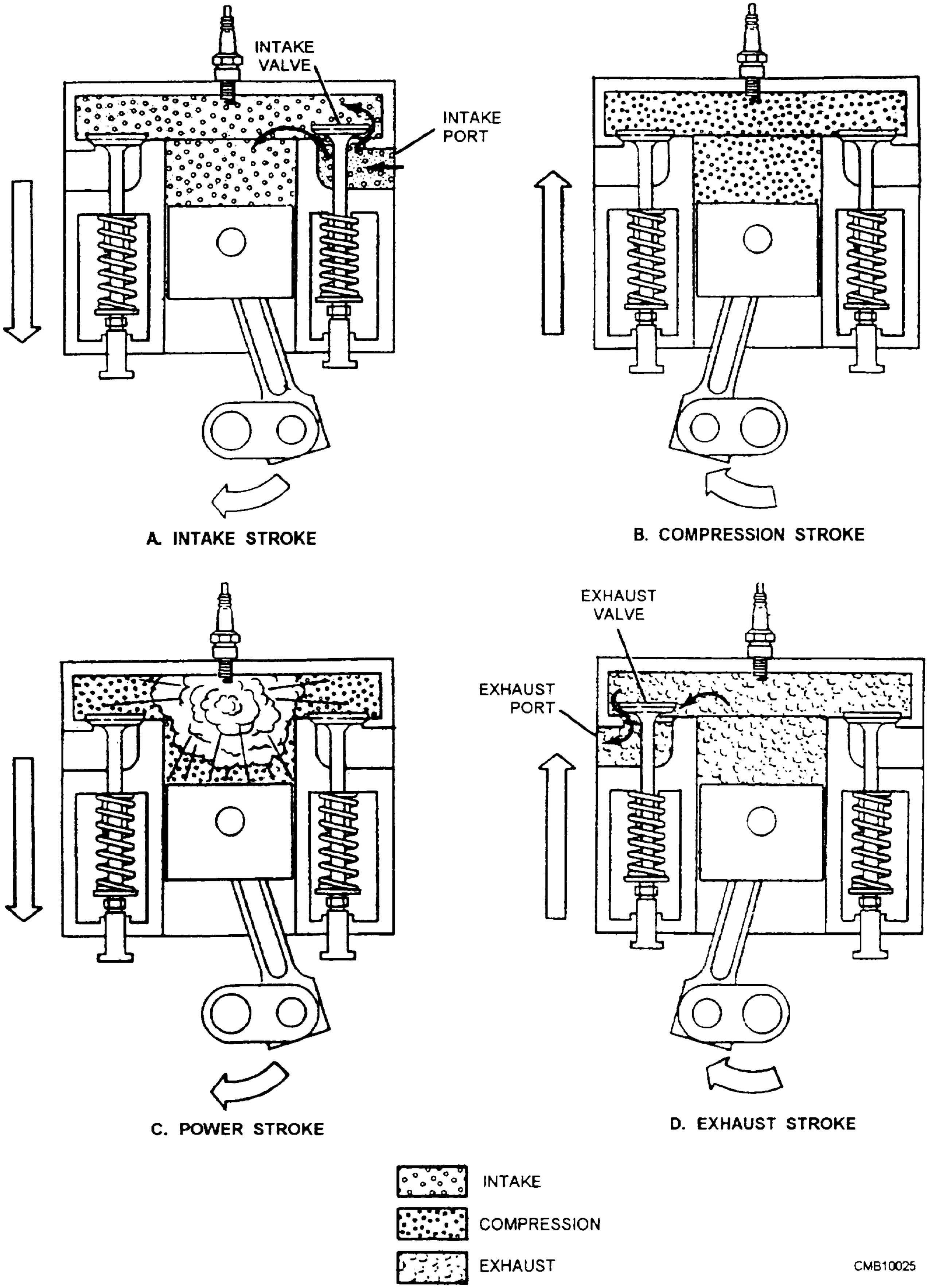


Figure 2-5.—Four-stroke cycle in a gasoline engine.

shows the motion of a piston in its cylinder. The piston is connected to the rotating crankshaft by a connecting rod. In view A of figure 2-4, the piston is at the beginning or top of the stroke. As the crankshaft rotates, the connecting rod pulls the piston down. When the crankshaft has rotated one-half turn, the piston is at the bottom of the stroke. Now look at view B of figure 2-4. As the crankshaft continues to rotate, the connecting rod begins to push the piston up. The position of the piston at the instant its motion changes from down to up is known as **bottom dead center (BDC).** The piston continues moving upward until the motion of the crankshaft causes it to begin moving down. This position of the piston at the instant its motion changes from up to down is known as **top dead center (TDC).** The term *dead* indicates where one motion has stopped (the piston has reached the end of the stroke) and its opposite turning motion is ready to start. These positions are called **rock** positions and discussed later under "Timing."

The following paragraphs provide a simplified explanation of the action within the cylinder of a four-stroke-cycle gasoline engine. It is referred to as a four-stroke cycle because it requires four complete strokes of the piston to complete one engine cycle. Later a two-stroke-cycle engine is discussed. The action of a four-stroke-cycle engine may be divided into four parts: the intake stroke, the compression stroke, the power stroke, and the exhaust stroke.

Intake Stroke

The first stroke in the sequence is called the **INTAKE** stroke (figs. 2-5 and 2-6). During this stroke, the piston is moving downward and the intake valve is open. This downward movement of the piston produces a partial vacuum in the cylinder, and the air-fuel mixture rushes into the cylinder past the open intake valve. This is somewhat the same effect as when you drink through a straw. A partial vacuum is produced in the mouth and the liquid moves up through the straw to fill the vacuum.

Compression Stroke

When the piston reaches bottom dead center (BDC) at the end of the intake stroke and is therefore at the bottom of the cylinder, the intake valve closes. This seals the upper end of the cylinder. As the crankshaft continues to rotate, it pushes up through the connecting rod on the piston. The piston is therefore pushed upward and compresses the combustible mixture in the cylinder; this is called the **COMPRESSION** stroke (figs. 2-5 and 2-6). In gasoline engines, the mixture is compressed to about one eighth of its original volume; this is called 8 to 1 compression ratio. This compression of the air-fuel mixture increases the pressure within the cylinder. Compressing the mixture makes it even more combustible; not only does the pressure in the cylinder increase, but the temperature of the mixture also increases.

Power Stroke

As the piston reaches top dead center (TDC) at the end of the compression stroke and therefore has moved to the top of the cylinder, the compressed air-fuel mixture is ignited. The ignition system causes an electric spark to occur suddenly in the cylinder, and the spark ignites the air-fuel mixture. In burning, the mixture gets very hot and tries to expand in all directions. The pressure rises between 600 to 700 pounds per square inch. Since the piston is the only thing that can move, the force produced by the expanded gases forces the piston down. This force, or thrust, is carried through the connecting rod to the crankshaft throw on the crankshaft. The crankshaft is given a powerful push This is called the **POWER** stroke (figs. 2-5 and 2-6). This turning effort, rapidly repeated in the engine and carried through gears and shafts, turns the wheels of a vehicle and causes it to move.

Exhaust Stroke

After the air-fuel mixture has burned, it must be cleared from the cylinder. This is done by opening the exhaust valve just as the power stroke is finished, and the piston starts back up on the **EXHAUST** stroke (figs. 2-5 and 2-6). The piston forces the burned gases out of the cylinder past the open exhaust valve.

TWO-STROKE-CYCLE ENGINE

In the two-stroke-cycle engine (fig. 2-7), the same four events (intake, compression, power, and exhaust) take place in only two strokes of the piston and one complete revolution of the crankshaft. The two piston strokes are the compression stroke (upward stroke of the piston) and power stroke (the downward stroke of the piston). Remember that a diesel engine has six events that must happen to complete a cycle of operation. To better understand the cycle of operation that happens inside the cylinders of a two-stroke diesel engine, refer to the chart below while reviewing figure 2-7.

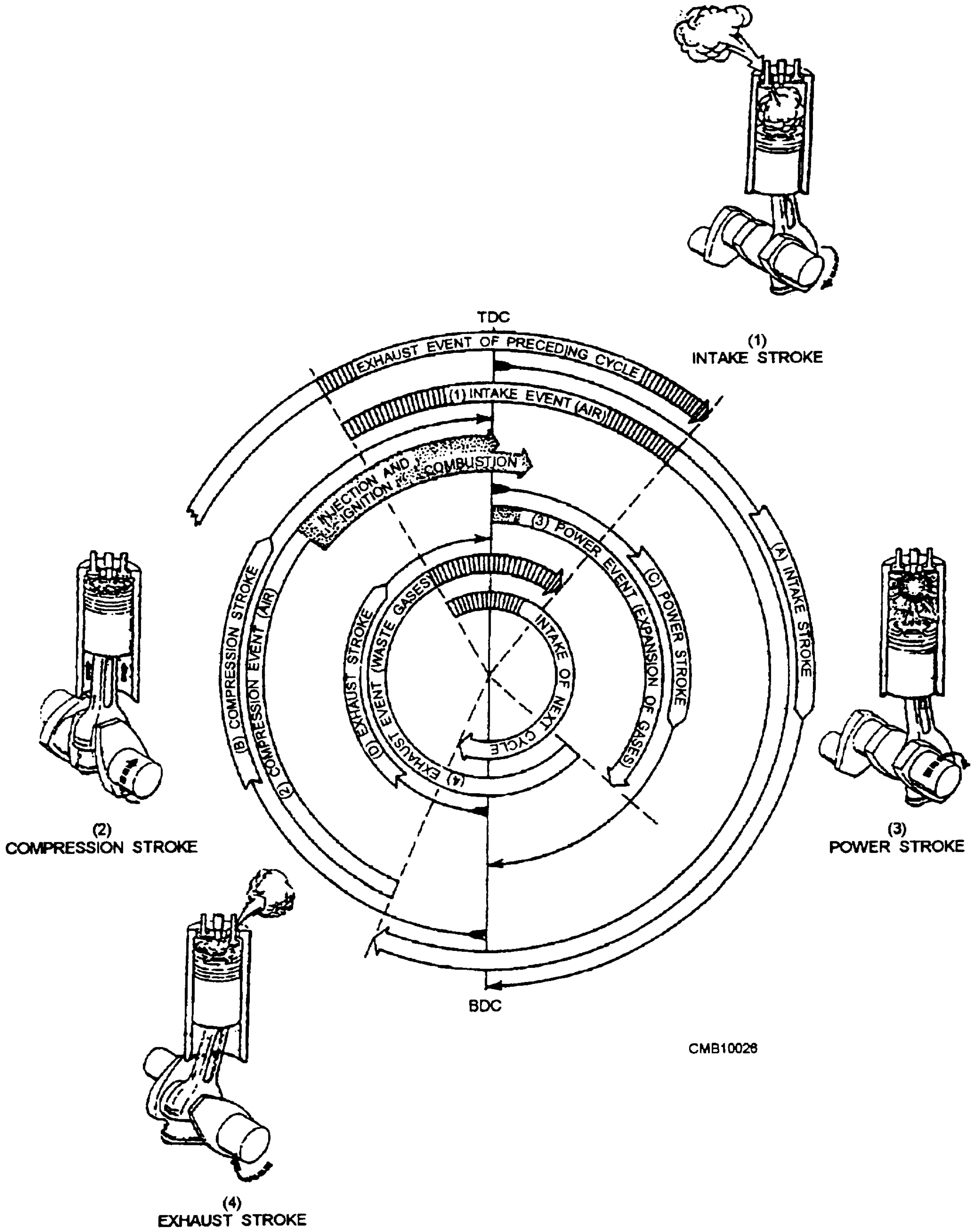


Figure 2-6.—Strokes and events in a four-stroke-cycle diesel engine.

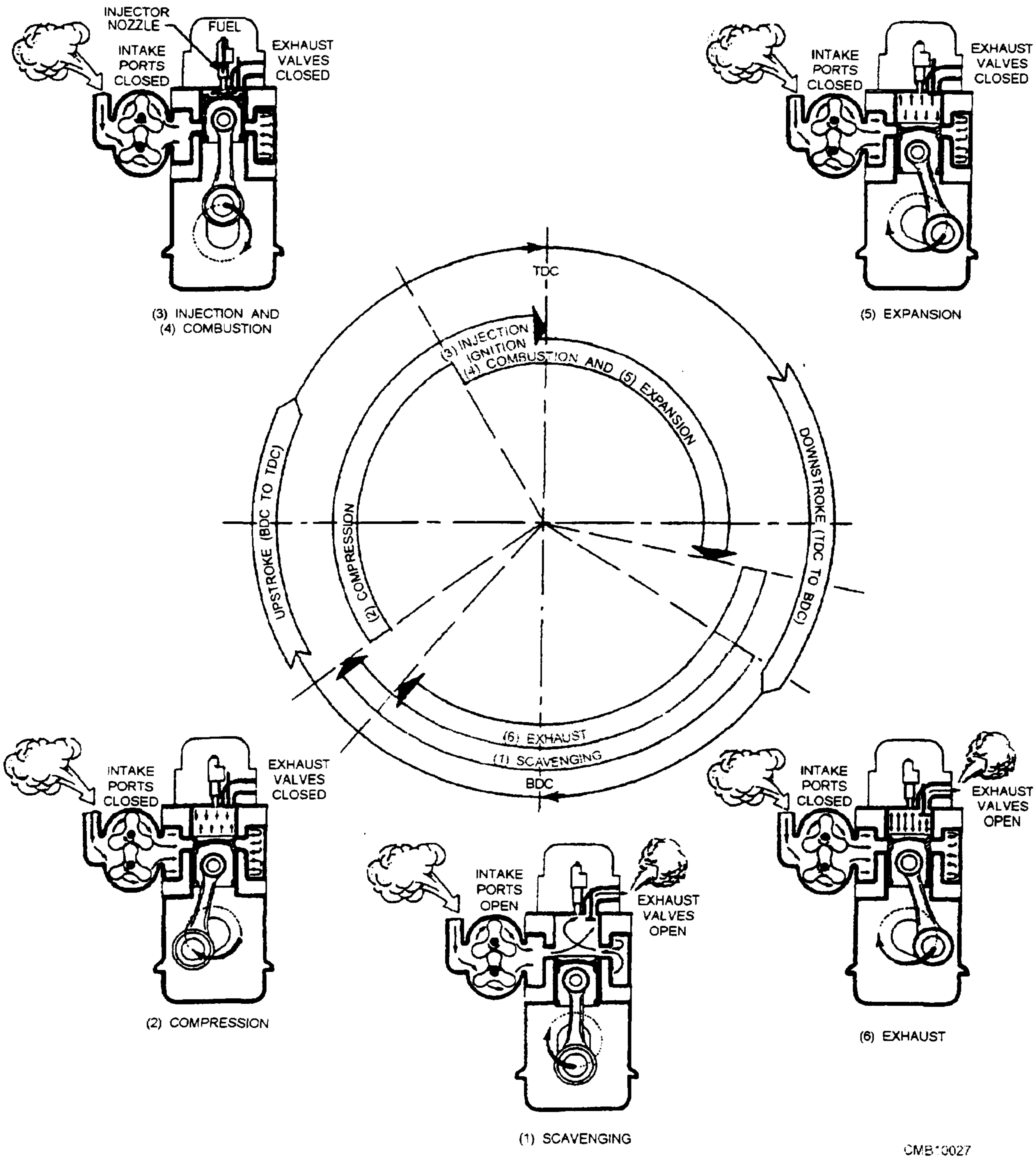


Figure 2-7.—Strokes and events in a two-stroke-cycle diesel engine cylinder.

Sequence of events	Description of Events
(1) Scavenging (intake)	A fresh change of air is forced into the cylinder intake **ports** by the blower. Exhaust gases escape through the open exhaust **valves.**
(2) Compression	As the piston moves upward, the intake ports are covered and the exhaust valves close. The air is compressed in the cylinder; the piston continues to move towards TDC.
(3) Injection/ignition and (4) Combustion	When the piston nears the top of its stroke, fuel is injected into the cylinder. The fuel ignites due to the heat of compression.
(5) Expansion (power)	The rapid expansion of burning gases forces the piston down.
(6) Exhaust	As the piston nears BDC, the exhaust valves open, starting the release of exhaust.

As shown earlier, a power stroke is produced every crankshaft revolution within the two-stroke-cycle engine, whereas the four-stroke-cycle engine requires two revolutions for one power stroke. It might appear then that the two-stroke-cycle engine can produce twice as much power as the four-stroke-cycle engine of the same size, operating at the same speed; however, this power increase is limited to approximately 70 to 80 percent because some of the power is used to drive a blower that forces the air charge into the cylinder under pressure. Also, the burned gases are not completely cleared from the cylinder, reducing combustion efficiency. Additionally, because of the much shorter period the intake port is open (compared to the period the intake valve in a four stroke is open), a relatively smaller amount of air is admitted. Hence, with less air, less power per stroke is produced in a two-stroke-cycle engine.

You need to know the differences between a two-stroke and four-stroke engine. Study the following chart.

TWO-STROKE	FOUR-STROKE
1. One cycle equals one crankshaft revolution and two piston strokes.	1. One cycle equals two crankshaft revolutions and four piston strokes.
2. Requires a blower.	2. Blower is optional.
3. Requires intake and exhaust ports or intake ports and exhaust valves.	3. Requires only intake and exhaust valves.

Figure 2-8 shows a comparison of events that occur during the same length of time for both two-stroke- and four-stroke-cycle engines. Notice the shaded areas that represent the overlapping of events.

Q1. For a vehicle to move, reciprocating motion must be changed to what type of motion?

Q2. On what three things must an internal combustion engine rely to operate ?

Q3. A one-cylinder engine consists of what number of parts?

Q4. A two-stroke engine has approximately what percentage of power increase over a four-stroke engine?

Q5. In a two-stroke diesel engine, what sequence of events happens during the intake stroke?

CLASSIFICATION OF ENGINES

LEARNING OBJECTIVE: *Recognize the differences in the types, the cylinder arrangements, and the valve arrangements of internal combustion engines.*

Engines for automotive and construction equipment may be classified in a number of ways: type of fuel used, type of cooling used, or valve and cylinder arrangement. They all operate on the internal combustion principle, and the application of basic principles of construction to particular needs or systems of manufacture has caused certain designs to be recognized as conventional.

The most common method of classification is by the type of fuel used; that is, whether the engine burns gasoline or diesel fuel.

ENGINE COMPARISON

Mechanically and in overall appearance, gasoline and diesel engines resemble one another; however, in

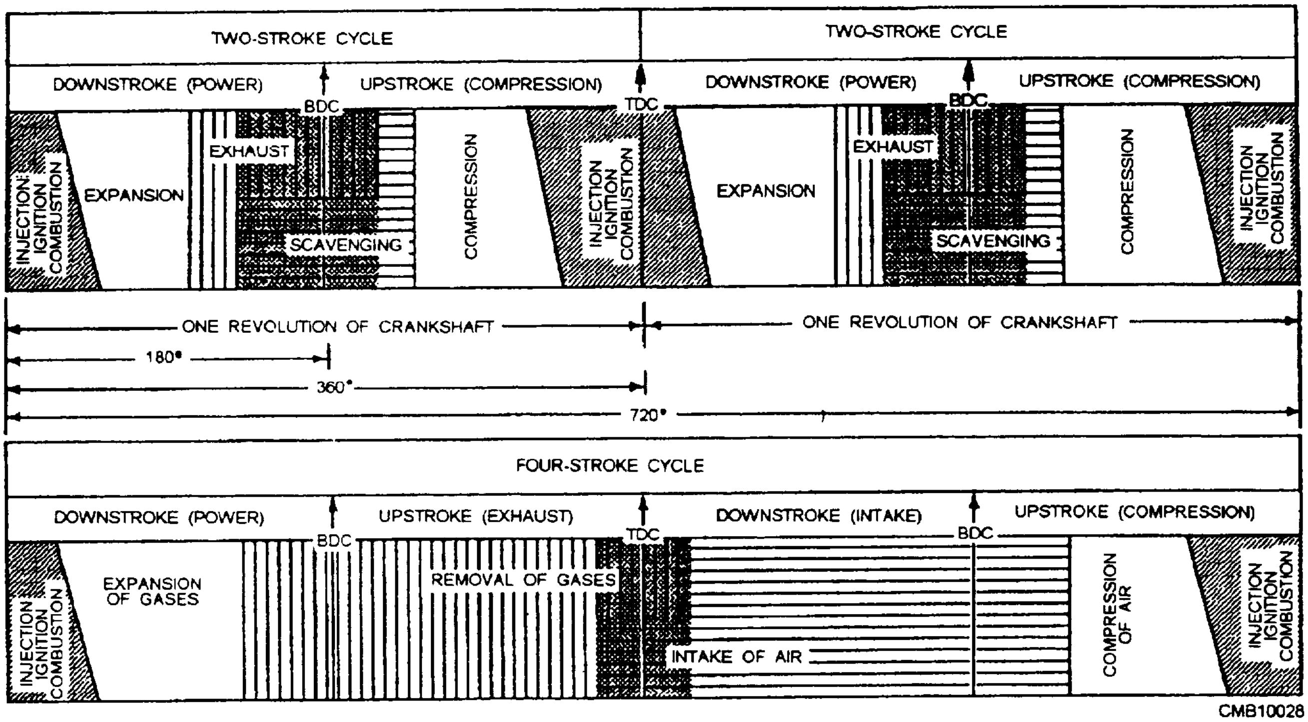


Figure 2-8.—Comparison of two-stroke and four-stroke cycles.

the diesel engine, many parts are somewhat heavier and stronger, so they can withstand higher temperatures and pressures that the engine generates. The engines differ also in the type of fuel used and how the air-fuel mixture is ignited. In a gasoline engine, the air and fuel are mixed together in a carburetor or fuel injection system. After this mixture is compressed in the cylinders, it is ignited by an electrical spark from the spark plugs.

A diesel engine has no carburetor. Air alone enters the cylinder where ii is compressed and reaches a high temperature due to compression. The heat of compression ignites the fuel injected into the cylinder and causes the air-fuel mixture to burn. A diesel engine requires no spark plugs; the contact of diesel fuel with hot air in the cylinders causes ignition. In a gasoline engine, the heat from compression is not enough to ignite the air-fuel mixture, so spark plugs are required.

MULTIPLE-CYLINDER ENGINES

The discussion so far has been on a single cylinder engine. A single cylinder provides one power impulse every two crankshaft revolutions in a four-stroke-cycle engine and is delivering power only one fourth of the time. To provide for a more continuous flow of power, modem engines use four, six, eight. or more cylinders. The same series of cycles discussed previously take place in each cylinder.

In a four-stroke cycle, six-cylinder engine, for example, the throws on the crankshaft are set 120 degrees apart, the throws for cylinders 1 and 6, 2 and 5, 3 and 4 being in line with each other (fig. 2-9). The cylinders fire or deliver power strokes in the following order: l-5-3-6-2-4. The power strokes follow each other so closely that there is a fairly continuous and even delivery of power to the crankshaft.

Even so, additional leveling off of the power impulses is desirable, so the engine runs more smoothly. A flywheel (fig. 2-9) is used to achieve this result.

To understand how the flywheel functions, let’s consider a single cylinder engine. It is delivering power only one fourth of the time during the power stroke.

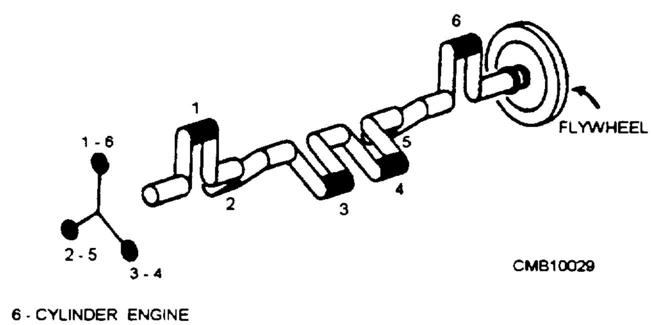


Figure 2-9.—Crankshaft for a sixcylinder engine.

During the other three strokes, it is absorbing power to push out the exhaust gas, to pull in a fresh charge, and to compress the charge. The flywheel makes the engine run without varying much of the speed during each revolution. It is a heavy steel wheel, attached to the end of the crankshaft. When it is rotating, considerable effort is required to slow it down or stop it. Although the wheel does slow down somewhat as it delivers power to the engine during the exhaust, intake, and compression strokes, the wheel speed increases during the power stroke. In effect, the flywheel absorbs some of the engine power during the power stroke and then provides it back to the engine during the other three strokes.

In a multi-cylinder engine, the flywheel functions in a similar manner. It absorbs power when the engine tends to speed up during the power stroke, and it provides power to the engine when the engine tends to slow down during intervals when little power is being delivered by the engine.

In addition to the engine itself, which is the power producer, there must be accessory systems to provide the engine with other requirements necessary to operate it. These systems are the fuel system, the lubrication system, the electrical system, the cooling system, and the exhaust system

ARRANGEMENT OF CYLINDERS

Engines are also classified according to the arrangement of the cylinders (fig. 2-10): **IN-LINE** with all cylinders cast in a straight line above the crankshaft; **V-TYPE** with two banks of cylinders mounted in a V-shape above the crankshaft; **HORIZONTAL OPPOSED** with cylinders arranged 180 degrees from other with opposing cylinders sharing a common crankshaft journal; and **RADIAL** with the cylinders placed in a circle around the crankshaft

- **IN-LINE**—In-line is a common arrangement for both automotive and truck applications. It is commonly built in four- and six-cylinder configurations.

- **V-TYPE**—V-type is also a common arrangement for both automotive and truck applications. The V-type engine in a six-cylinder configuration is suitable for front-wheel drive cars where the engine is mounted transversely.

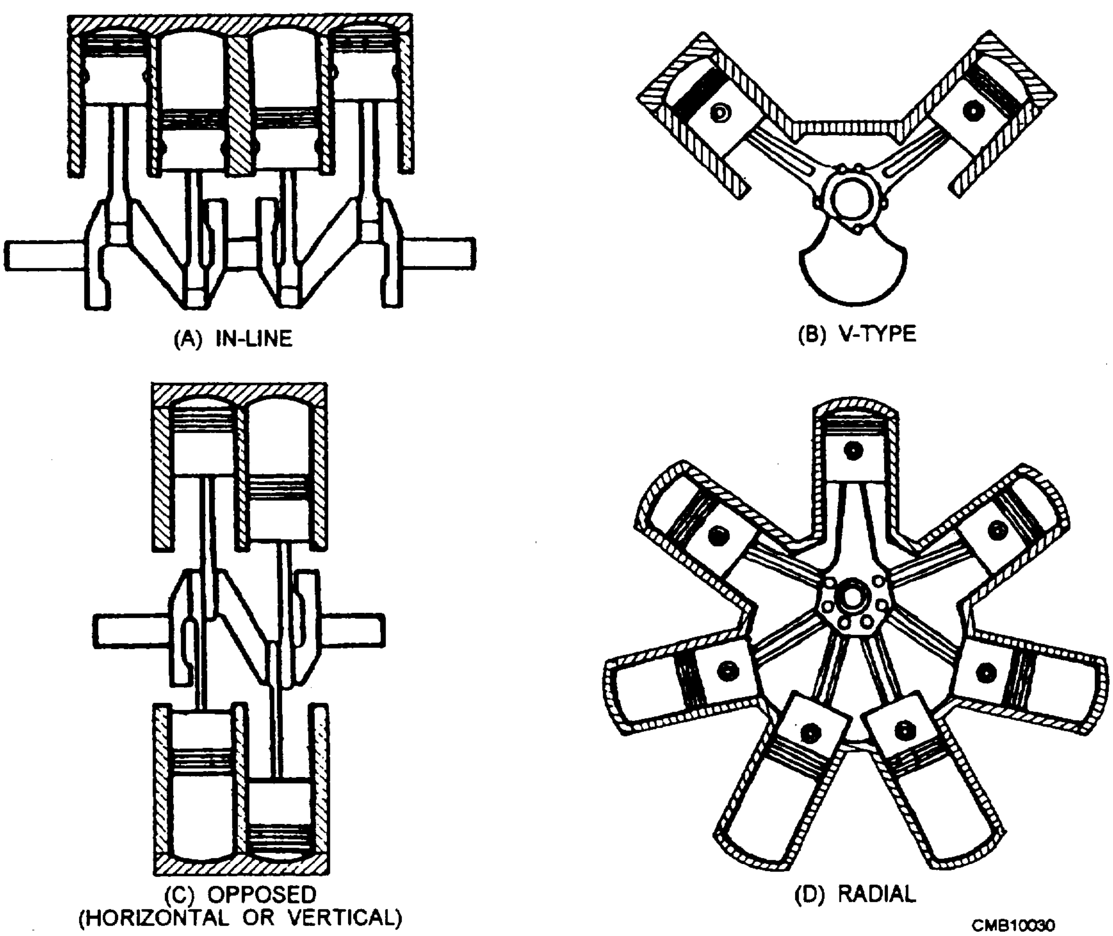


Figure 2-10.—Typical cylinder arrangements

- **HORIZONTAL OPPOSED**—This engine is designed to fit into compartments where height is a consideration. It is used for air-cooled configurations.
- **RADIAL**—This engine is designed almost exclusively for an aircraft engine.

The cylinders are numbered. The cylinder nearest the front of an in-line engine is number 1. The others are numbered 2, 3, 4, and so on, from front to rear. In V-type engines, the numbering sequence varies by manufacturer. You should always consult the manufacturer's manual for the correct order.

The **FIRING ORDER** (which is different from the **NUMBERING ORDER)** of the cylinders of most engines is stamped on the cylinder block or on the manufacturer’s nameplate. If you are unable to locate the firing order and no operation or instruction manual is available, turn the engine over by the crankshaft and watch the order in which the intake valves open.

ARRANGEMENT OF VALVES

The majority of internal combustion engines also are classified according to the position and arrangement of the intake and exhaust valves, whether the valves are located in the cylinder head or cylinder block. The following are types of valve arrangements with which you may come in contact:

- **L-HEAD** (fig. 2-11)—The intake and the exhaust valves are both located on the same side of the piston and cylinder. The valve operating mechanism is located directly below the valves, and one camshaft actuates both the intake and the exhaust valves.

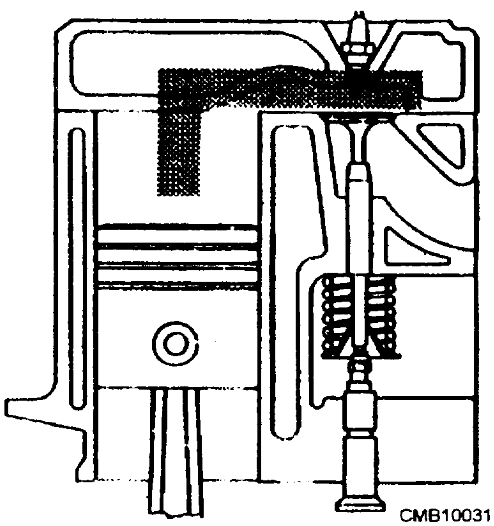


Figure 2-11.—L-head engine.

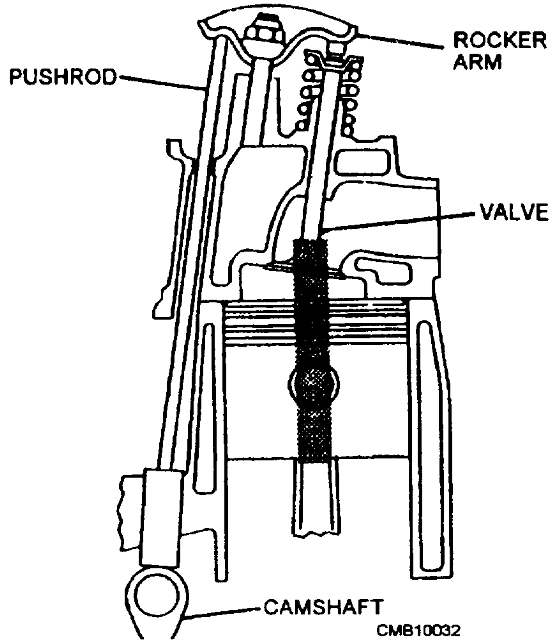


Figure 2-12.—I-head engine.

- **I-HEAD** (fig. 2-12)—The intake and the exhaust valves are both mounted in a cylinder head directly above the cylinder. This arrangement requires a tappet, a pushrod, and a rocker arm above the cylinder to reverse the direction of valve movement. Although this configuration is the most popular for current gasoline and diesel engines, it is rapidly being superseded by the overhead camshaft.
- **F-HEAD** (fig. 2-13)—The intake valves are normally located in the head, while the exhaust

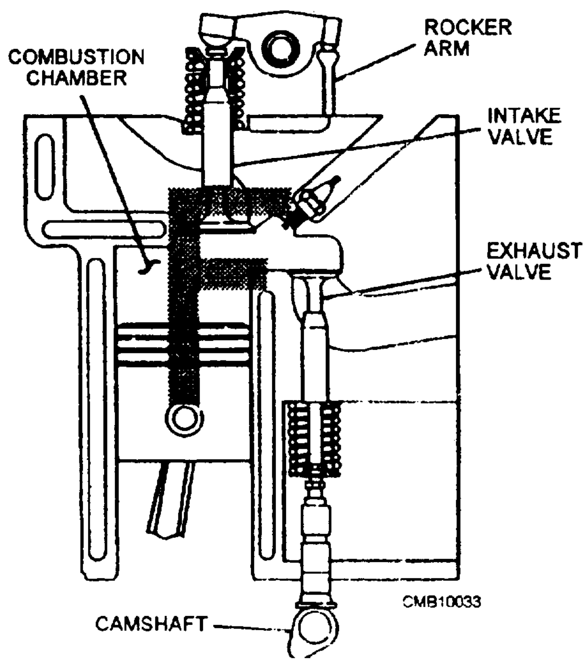


Figure 2-13.—F-head engine.

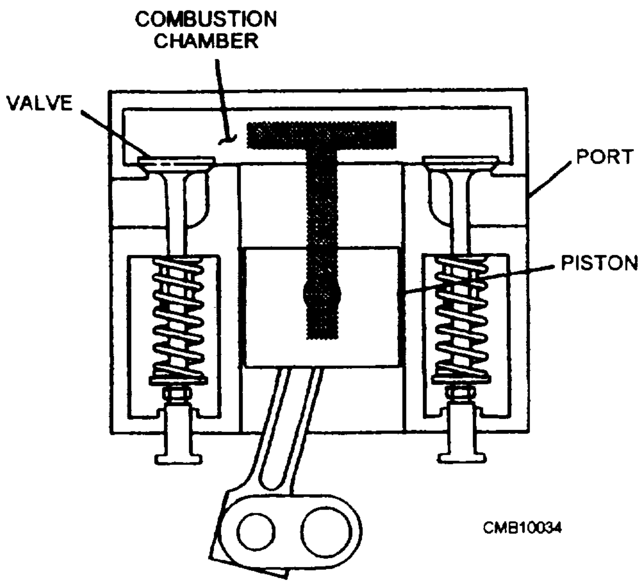


Figure 2-14.—T-head engine.

valves are located in the engine block. The intake valves in the head are actuated from the camshaft through tappets, pushrods, and rocker arms. The exhaust valves are actuated directly by tappets on the camshaft.

- **T-HEAD** (fig. 2-14)—The intake and the exhaust valves are located on opposite sides of the cylinder in the engine block, each requires their own camshaft.
- **SINGLE OVERHEAD CAMSHAFT** (fig. 2-15)—The camshaft is located in the cylinder head. The intake and the exhaust valves are both operated from a common camshaft. The valve train may be arranged to operate directly through the lifters, as shown in view A, or by rocker arms, as shown in view B. This configuration is becoming popular for passenger car gasoline engines.
- **DOUBLE OVERHEAD CAMSHAFT** (fig. 2-16)—When the double overhead camshaft is used, the intake and the exhaust valves each operate from separate camshafts directly through the lifters. It provides excellent engine performance and is used in more expensive automotive applications.

Q6. Other than construction, what three things differ in gasoline and diesel engines?

Q7. What type of cylinder arrangement is used when height is a consideration?

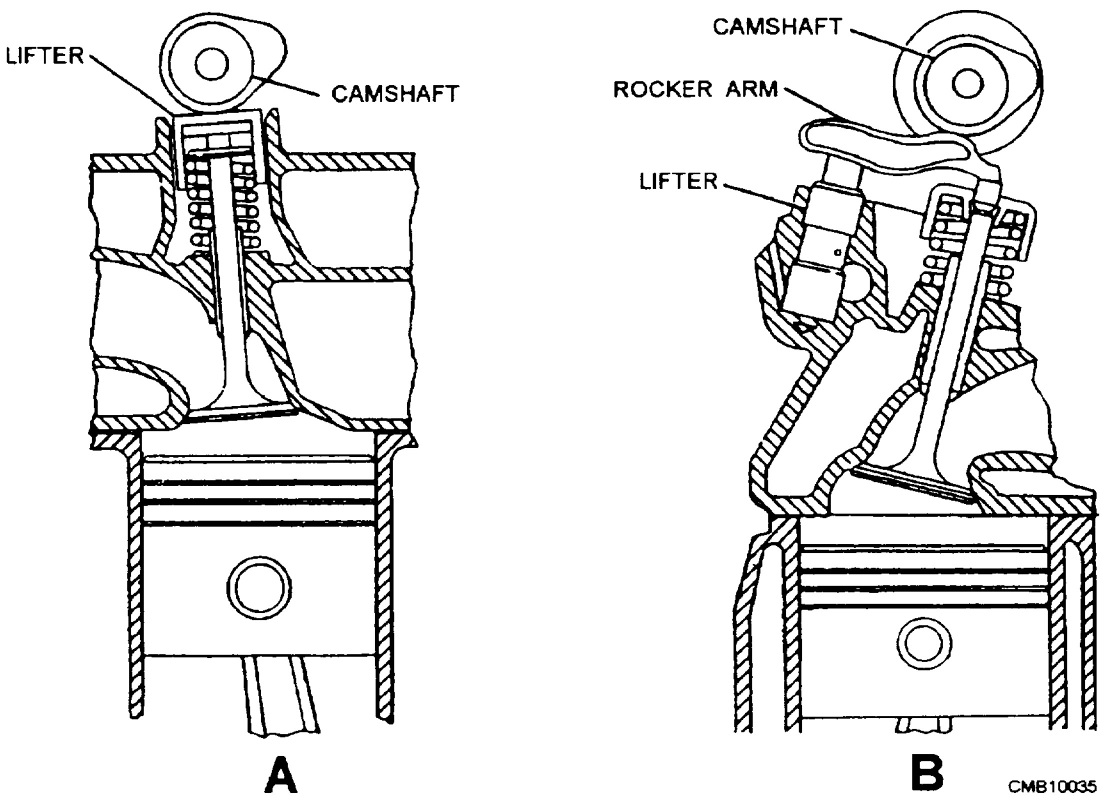


Figure 2-15.—Single overhead camshaft configurations.

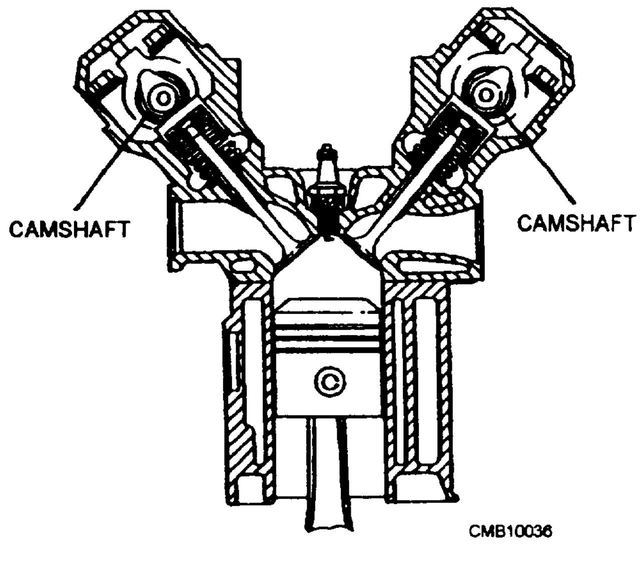


Figure 2-16.—Double overhead camshaft configuration.

Q8. In a horizontal-opposed engine, the cylinders are arranged at what number of degrees from each other?

Q9. What type of head design has the valves arranged directly over the cylinder?

Q10. What type of head design has exhaust valves located in the engine block?

ENGINE MEASUREMENTS AND PERFORMANCE

LEARNING OBJECTIVE: *Identify terms, engine measurements, and performance standards of an internal combustion engine.*

As a Construction Mechanic, you must know the various ways that engines and engine performance are measured. An engine may be measured in terms of cylinder diameter, piston stroke, and number of cylinders. It may be measured, performance wise, by the torque and horsepower it develops and by efficiency.

DEFINITIONS

WORK is the movement of a body against an opposing force. In the mechanical sense of the term, this is done when resistance is overcome by a force acting through a measured distance. Work is measured in units of foot-pounds. One foot-pound of work is equivalent to lifting a l-pound weight a distance of 1 foot (fig. 2-17). Work is always the force exerted over a distance. When there is no movement of an object, there is no work, regardless of how much force is exerted

ENERGY is the ability to do work. Energy takes many forms, such as heat, light, sound, stored energy (potential), or as an object in motion (kinetic energy). Energy performs work by changing from one form to another. Take the operation of an automobile for example; it does the following:

- When a car is sitting still and not running, it has potential energy stored in the gasoline.
- When a car is set in motion, the gasoline is burned, changing its potential energy into heat energy. The engine then transforms the heat energy into kinetic energy by forcing the car into motion.
- The action of stopping the car is accomplished by brakes. By the action of friction, the brakes transform kinetic energy back to heat energy. When all the kinetic energy is transformed into heat energy, the car stops.

POWER is the rate at which work is done. It takes more power to work rapidly than to work slowly. Engines are rated by the amount of work they can do per minute. An engine that does more work per minute than another is more powerful.

The work capacity of an engine is measured in **horsepower** (hp). Through testing, it was determined that an average horse can lift a 200-pound weight to a height of 165 feet in 1 minute. The equivalent of one horsepower can be reached by multiplying 165 feet by 200 pounds (work formula) for a total of 33,000 foot-

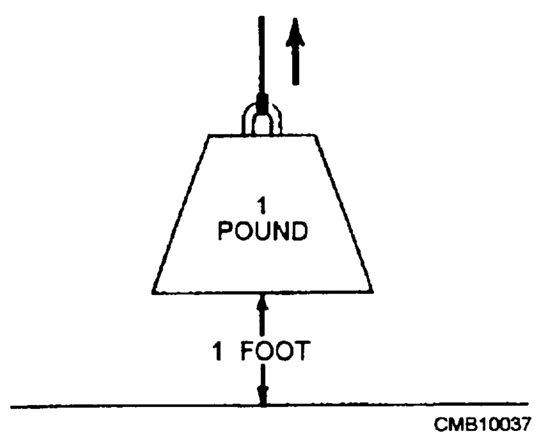


Figure 2-17.—One foot-pound of work.

pounds per minute (fig. 2-18). The formula for horsepower is the following:

$$Hp = \frac{\text{ft-lb. per min}}{33{,}000} = \frac{L \times W}{33{,}000 \times t}$$

L = length, in feet, through which W is moved

W = force, in pounds, that is exerted through distance L

T = time, in minutes, required to move W through L

A number of devices are used to measure the hp of an engine. The most common device is the dynamometer.

An **ENGINE DYNAMOMETER** (fig. 2-19) may be used to bench test an engine that has been removed from a vehicle. If the engine does not develop the recommended horsepower and torque of the manufacturer, you know further adjustments and/or repairs on the engine are required.

The **CHASSIS DYNAMOMETER** (fig. 2-19) is used for automotive service, since it can provide a quick report on engine conditions by measuring output at various speeds and loads. This type of machine is useful in shop testing and adjusting an automatic transmission. On a chassis dynamometer, the driving wheels of a vehicle are placed on rollers. By loading the rollers in varying amounts and by running the engine at different speeds, you can simulate many driving conditions. These tests and checks are made without interference by other noises, such as those that occur when you check the vehicle while driving on the road.

Another device that measures the actual usable horsepower of an engine is the **PRONY BRAKE** (fig. 2-20). It is used very little today, but is simple to understand. It is useful for learning the concept of horsepower-measuring tools. It consists of a flywheel surrounded by a large braking device. One end of an arm is attached to the braking device, while the other end exerts pressure on a scale. In operation, the engine is attached to, and drives, the flywheel. The braking device is tightened until the engine is slowed to a predetermined rpm. As the braking device slows the engine, the arm attached to it exerts pressure on a scale. Based on the reading at the scale and engine rpm, a brake horsepower valve is calculated by using the following formula:

$$\frac{6.28 \times \text{length of arm} \times \text{engine rpm} \times \text{scale reading}}{33{,}000}$$

It must be noted that 6.28 and 33,000 are constants in the formula, meaning they never change. For example, a given engine exerts a force of 300 pounds on a scale through a 2-foot-long arm when the brake device holds the speed of the engine at 3,000 rpm. By using the formula, calculate the brake horsepower as follows:

$$\frac{6.28 \times 2 \times 3000 \times 300}{33{,}000} = 342.55 \text{ brake horsepower}$$

TORQUE is a force that, when applied, tends to result in twisting an object, rather than its physical movement. When the torque is being measured, the force that is applied must be multiplied by the distance from the axis of the object. Torque is measured in pound-feet (not to be confused with work which is measured in foot-pounds). When torque is applied to an object, the force and distance from the axis depends on each other. For example, when 100 foot-pounds of torque is applied to a nut, it is equivalent to a 100-pound

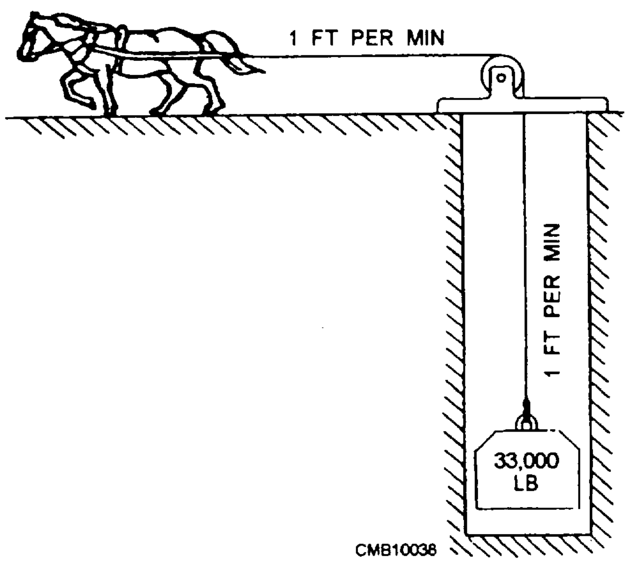


Figure 2-18.—Horsepower.

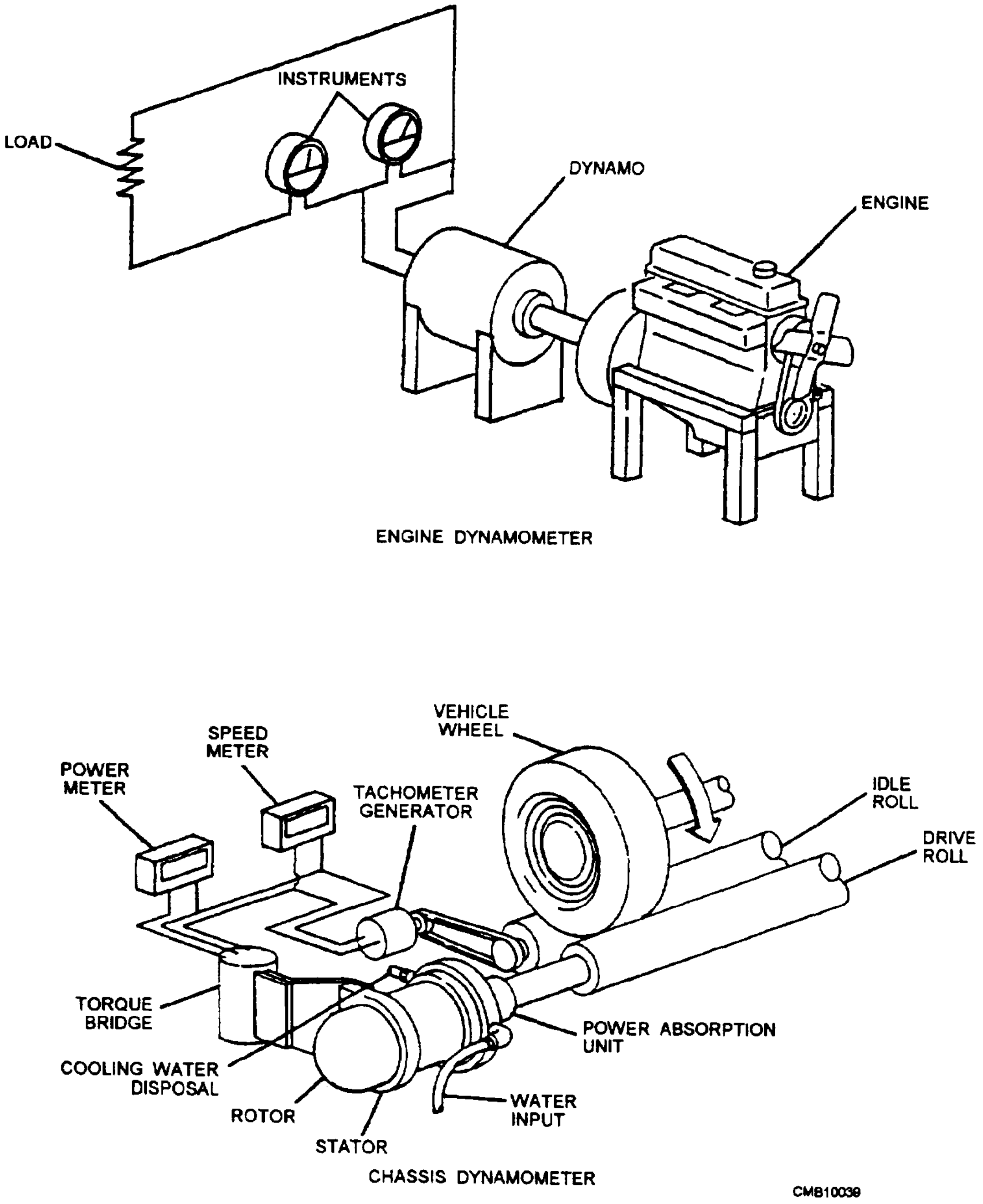


Figure 2-19.—Dynamometers.

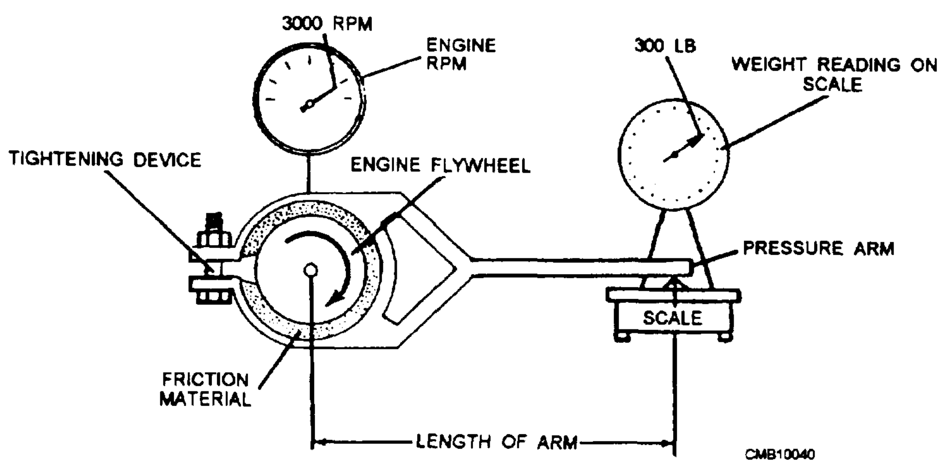


Figure 2-20.—Prony brake.

force being applied from a wrench that is l-foot long. When a 2-foot-long wrench is used, only a 50-pound force is required. An illustration of a torque wrench in use is shown in figure 2-21.

DO NOT confuse torque with work or with power. Both work and power indicate motion, but torque does not. It is merely a turning effort the engine applies to the wheels through gears and shafts.

ENGINE TORQUE is a rating of the turning force at the engine crankshaft. When combustion pressure pushes the piston down, a strong rotating force is applied to the crankshaft. This turning force is sent to the transmission or transaxle, drive line or drive lines, and drive wheels, moving the vehicle. Engine torque specifications are provided in a shop manual for a particular vehicle. One example, 78 pound-feet @ 3,000 (at 3,000) rpm is given for one particular engine. This engine is capable of producing 78 pound-feet of torque when operating at 3,000 revolutions per minute.

FRICTION is the resistance to motion between two objects in contact with each other. The reason a sled does not slide on bare earth is because of friction It slides on snow because snow offers little resistance, while the bare earth offers a great deal of resistance.

Friction is both desirable and undesirable in an automobile or any other vehicle. Friction in an engine is undesirable because it decreases the power output; in other words, it dissipates some of the energy the engine produces. This is overcome by using oil, so moving components in the engine slide or roll over each other smoothly. **Frictional horsepower** (fhp) is the power needed to overcome engine friction. It is a measure of resistance to movement between engine parts. Frictional horsepower is **POWER LOST** to friction. It reduces the amount of power left to propel a vehicle. Friction, however, is desirable in clutches and brakes, since friction is exactly what is needed for them to perform their function properly.

One other term you often encounter is **INERTIA.** Inertia is a characteristic of all material objects. It causes them to resist change in speed or direction of travel. A motionless object tends to remain at rest, and a moving object tends to keep moving at the same speed and in the same direction. A good example of inertia is the tendency of your automobile to keep moving even after you have removed your foot from the accelerator. You apply the brake to overcome the inertia of the automobile or its tendency to keep moving.

The term *efficiency* means the relationship between the actual and theoretical power output. **Volumetric efficiency** (fig. 2-22) is the ratio between the amount of air-fuel mixture that actually enters the cylinder and the amount that could enter under ideal conditions. The greater volumetric efficiency, the greater the amount of air-fuel mixture entering the cylinder; and the greater

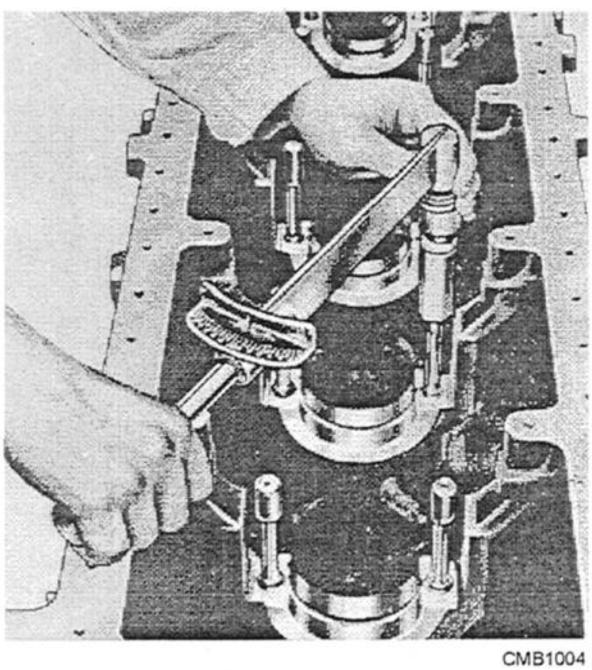
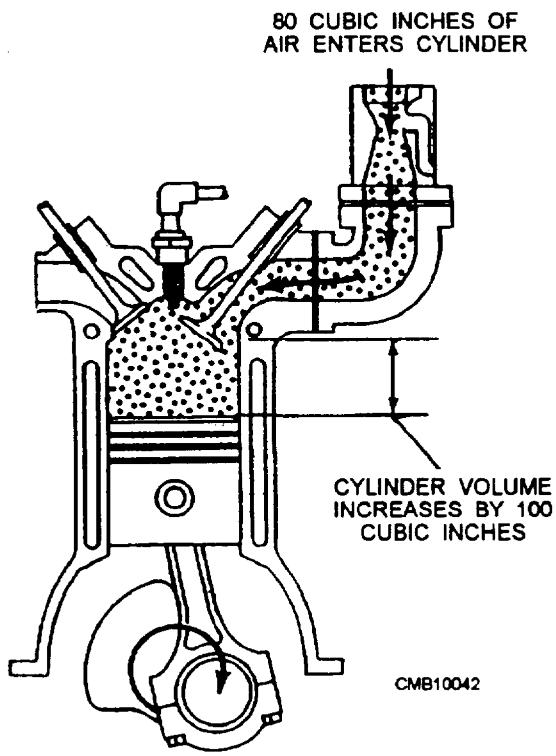


Figure 2-21.—Torque wrench in use, tightening main bearing stud of an engine.



Fire 2-22.—Demonstrating volumetric efficiency.

the amount of air-fuel mixture, the greater the power produced by the engine.

Increasing volumetric efficiency increases engine performance. Volumetric efficiency can be increasedin the following ways:

- Keep the intake mixture cool by ducting intake air from outside the engine compartment. By keeping the fuel cool, you can keep the intake mixture cooler. The cooler the mixture, the higher the volumetric efficiency. This is because a cool mixture is denser or more tightly packed.
- Modify the intake passages (fig. 2-23). Changes to the intake passages that make it easier for the mixture to flow through will increase the volumetric efficiency. Other changes include reshaping ports to smooth bends, reshaping the back of the valve heads, or polishing the inside of the ports.
- Altering the time that the valves open or how far they open can increase volumetric efficiency.
- By supercharging and turbocharging, you can bring the volumetric efficiency figures to over 100 percent.

MECHANICAL EFFICIENCY is the relationship between the actual power produced in the engine (indicated horsepower) and the actual power delivered at the crankshaft (brake horsepower). The actual power is always less than the power produced within the engine. This is due to the following:

- Friction losses between the many moving parts of the engine.
- In a four-stroke-cycle engine, a considerable amount of horsepower is used to drive the valve train.

From a mechanical efficiency standpoint, you can tell what percentage of power developed in the cylinder is actually delivered by the engine. The remaining percentage of power is consumed by friction, and it is computed as frictional horsepower (fhp).

THERMAL EFFICIENCY is the relationship between actual heat energy stored within the fuel and power produced in the engine (indicated horsepower). The thermal efficiency figure indicates the amount of potential energy contained in the fuel that is actually used by the engine to produce power and what amount of energy is actually lost through heat. A large amount of energy from the fuel is lost through heat and not used in an internal combustion engine. This unused heat is of no value to the engine and must be removed from it. Heat is dissipated in the following ways:

- The cooling system removes heat from the engine to control engine operating temperature.
- A major portion of the heat produced by the engine exits through the exhaust system.
- The engine radiates a portion of the heat to the atmosphere.

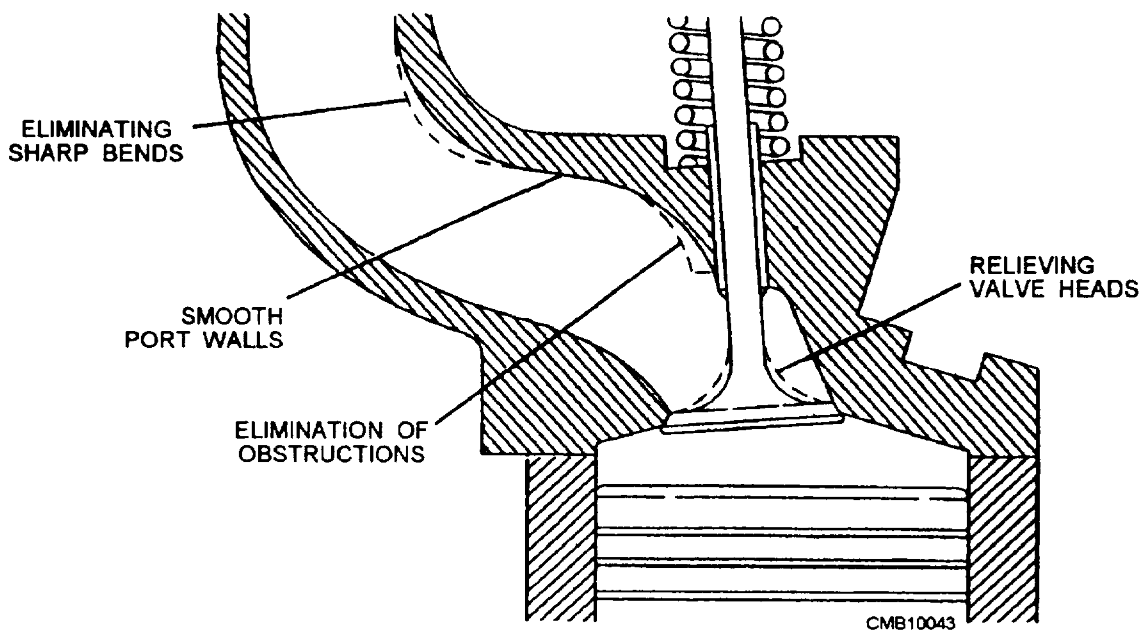


Figure 2-23.—Port design consideration.

- A portion of this waste heat may be channeled to the passenger compartment to heat it.
- The lubricating oil in the engine removes a portion of the waste heat.

In addition to energy lost through waste heat, there are the following inherent losses in the piston engine.

- Much energy is consumed when the piston must compress the mixture on the compression stroke.
- Energy from the fuel is consumed to pull the intake mixture into the cylinder.
- Energy from the fuel is consumed to push the exhaust gases out of the cylinder.

The combination of all these factors in a piston engine that uses and wastes energy leaves the average engine approximately 20 to 25 percent thermally efficient.

LINEAR MEASUREMENTS

The size of an engine cylinder is indicated in terms of bore and stroke (fig. 2-24). **BORE** is the inside diameter of the cylinder. **STROKE** is the distance between top dead center (TDC) and bottom dead center (BDC). The bore is always mentioned first. For example, a 3 1/2 by 4 cylinder means that the cylinder bore, or diameter, is 3 1/2 inches and the length of the stroke is 4 inches. These measurements are used to figure displacement.

PISTON DISPLACEMENT is the volume of space that the pistondisplaces, as it moves from one end of the stroke to the other. Thus the piston displacement in a 3 1/2-inch by 4-inch cylinder would be the area of a 3 1/2-inch circle multiplied by 4 (the length of the stroke.) The area of a circle is πR^2, where R is the radius (one half of the diameter) of the circle. With S being the length of the stroke, the formula for volume (V) is the following:

$V = \pi R^2 \times S$

If the formula is applied to figure 2-22, the piston displacement is computed as follows:

R = 1/2 the diameter = 1/2 x 3.5 = 1.75 in.

$\pi = 3.14$

$V = \pi (1.75)^2 \times 4$

V = 3.14 x 3.06 x 4

V = 38.43 cu in.

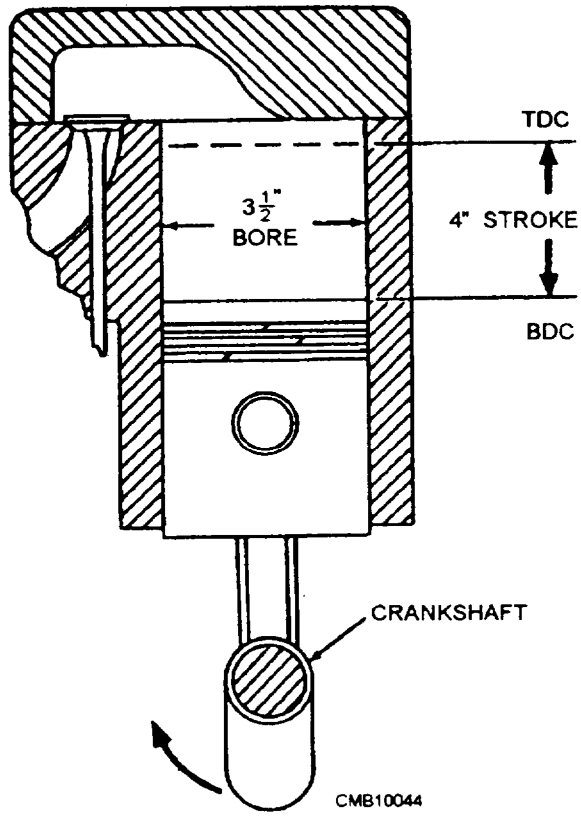


Figure 2-24.—Bore and stroke of an engine cylinder.

The total displacement of an engine is found by multiplying the volume of one cylinder by the total number of cylinders.

38.43 cu in. x 8 cylinders = 307.44 cu in.

The displacement of the engine is expressed as 307 cubic inches in the English system. To express the displacement of the engine in the metric system, convert cubic inches to cubic centimeters. This is done by multiplying cubic inches by 16.39. It must be noted that 16.39 is constant.

307.44 cu in. x 16.39 = 5,038.9416 cc

To convert cubic centimeters into liters, divide the cubic centimeters by 1,000. This is because 1 liter = 1,000 cc.

$$\frac{5{,}038.9416}{1{,}000} = 5.0389416$$

The displacement of the engine is expressed as 5.0 liters in the metric system.

ENGINE PERFORMANCE

The **COMPRESSION RATIO** of an engine is a measurement of how much the air-fuel charge is compressed in the engine cylinder. It is calculated by dividing the volume of one cylinder with the piston at BDC by the volume with the piston TDC (fig. 2-25). One should note that the volume in the cylinder at TDC is called the clearance volume.

For example. suppose that an engine cylinder has a volume of 80 cubic inches with the piston at BDC and a volume of 10 cubic inches with the piston at TDC. The compression ratio in this cylinder is 8 to 1, determined by dividing 80 cubic inches by 10 cubic inches; that is, the air-fuel mixture is compressed from 80 to 10 cubic inches or to one eighth of its original volume.

Two major advantages of increasing compression ratio are that power and economy of the engine improve without added weight or size. The improvements come about because with higher compression ratio the air-fuel mixture is squeezed more. This means a higher initial pressure at the start of the power stroke. As a result. there is more force on the piston for a greater part of the power stroke; therefore, more power is obtained from each power stroke.

Increasing the compression ratio, however, brings up some problems. Fuel can withstand only a certain amount of squeezing without knocking. Knocking is the sudden burning of the air-fuel mixture that causes a quick increase in pressure and a rapping or knocking noise,. The fuel chemists have overcome knocking by creating antiknock fuels. (Antiknock fuels are described in a later module).

Oxygen must be present if combustionis to occur in the cylinder, and since air is the source of the supply of oxygen used in engines, the problem arises of getting the proper amount of air to support combustion. This factor is known as the **AIR-FUEL RATIO.** Agasoline engine normally operates at intermediate speeds on a 15 to 1 ratio; that is, 15 pounds of air to 1 pound of gasoline.

TIMING

In a gasoline engine, the valves must open and close at the proper times with regard to piston position and stroke. In addition, the ignition system must produce sparks at the proper time, so power strokes can start. Both valve and ignition system action must he timed properly to obtain good engine performance.

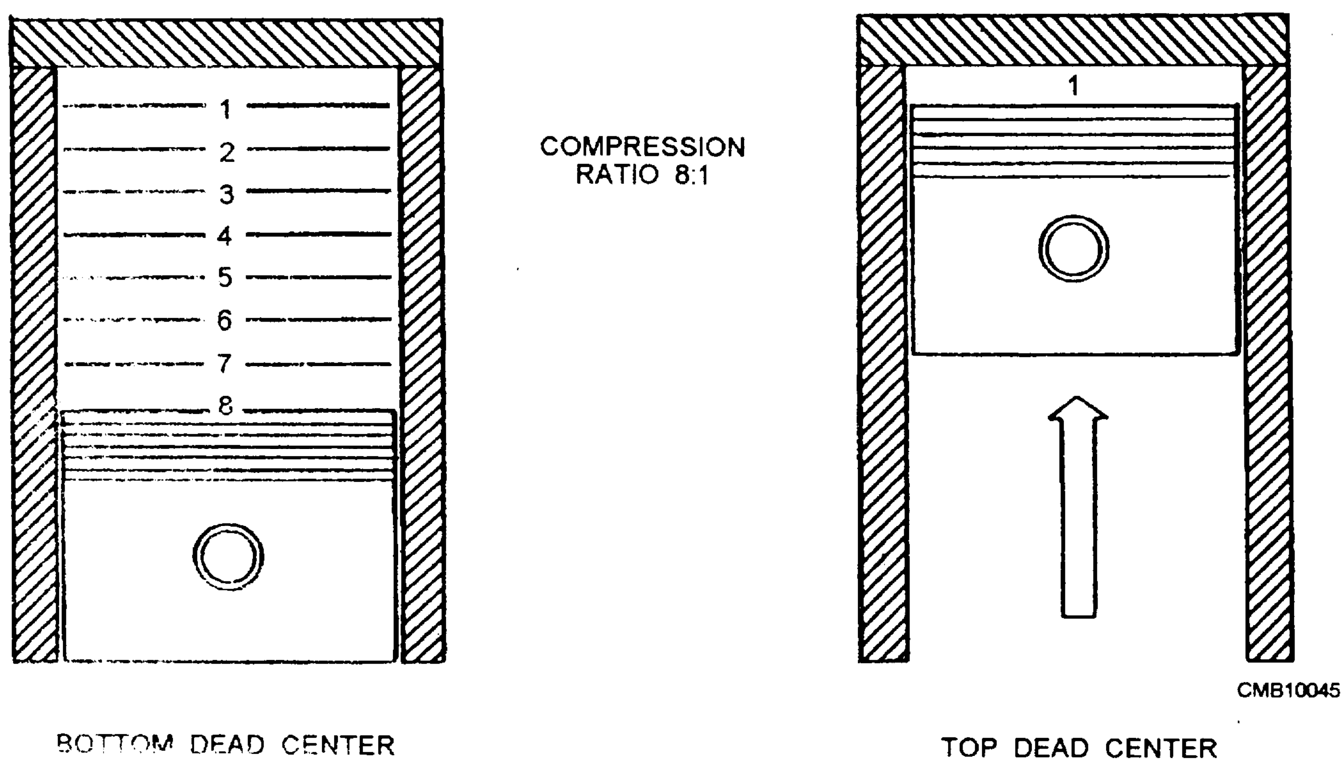


Figure 2-25.—Compression ratio.

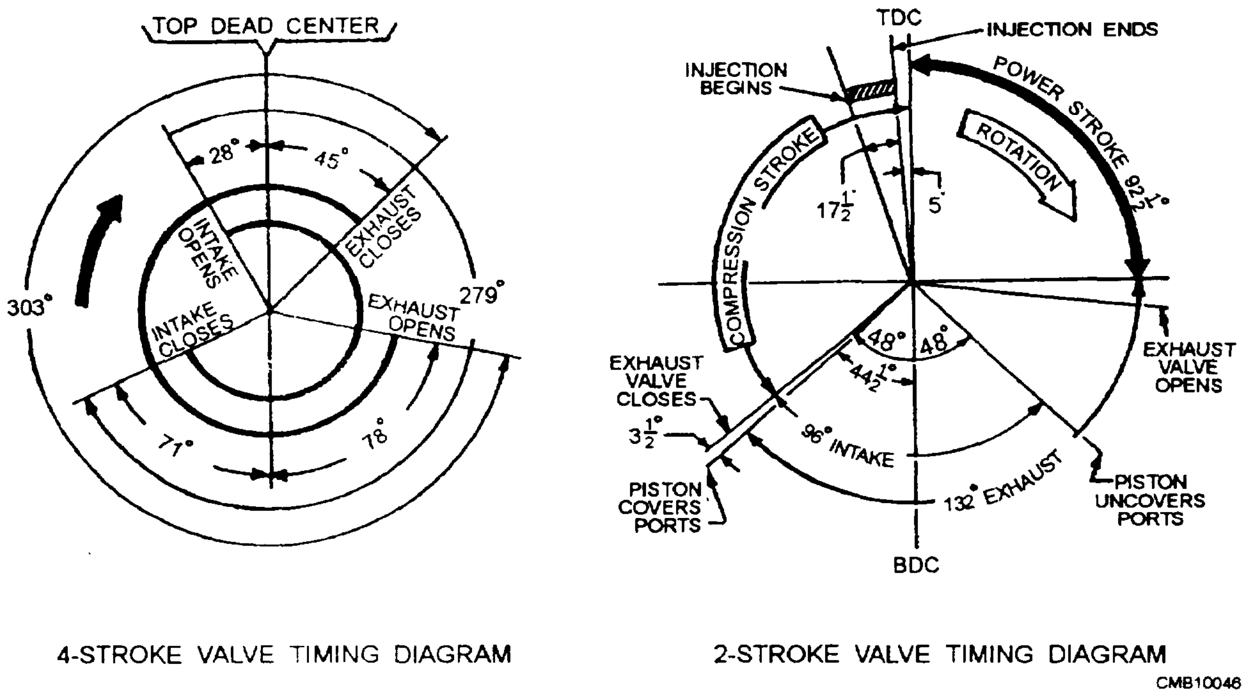


Figure 2-26.—Typical valve timing diagrams.

VALVE TIMING (fig. 2-26) is a system developed for measuring valve operation in relation to crankshaft position (in degrees), particularly the points when the valves open, how long they remain open, and when they close. Valve timing is probably the single most important factor in tailoring an engine for special needs. An engine can be made to produce its maximum power in various speed ranges by altering valve timing. The following factors together make up a valve operating sequence:

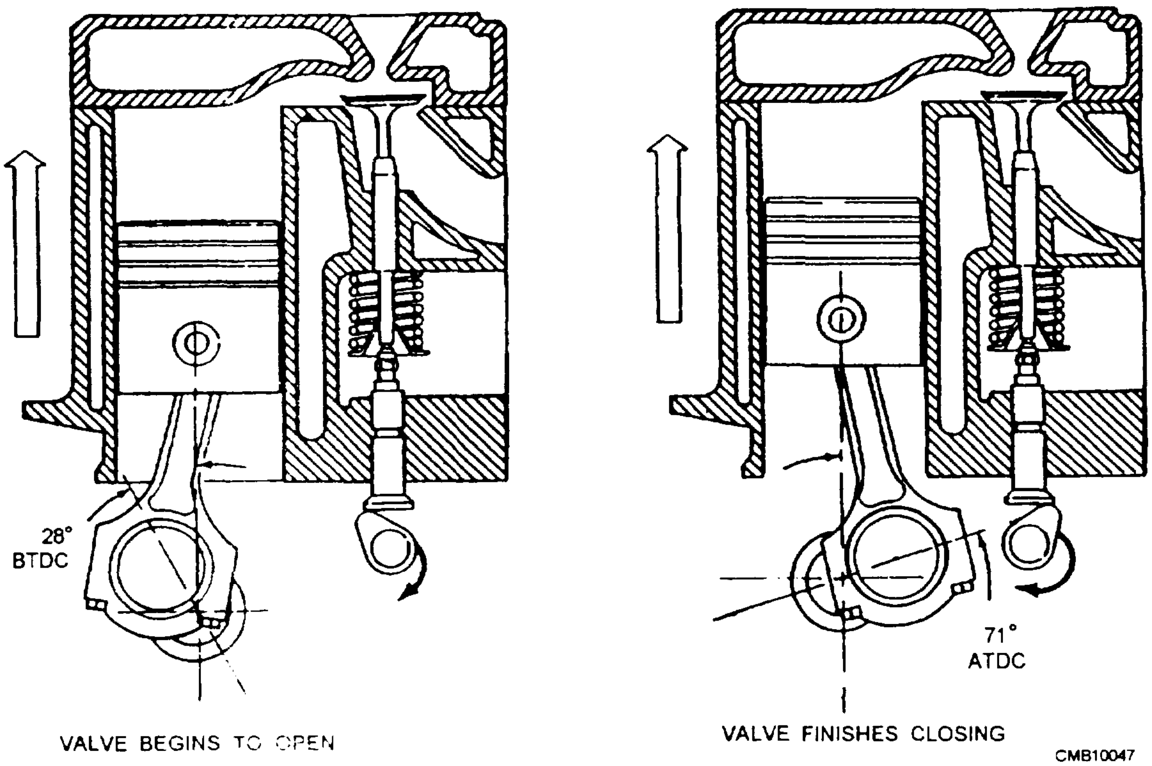


Figure 2-27.—Opening and closing points of the valve.

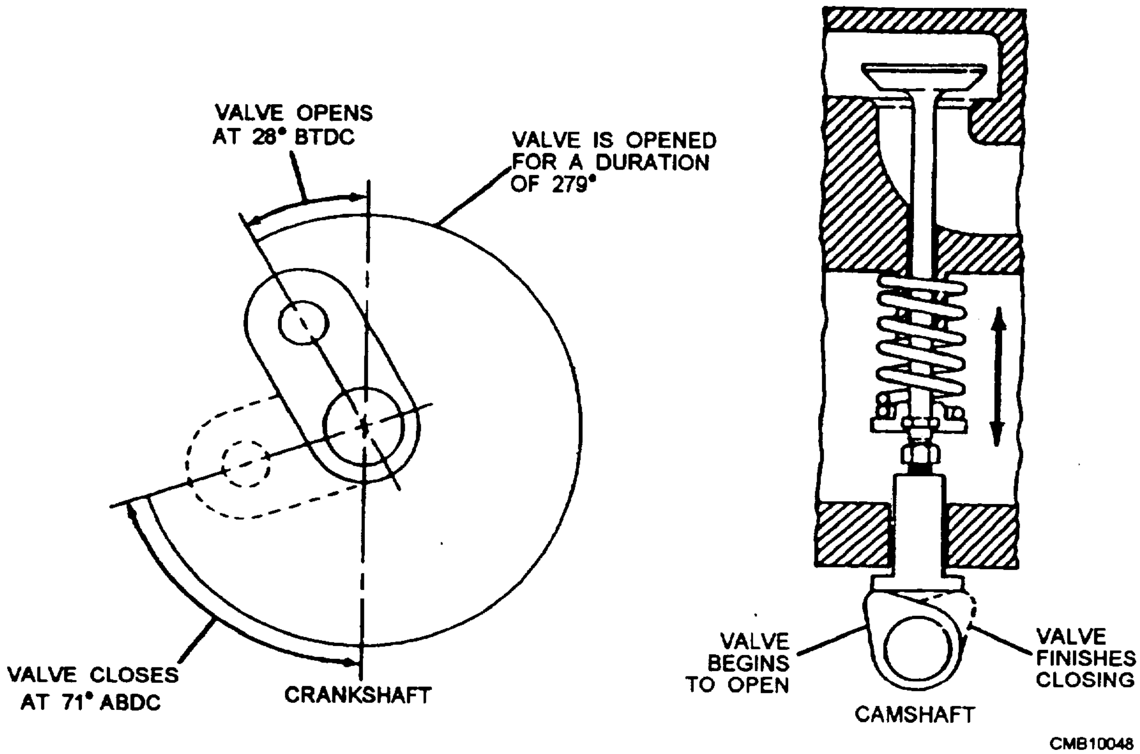


Figure 2-28.—Valve opening duration.

1. The opening and closing points (fig. 2-27) are positions of the crankshaft (in degrees) when the valves just begin to open and just finish closing.

2. Duration (fig. 2-28) is the amount of crankshaft rotation (in degrees) that a given valve remains open.

3. Valve overlap (fig. 2-29) is a period in a four-stroke cycle when the intake valve opens before the exhaust valve closes.

4. Valve timing considerations, throughout the crankshaft revolution, the speed of the piston changes. From a stop at the bottom of the stroke, the piston reaches its maximum speed halfway through the stroke and gradually slows to a stop as it reaches the end of the stroke. The piston behaves exactly the same on the downstroke. One of these periods begins at approximately 15 to 20 degrees before top dead center (BTDC) and ends at approximately 15 to 20 degrees

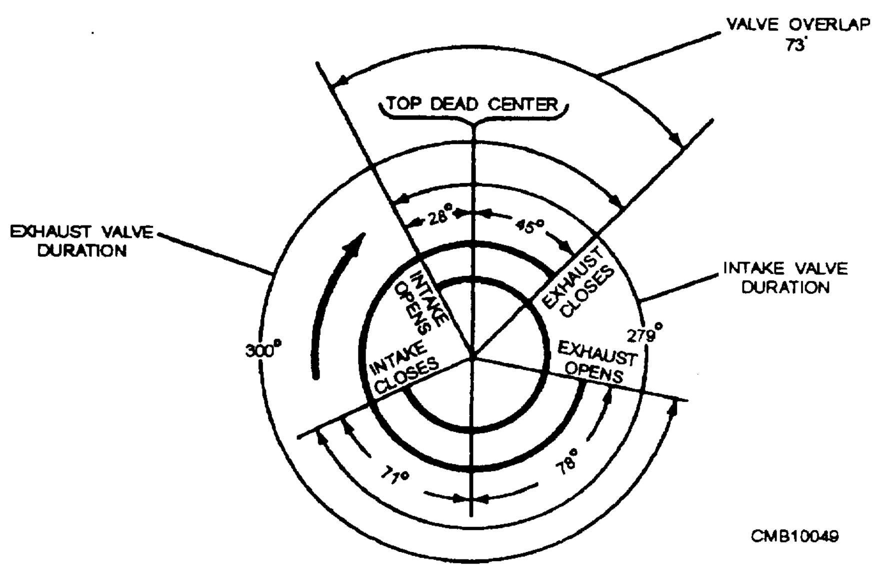


Figure 2-29.—Valve timing diagram showing valve overlap,

after top dead center (ATDC). The other period begins approximately 15 to 20 degrees before bottom dead center (BBDC) and ends approximately 15 to 20 degrees after bottom dead center (ABDC). These two positions are shown in figure 2-30. These positions are commonly referred to as **ROCK POSITIONS**

IGNITION TIMING (fig. 2-31) refers to the timing of the spark plug firing with relation to the piston position during compression and power strokes. The ignition system is timed, so the spark occurs before the piston reaches TDC on the compression stroke. This gives the mixture enough time to ignite and start burning.

If this time were not provided—that is, if spark occurred at or after TDC—then the pressure increases would take place too late to provide a full-power stroke.

In figure 2-31, view A, the spark occurs at 10 degrees before top dead center; view B, the spark occurs at top dead center; and view C, the spark occurs at 10 degrees after top dead center.

At higher speeds, there is still less time for the air-fuel mixture to ignite and burn. The ignition system includes both the vacuum and mechanical advance mechanisms that alter ignition timing to compensate for this and avoid power loss, as engine speeds increases.

Q11. One foot-pound of work is equivalent to lifting I pound what distance?

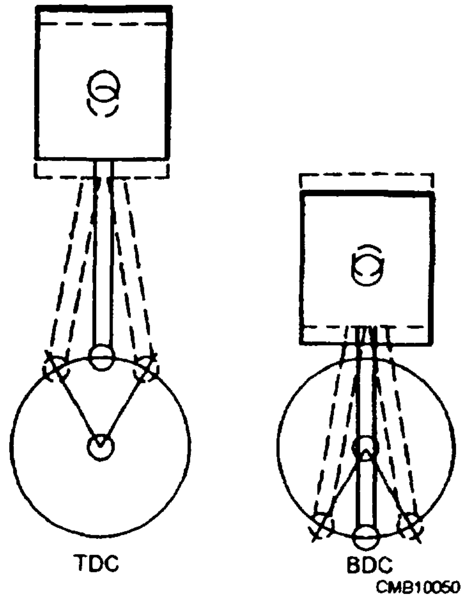


Figure 2-30.—Rock position.

Q12. What device uses a flywheel to measure actual usable horsepower?

Q13. What term is used for resistance to motion?

Q14. The relationship between actual power produced by an engine and actual power delivered to the crankshaft is known by what term?

Q15. What metric unit of measurement is used to express engine displacement?

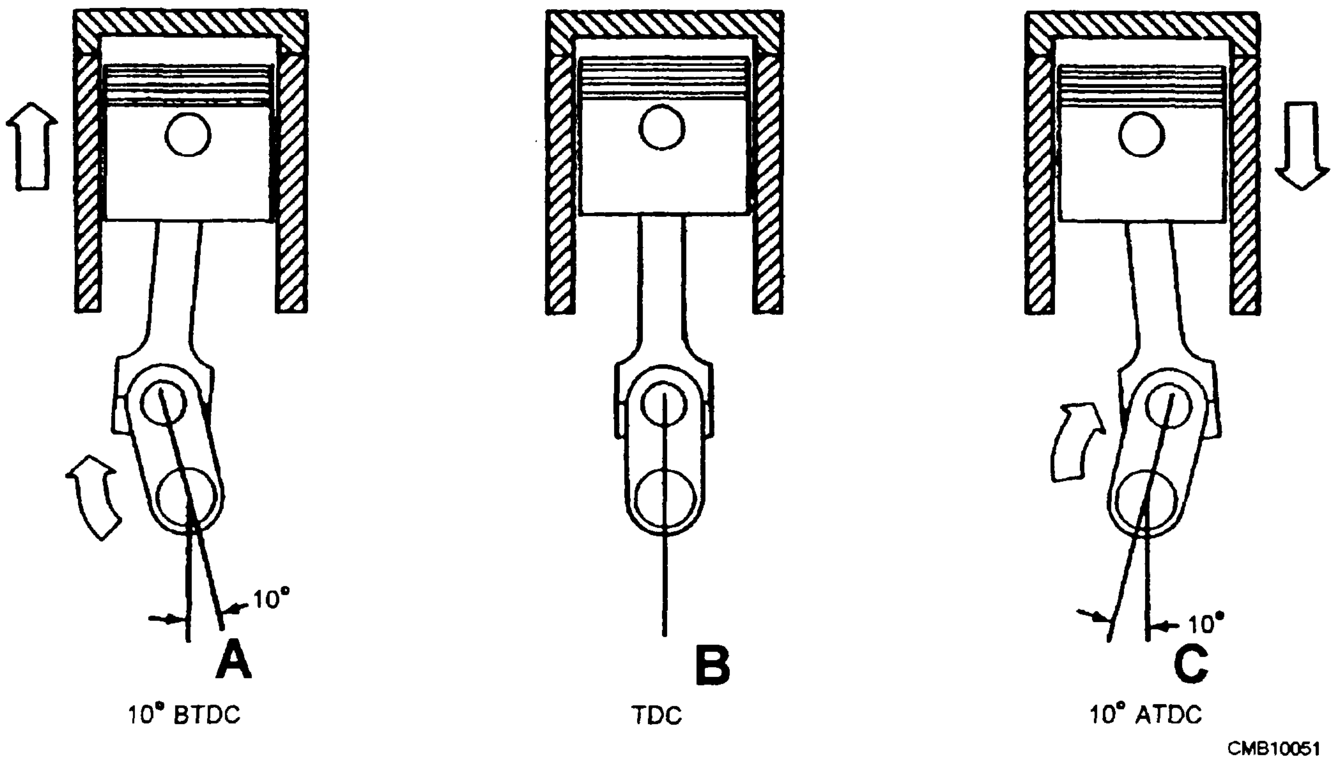


Figure 2-31.—Ignition timing.

CHAPTER 3

CONSTRUCTION OF AN INTERNAL COMBUSTION ENGINE

LEARNING OBJECTIVE: *Identify the stationary and moving parts, the operating principles and their functions, and the basic testing procedures used in constructing an internal combustion engine. Describe the techniques used in reconditioning and adjusting valves and timing gear installation.*

In the preceding chapter, you learned how the internal combustion engine operates. You also learned how the basic moving parts of an engine move in a timed relationship to one another during engine operation.

This chapter provides information on the many stationary and moving parts of an internal combustion engine. As a CM, you should be concerned with how these parts are made, what materials they are made of, and their relationship to one another for smooth and efficient operation of an internal combustion engine.

The information provided is to help you diagnose malfunctions of an engine and ways to correct them. Since the gasoline and diesel engines used in construction equipment of today are basically the same internally, the majority of information provided applies to both.

ENGINE CONSTRUCTION

LEARNING OBJECTIVE: *Recognize operating principles and functions of stationary and moving parts within an internal* combustion engine. *Describe techniques used in valve reconditioning and timing gear installation.*

Basic engine construction varies little, regardless of size and design of the engine. The intended use of an engine must be considered before the design and size can be determined.The temperature at which an engine operates determines what metals must be used in its construction.

To simplify the service parts and to simplify process and servicing procedures in the field, the present-day trend in engine construction and design is toward **ENGINE FAMILIES.** Typically, there are several types of engines because of the many jobs to be done; however, the service and service parts problem can be simplified by designing engines so they are closely related in cylinder size, valve arrangement, and so forth. For example, the GM series 71 engines can be obtained in two-, three-, four-, and six-cylinder in-line models. GM V-type engines come in 6-, 8-, 12-, and 16-cylinder models. These engines are designed in such a way that many of the internal parts can be used on any of the models.

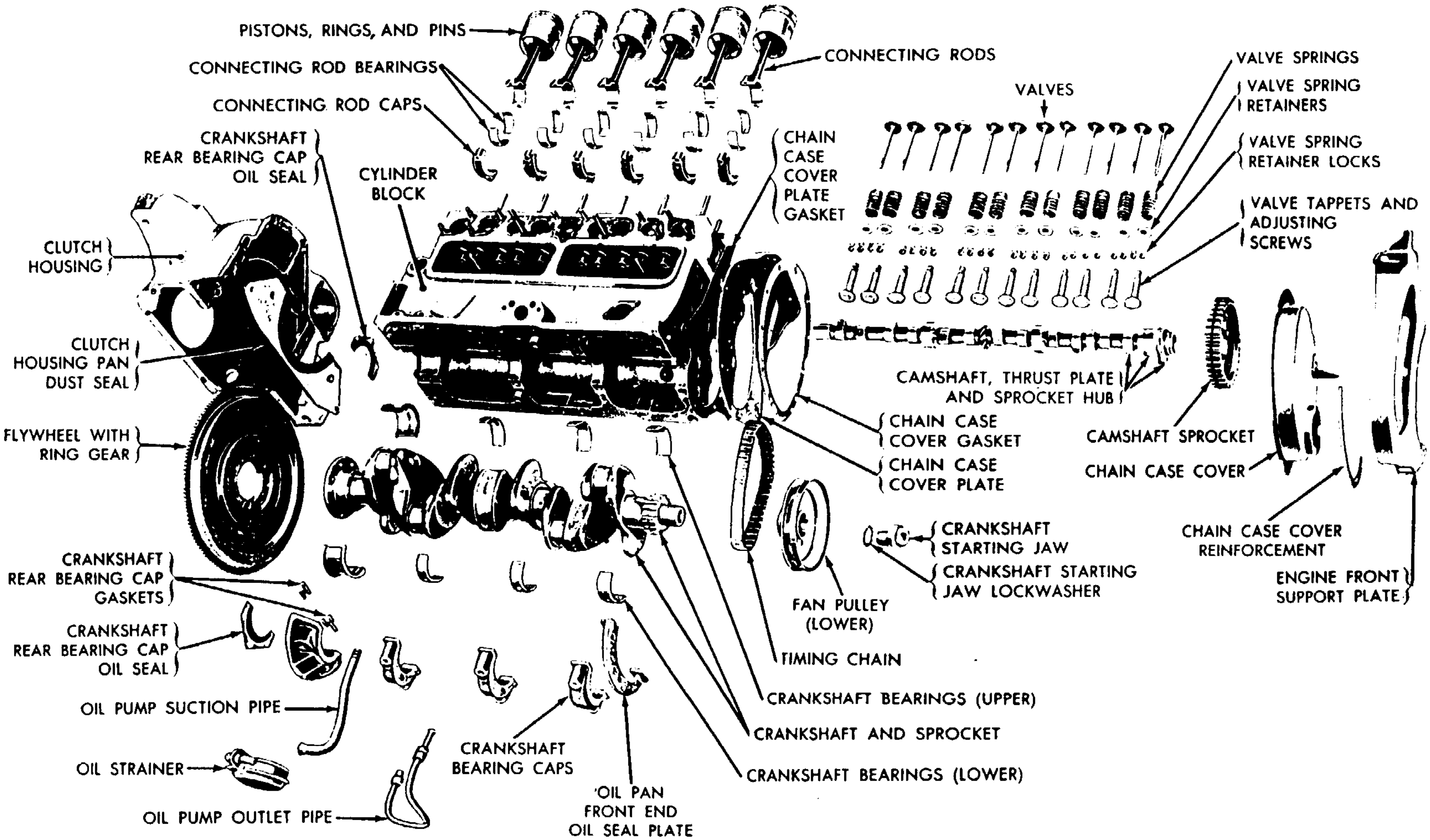
STATIONARY PARTS OF AN ENGINE

The stationary parts of an engine include the cylinder block and cylinders, the cylinder head or heads, and the exhaust and intake manifolds. These parts furnish the framework of the engine. All movable parts are attached to or fitted into this framework.

Engine Cylinder Block

The cylinder block is the basic frame of a liquid-cooled engine whether it be in-line, horizontally opposed, or V-type. The cylinder block (fig. 3-1) is a solid casting made of cast iron or aluminum that contains the crankcase, the cylinders, the coolant passages, the lubricating passages, and, in the case of flathead engines, the valves seats. the ports, and the guides.

The cylinder block is a one-piece casting usually made of an iron alloy that contains nickel and molybdenum. This is the best overall material for cylinder blocks. It provides excellent wearing qualities, low material and production cost, and it only changes dimensions minimally when heated. Another material that is used for cylinder blocks, although not extensively, is aluminum. Aluminum is used whenever weight is a consideration. It is not practical to use for the following reasons:



FFigure 3-1.—Cylinder block and components.

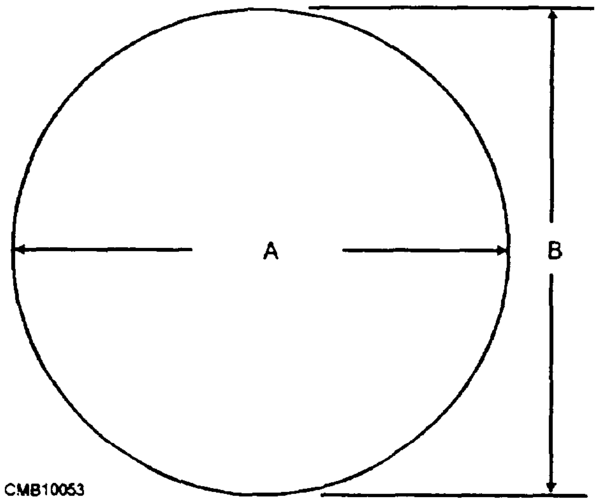
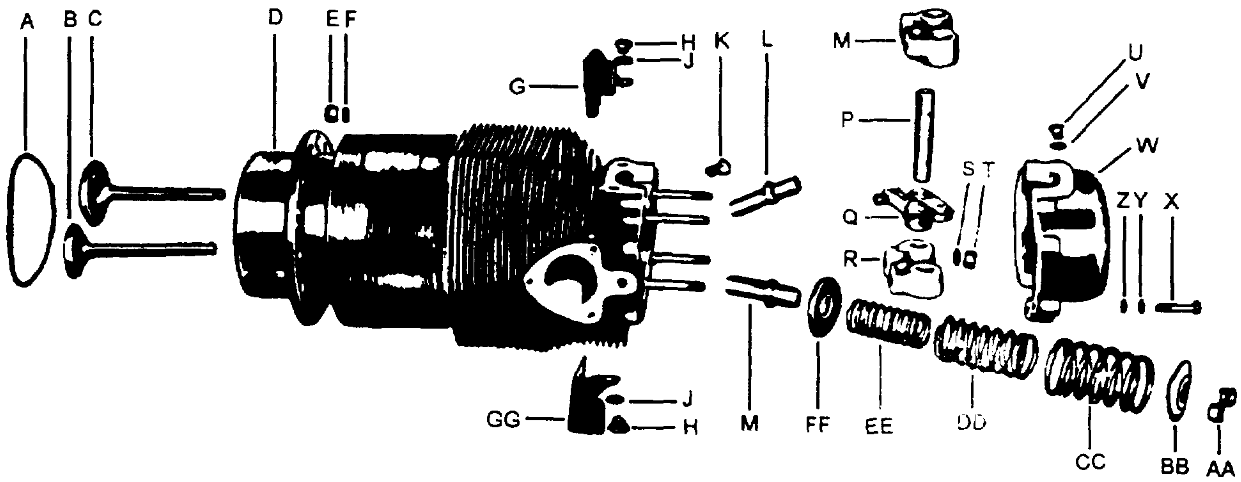


Figure 3-2.—Requirements of a cylinder.

- Aluminum is more expensive than cast iron.
- Aluminum is not as strong as cast iron.
- Because of its softness, it cannot be used on any surface of the block that is subject to wear. This necessitates the pressing, or casting, of steel sleeves into the cylinder bores. Threaded holes must be deeper. This introduces extra design considerations and increases production costs.
- Aluminum has a much higher expansion rate than iron when heated. This creates problems with maintaining tolerances.

The **CYLINDERS** are bored right into the block. A good cylinder must be round, not varying in diameter by more than approximately 0.0005 inch (0.012 mm) (fig. 3-2). The diameter of the cylinder must be uniform throughout its entire length. During normal engine operation, cylinder walls wear out-of-round, or they may become cracked and scored if not lubricated or cooled properly. The cylinders on an **AIR-COOLED** engine (fig. 3-3) are separate from the crankcase. They are made of forged steel. This material is most suitable for cylinders because of its excellent wearing qualities and its ability to withstand high temperatures that air-cooled cylinders obtain. The cylinders have rows of deep fins cast into them to dissipate engine heat. The cylinders are commonly mounted by securing the cylinder head to the crankcase with long studs and sandwiching the cylinders between the two. Another way of mounting the cylinders is to bolt them to the crankcase, and then secure the heads to the cylinders.



A– O-RING GASKET
B– EXHAUST VALVE
C– INTAKE VALVE
D– CYLINDER
E– CYLINDER BARREL NUT
F– LOCK NUT
G– DOME FIN DEFLECTOR (LH)
H– BOLT
J– LOCK WASHER
K– PRIMER NOZZLE ASSEMBLY
L– INTAKE VALVE GUIDE
M– EXHAUST VALVE GUIDE
N– CAMSHAFT BEARING CAP
P– ROCKER SHAFT
Q– ROCKER
R– ROCKER SUPPORT BRACKET
S– WASHER
T– SLOTTED NUT
U– ROCKER BOX COVER PLATE
V– TAB WASHER
W– VALVE ROCKER COVER
X– BOLT
Y– LOCK WASHER
Z– WASHER
AA– VALVE LOCK
BB– VALVE SPRING RETAINER
CC– OUTER VALVE SPRING
DD– INTERMEDIATE VALVE SPRING
EE– INNER VALVE SPRING
FF– VALVE RING SEAT
GG– DOME FIN DEFLECTOR (RH)

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Figure 3-3.—Air-cooled cylinder.

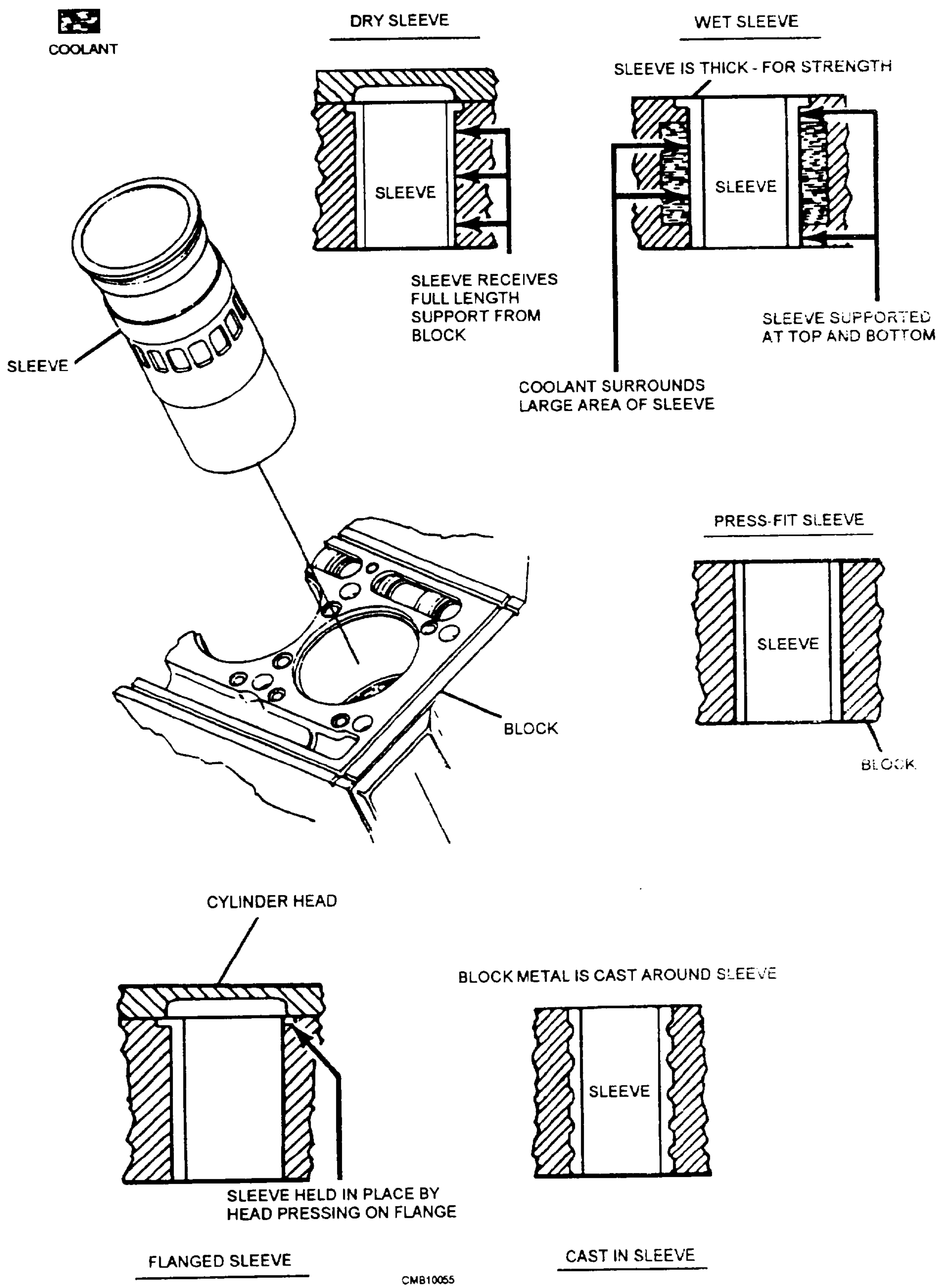


Figure 3-4.—Cylinder sleeves.

In liquid-cooled engines **CYLINDER SLEEVES** or **LINERS** (fig. 3-4) are used to provide a wearing surface, other than the cylinder block, for the pistons to ride against. This is important for the following reasons:

- Alloys of steel can be used that wears longer than the surfaces of the cylinder block. This increases engine life while keeping production costs down.
- Because the cylinders wear more than any other area of the block, the life of the block can be greatly extended by using sleeves. When overhaul time comes, the block can be renewed by just replacing the sleeves.
- Using a sleeve allows an engine to be made of other materials, such as aluminum, by providing the wearing qualities necessary for cylinders that aluminum cannot.

There are two types of cylinder sleeves: the **DRY-TYPE** and the **WET-TYPE.** A dry-type sleeve does not contact the coolant. The dry-type sleeve is pressed into a full cylinder that completely covers the water jacket. Because the sleeve has the block to support it, it can be very thin. The wet-type sleeve comes in direct contact with the coolant. It is also press-fitted into the cylinder. The difference is that the water jacket is open in the block and is completed by the sleeve. Because it gets no central support from the block, it is made thicker than a dry sleeve. Also because the sleeve completes the water jacket, it must fit so it seals in the coolant. This is accomplished by using a metallic sealing ring at the top and a rubber sealing ring at the bottom. There are three basic ways of securing the sleeves in the cylinder block as follows:

- Press in a sleeve that is tight enough to be held by friction.
- Provide a flange at the top of the block that locks the sleeve into place when the cylinder head is bolted into place. This is more desirable than a friction fit, because it locks the sleeve tightly.
- Cast the sleeve into the cylinder wall. This is a popular means of securing a sleeve in an aluminum block.

Whatever method is used to secure the sleeves, it is very important for the sleeve to fit tightly. This is so the sleeve can transfer heat effectively to the water jackets.

Most cylinder sleeve casualties are directly related to a lack of maintenance or improper operating procedures. Figure 3-5 shows two common types of cylinder sleeve casualties: cracks and scoring. Both types of casualties require replacement of the sleeve.

The cylinder block also provides the foundation for the cooling and lubricating systems. The cylinders of a liquid-cooled engine are surrounded by interconnecting passages cast in the block. Collectively, these passages form the **WATER JACKET** that allows the circulation of coolant through the cylinder block and the cylinder head to carry off excessive heat created by combustion. The water jacket is accessible through holes machined in the head and block to allow removal of the material used for casting of the cylinder block. These holes are called core holes and are sealed by **CORE HOLE PLUGS** (freeze plugs). These plugs are of two types: cup and disk. Figure 3-6 shows a typical installation of these plugs.

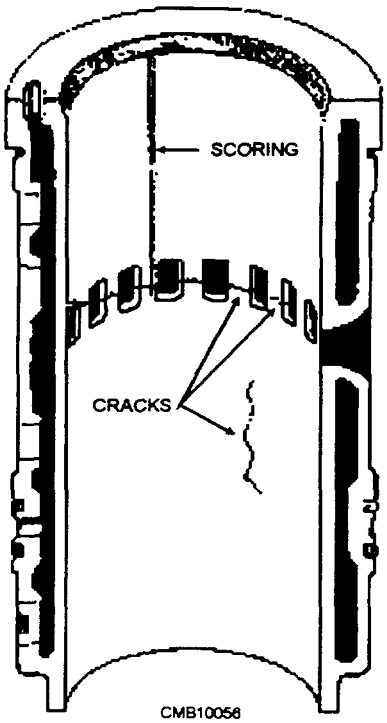


Figure 3-5.—Cylinder sleeve casualties.

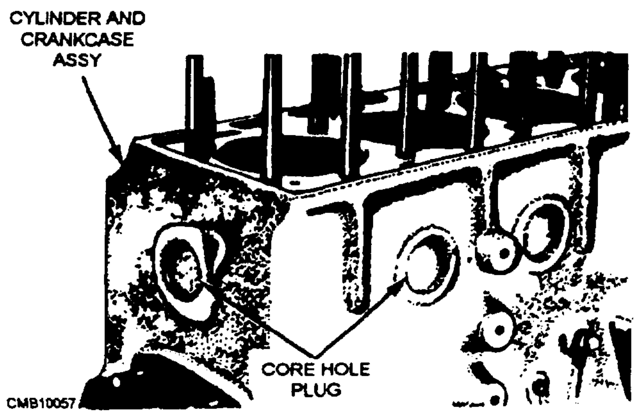


Figure 3-6.—Core hole plugs installed in cylinder block.

The **CRANKCASE** (fig. 3-7) is that part of the cylinder block below the cylinders. It supports and encloses the crankshaft and provides a reservoir for lubricating oil. The lower part of the crankcase is the **OIL PAN,** which is bolted at the bottom. The oil pan is made of cast aluminum or pressed steel and holds the lubricating oil for the engine. Since the oil pan is the lowest part of the engine, it must be strong enough to withstand blows from flying stones and obstructions sticking up from the road surface.

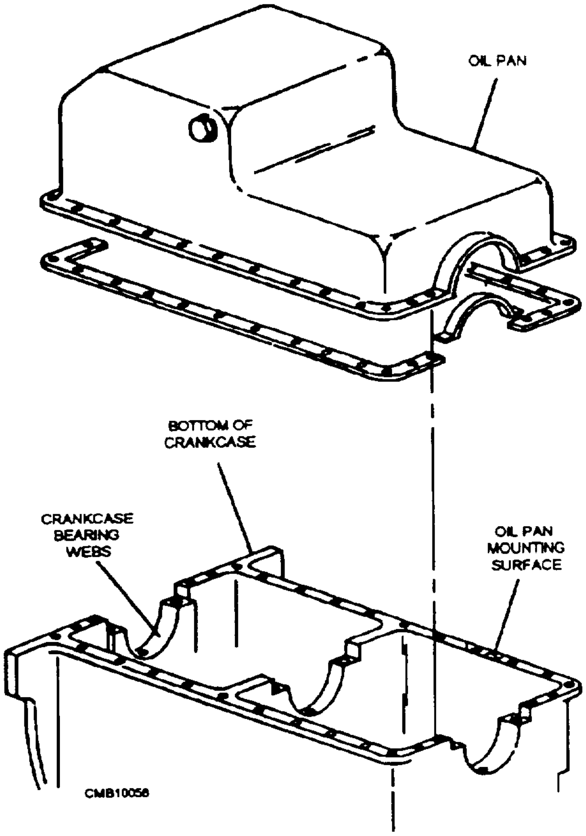


Figure 3-7.—Engine crankcase.

The crankcase also has mounting brackets to support the entire engine on the vehicle frame. These brackets are either an integral part of the crankcase or are bolted to it in such a way that they support the engine at three or four points. These points are cushioned by rubber mounts that insulate the frame and body of the vehicle from engine vibration. This prevents damage to engine supports and the transmission.

The crankcase (fig. 3-8) is the basic foundation of all air-cooled engines. It is made as a one- or two-piece casting that supports the crankshaft, provides the mounting surface for the cylinders and the oil pump, and has the lubrication passages cast into it. It is made

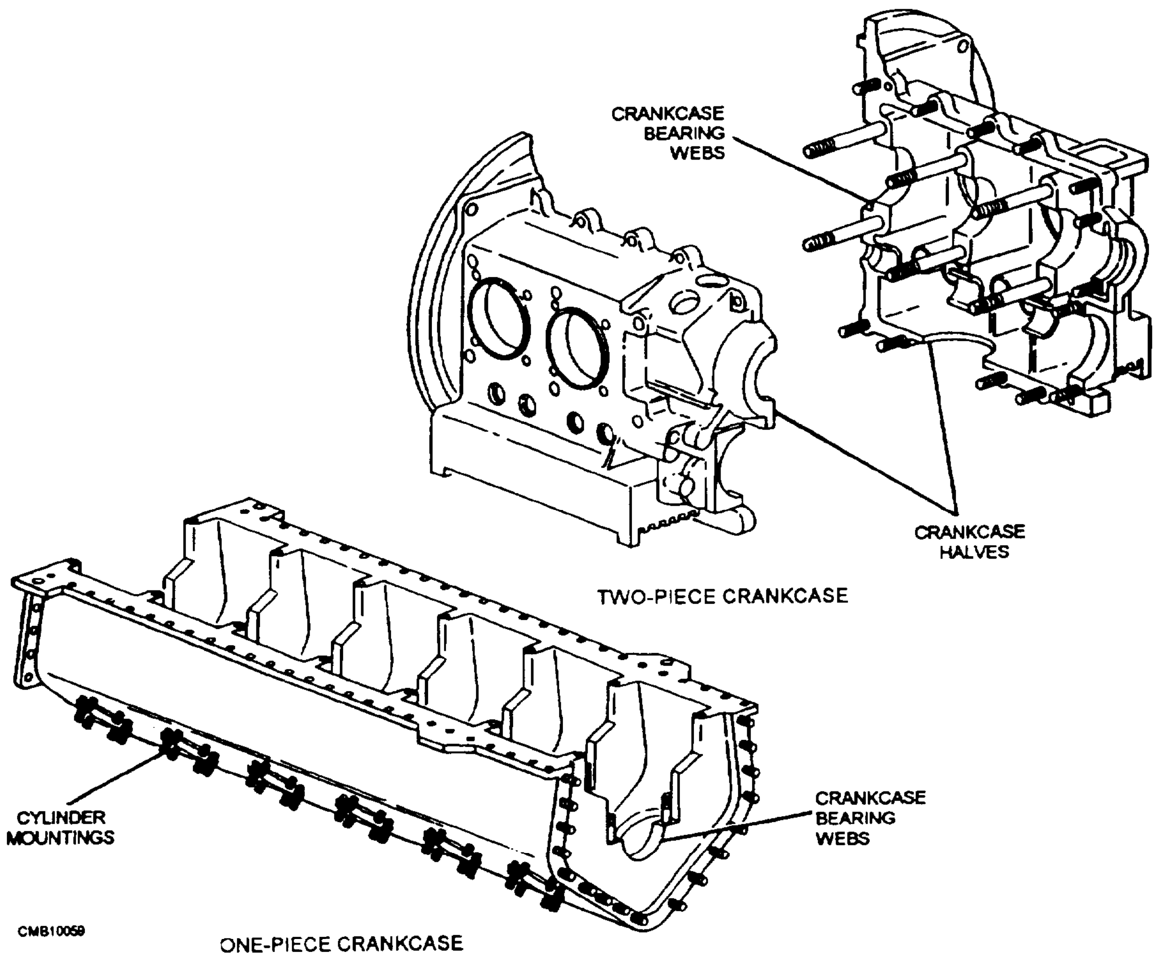


Figure 3-8.—Aircooled crankcase.

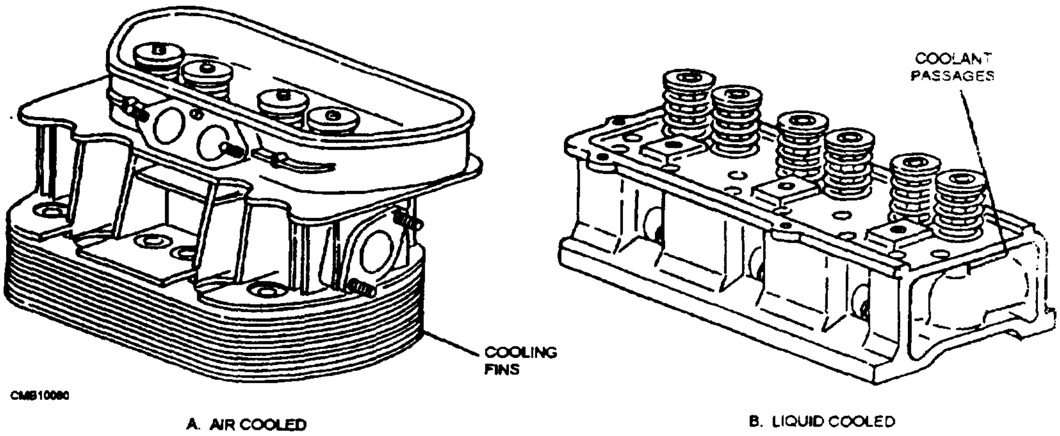


Figure 3-9.—Cylinder heads.

of aluminum since it needs the ability to dissipate large amounts' of heat. On air-cooled engines, the oil pan usually is made of cast aluminum, and it is covered with cooling fins. The oil pan on an air-cooled engine plays a key role in the removal of waste heat from the engine through its lubricating oil.

Cylinder Head

The cylinder head (fig. 3-9) provides combustion for the engine cylinders. It is built to conform to the arrangement of the valves: L-head, I-head, or others. Cylinder heads on liquid-cooled engines have been made almost exclusively from cast iron until recent years. Because weight has become an important consideration, a large percentage cylinder heads now are being made from aluminum. The cylinder heads on air-cooled engines are made exclusively from aluminum. This is due to the fact that aluminum conducts heat approximately three times as fast as cast iron. This is a critical consideration with air cooling.

In liquid-cooled engines. the cylinder (fig. 3-10) head is bolted to the top of the cylinder block to close the

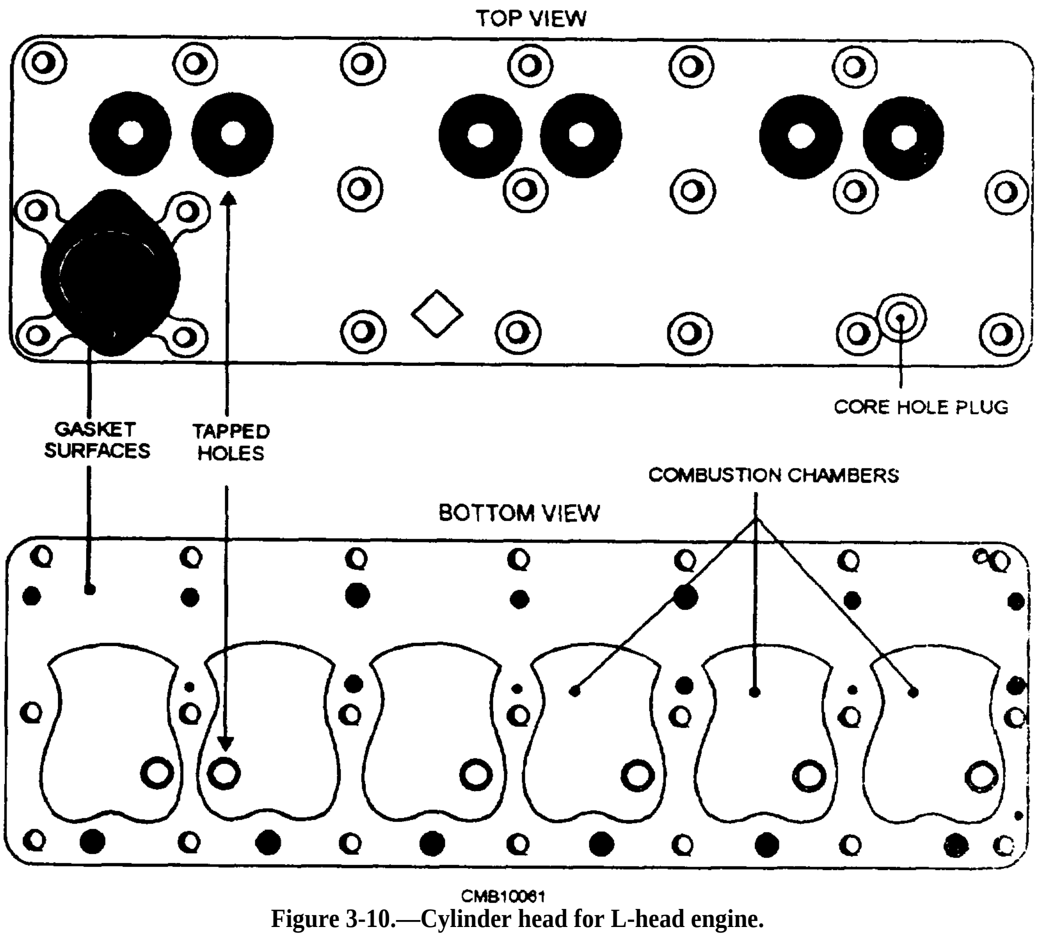


Figure 3-10.—Cylinder head for L-head engine.

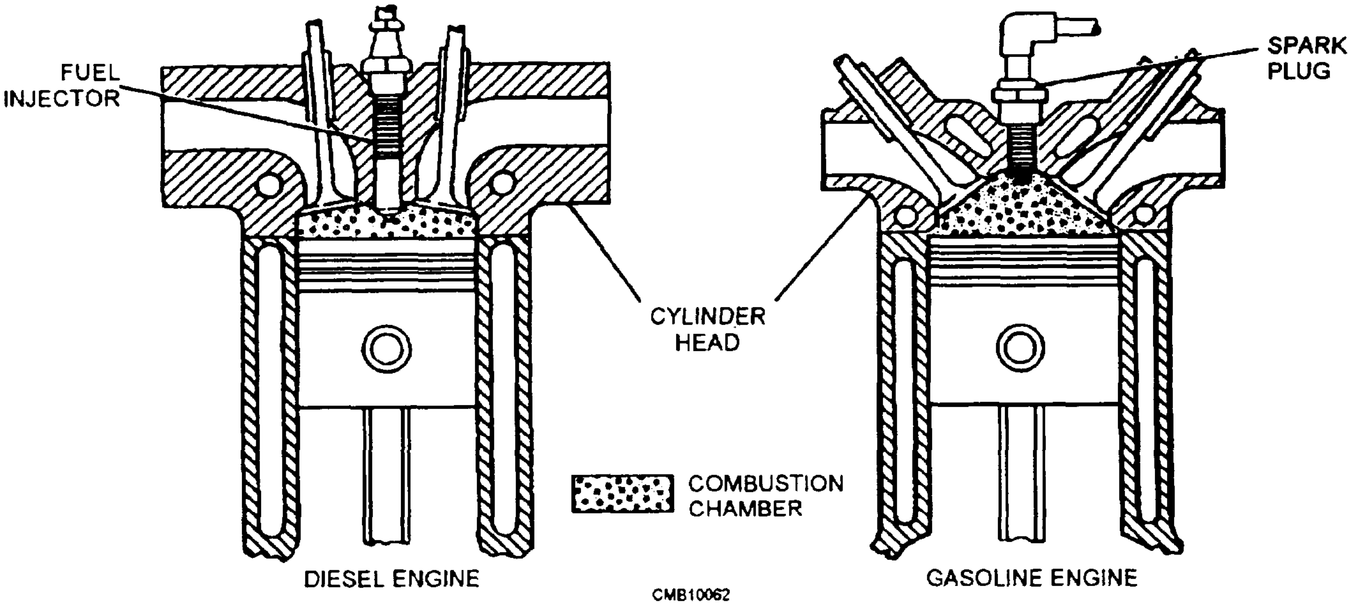


Figure 3-11.—Combustion chambers.

upper end of the cylinders and, in air-cooled engines, the cylinder heads are bolted to the top of the cylinders. This serves to provide a combustion chamber (fig. 3-11) for the ignition of the mixture and to hold the expansion forces of the burning gases so they may act on the piston. In a gasoline engine, there are threaded holes to position the spark plugs in the combustion chamber. On a diesel engine, there is a similar arrangement to position the fuel injectors. In a liquid-cooled engine, it also contains passages, matching those of the cylinder block, that allow cooling liquid to circulate in the head.

The I-head (overhead valve) type of cylinder head (fig. 3-12) contains not only water jackets for cooling spark plugs openings, valve pockets, and part of the combustion chamber, but it also contains and supports the valves and valve operating mechanisms. In this type of cylinder head, the water jackets must be large enough to cool not only the top of the combustion chamber but also the valve seats, valves, and valve operating mechanisms.

The cylinder heads are sealed (fig. 3-13) to the cylinder block to prevent gases from escaping. This is accomplished on liquid-cooled engines by the use of a head gasket. The head gasket is usually made of two sheets of soft steel that sandwich a layer of asbestos. Steel rings are used to line the cylinder openings. They are designed to hold the tremendous pressure created on the power stroke. Holes are cut in the gasket to match the coolant and lubrication feed holes between the cylinder head and the cylinder block. In an air-cooled engine, cylinder heads are sealed to the tops of the cylinders by soft metal rings. The lubrication system feeds oil to the heads through the pushrods.

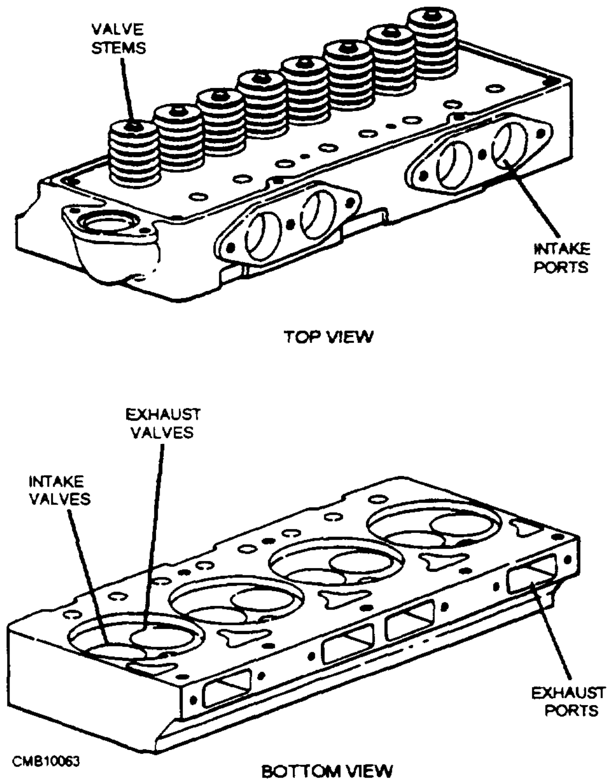


Figure 3-12.—Cylinder head for overhead valve engine.

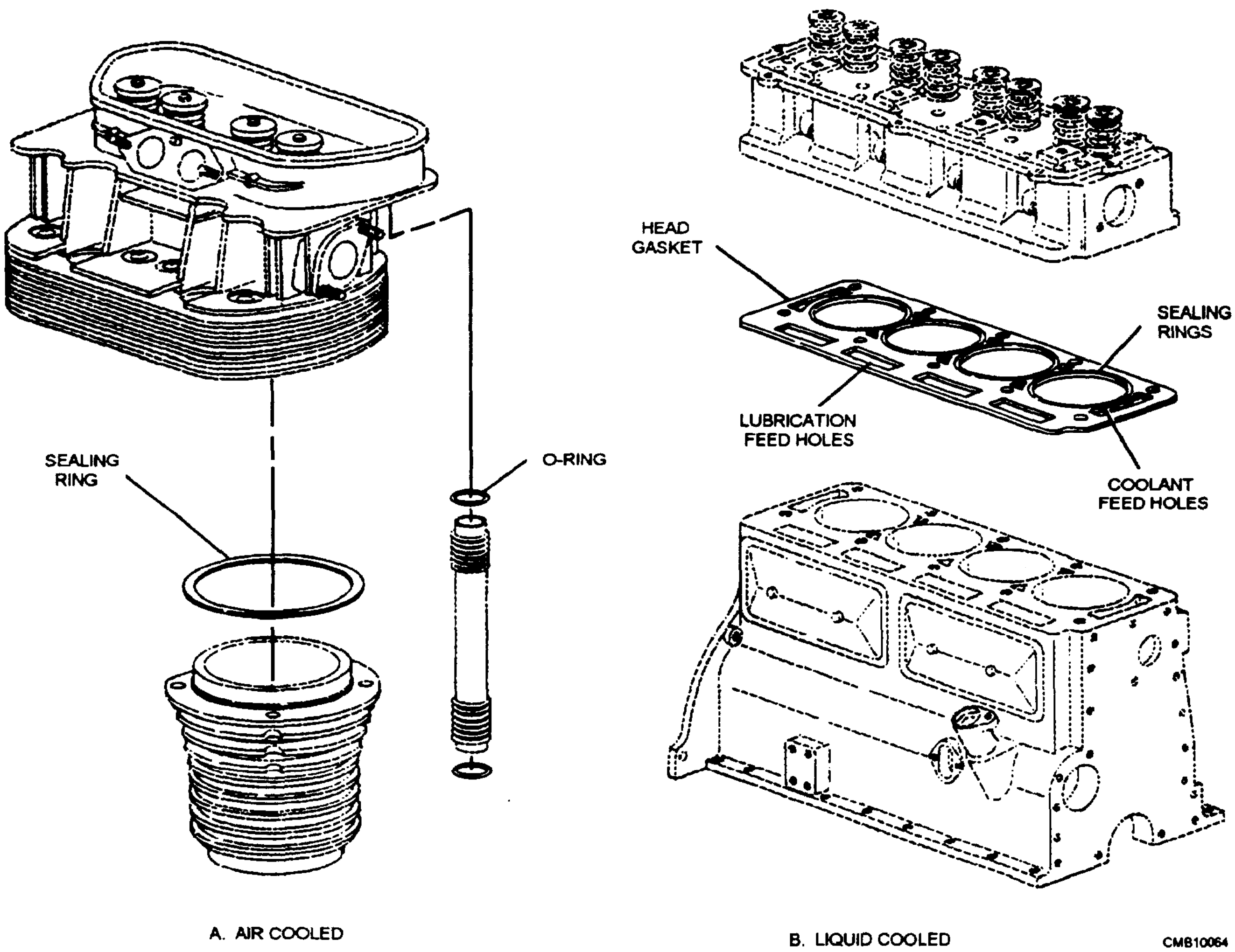


Figure 3-13.—Cylinder head sealing.

Exhaust Manifold

The exhaust manifold (fig. 3-14) connects all of the engine cylinders to the rest of the exhaust system. On L-head engines, the exhaust manifold bolts to the side of the engine block; and on overhead-valve engines, it bolts to the side of the cylinder head. It is usually made of cast iron, either singly or in sections. If the exhaust manifold is made properly, it can create a scavenging action that causes all of the cylinders to help each other get rid of the gases. Back pressure (the force that the pistons must exert to push out the exhaust gases) can be reduced by making the manifold with smooth walls and without sharp bends. Exhaust manifolds on vehicles today are constantly changing in design to allow the use of various types of emission controls. Each of these factors is taken into consideration when the exhaust manifold is designed, and the best possible manifold is manufactured to fit into the confines of the engine compartment.

Intake Manifold

The intake manifold on a gasoline engine carries the air-fuel mixture from the carburetor and distributes it to the cylinders. On a diesel engine, the manifold carries only air into the cylinders. The gasoline engine intake manifold (fig. 3-15) is designed with the following functions in mind:

- Deliver the air-fuel mixture to the cylinders in equal quantities and proportions. This is important for smooth engine performance. The lengths of the passages should be near to equal as possible to distribute the air-fuel mixture equally.

- Help to keep the vaporized air-fuel mixture from condensing before it reaches the combustion chamber. The ideal air-fuel mixture should be vaporized completely, as it enters the combustion chamber. This is very important. The manifold passages are designed with smooth

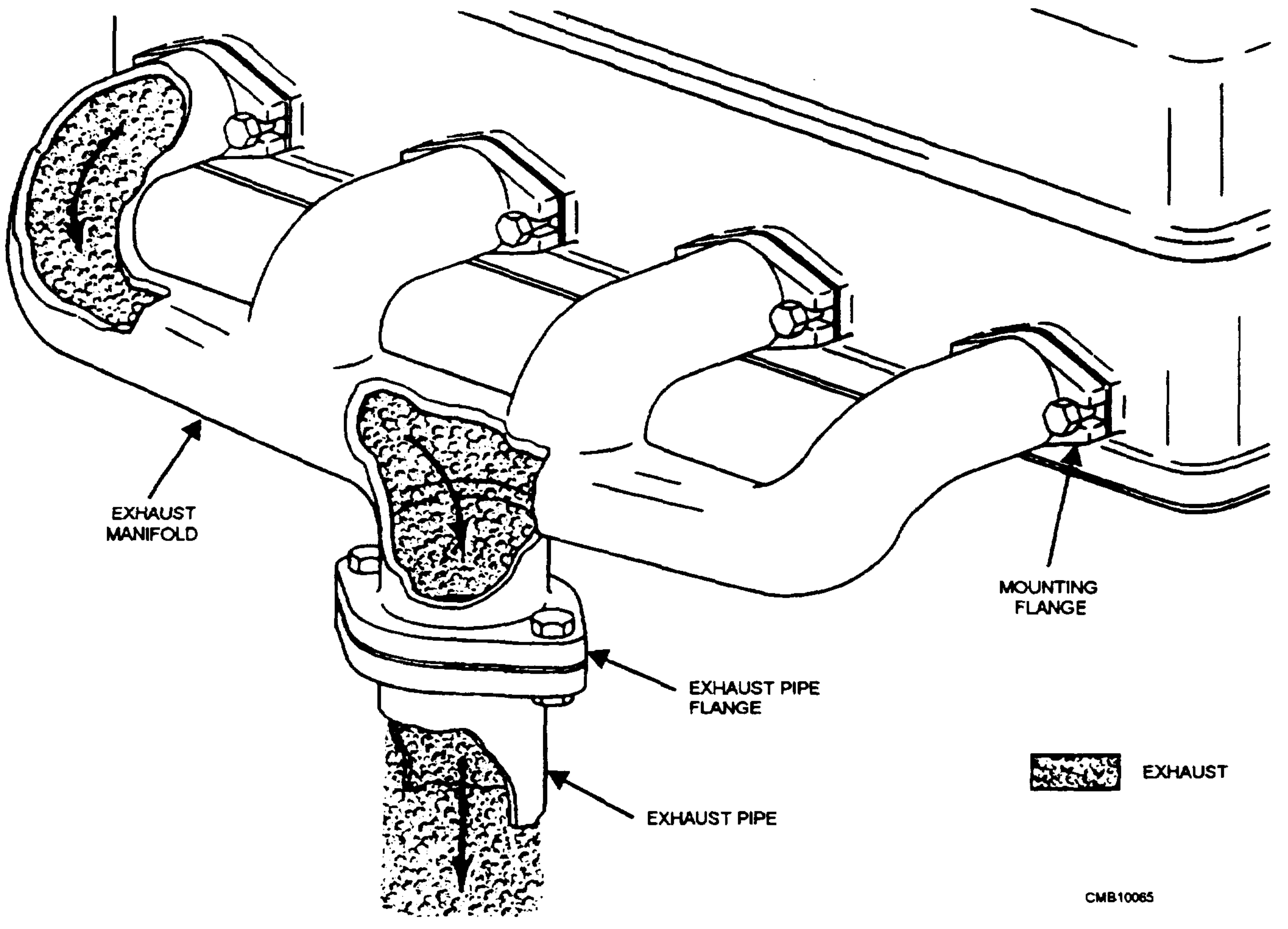


Figure 3-14.—Exhaust manifold.

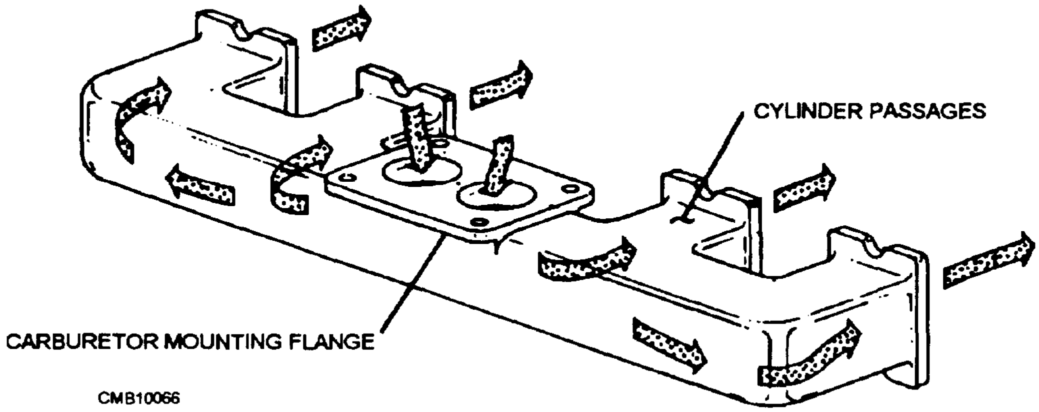


Figure 3-15.—Typical intake manifold.

walls and a minimum of bends that collect fuel to reduce the condensing of the mixture. Smooth flowing intake manifold passages also increase volumetric efficiency.

- Aid in the vaporization of the air-fuel mixture. To do this, provide the intake manifold a controlled system of heating. This system of heating must heat the mixture enough to aid in vaporization—without heating it to the point of reducing volumetric efficiency.

The intake manifold on an L-head engine is bolted to the block, whereas the overhead-valve engine has the intake manifold bolted to the side of the cylinder head.

Intake manifolds can be designed to provide optimum performance for a given speed range by varying the length of the passages (fig. 3-16). The inertia of the moving intake mixture causes it to bounce back and forth in the intake manifold passage from the end of one intake stroke to the beginning of the next intake stroke. If the passage is the proper length so the next intake stroke is just beginning as the mixture is rebounding, the inertia of the mixture causes it to ram itself into the cylinder. This increases the volumetric efficiency of the engine in the designated speed range. It should be noted that the ram manifold serves no purpose outside its designated speed range.

As stated earlier, providing controlled heat for the incoming mixture is very important for good performance. The heating of the mixture may be accomplished by doing one or both of the following:

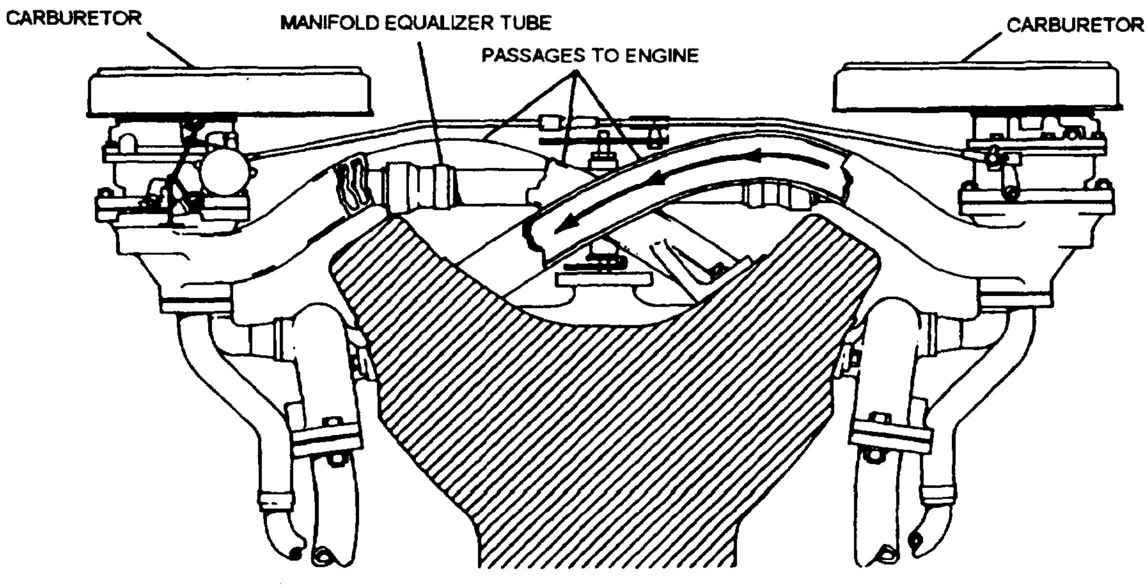


Figure 3-16.—Ram induction manifold.

- Directing a portion of the exhaust through a passage in the intake manifold (fig. 3-17). The heat from the exhaust transfers and heats the mixture. The amount of exhaust that is diverted into the intake manifold heat passage is controlled by the manifold heat control valve.

- Directing the engine coolant, which is heated by the engine, through the intake manifold on its way to the radiator (fig. 3-18).

Gaskets

Gaskets (fig. 3-19), otherwise known as static seals, are used to form pressure-tight joints between stationary members. They are usually made of a deformable material in the shape of a sheet or ring, which conforms to the irregularities in mating surfaces when compressed. Steel, aluminum, copper, asbestos, cork, synthetic rubber, paper, and felt are just a few of the materials that are used singly or in combination to produce leakproof joints. The proper material used in gasket construction depends on the temperature, type of fluid to be contained, smoothness of mating surfaces, fastener tension, pressure of the substance to be confined, material used in construction of mating parts, and part clearance relationship. Some of the most common engine gaskets are as follows:

- **CYLINDER HEAD GASKET** which is placed between the cylinder head and the cylinder block to maintain a gastight and coolant-tight seal. It is made in the form of two thin plates of soft metal with asbestos tilling between them.

- **INTAKE AND EXHAUST GASKETS** are made from asbestos and formed to a desired shape. Some of them are metal-covered and similarin construction to a cylinder head gasket.

- **OIL PAN GASKET** is generally made from pressed cork. It may be made in one piece but is often made as two pieces.

Gaskets also can be formed by using a silicone sealant. This type is formed by applying sealant from a squeeze tube to the mating surfaces and allowing it to dry, forming a sealed flexible joint. This type of seal is becoming more popular on modern vehicles.

Oil Seals

Oil seals used in vehicle assembly are designed to prevent leakage between rotating and non-rotating

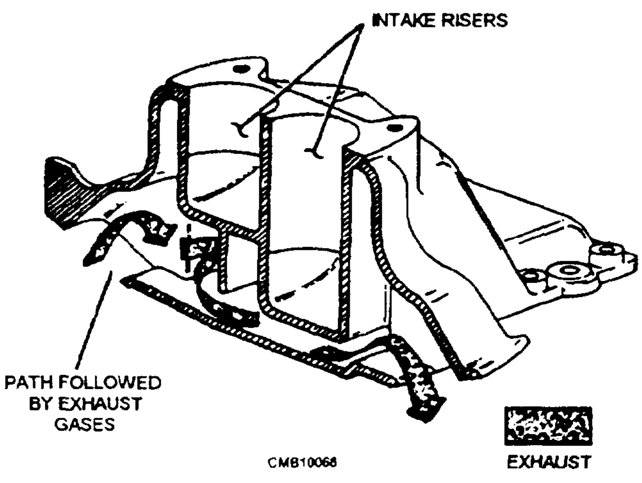


Figure 3-17.—Exhaust-heated intake manifold.

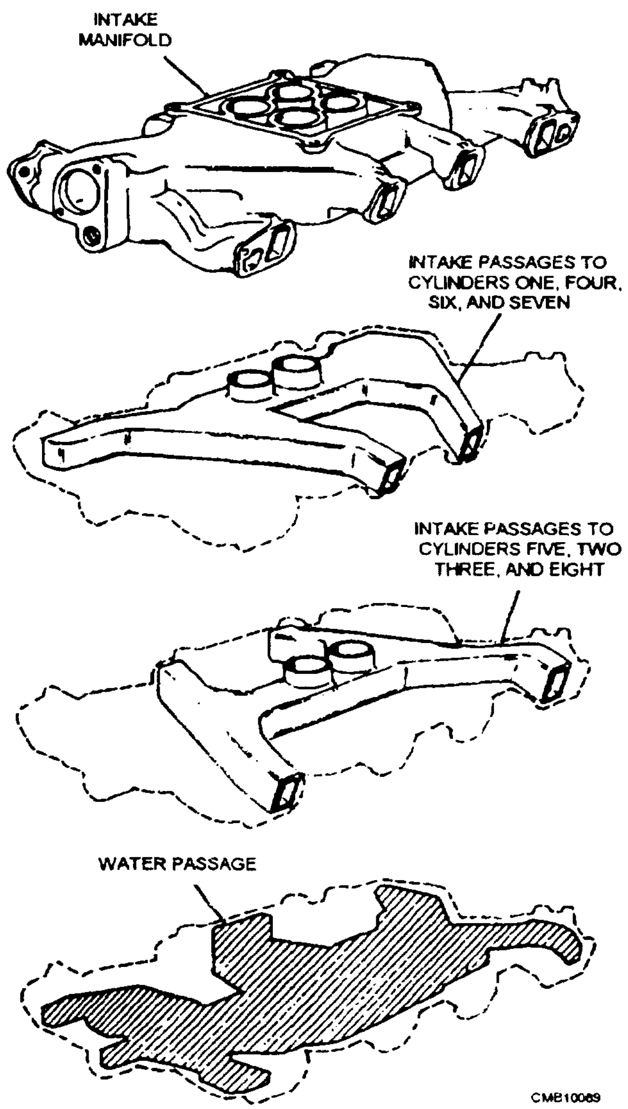


Figure 3-18.—Water-heated intake manifold.

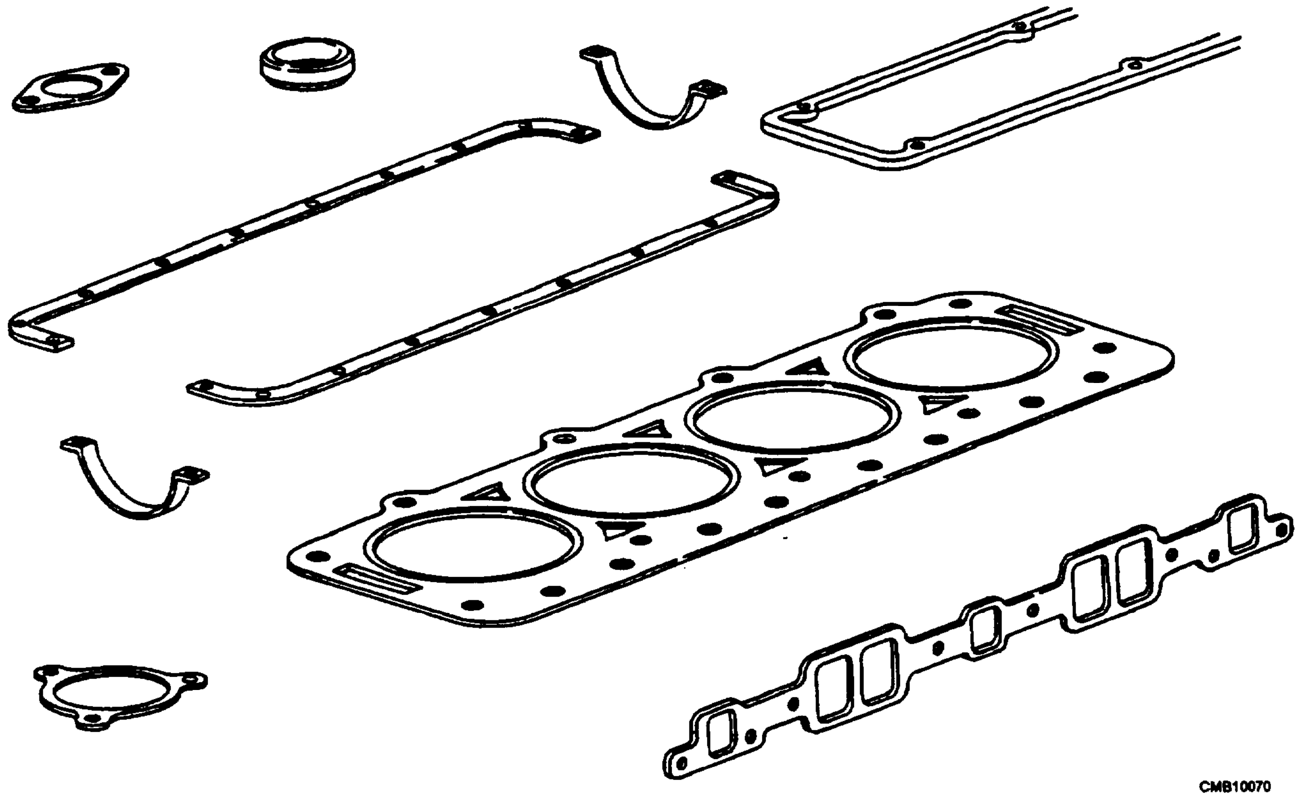


Figure 3-19.—Typical gaskets.

members. Two basic types of oil seals used on vehicles today are synthetic rubber seals and wick seals. Each is discussed below.

- **SYNTHETIC RUBBER SEALS.** The synthetic rubber seal (fig. 3-20) is the most common type of oil seal. It is composed of a metal case used to retain its shape and maintain rigidity. A rubber element is bonded to the case, providing a sealing lip or lips against the rotating shaft. Different types of oil seal designs are shown in figure 3-20. A coil spring, sometimes called a garter spring, is used to hold the rubber element around the shaft with a controlled force. This allows the seal to conform to minor shaft runout. Some synthetic rubber seals fit into bores mounted around the shaft This type is generally a split design and does not require a metal case or garter spring. Figure 3-20 shows the effects of pressure on lip seals. The internal pressure developed during operations forces the sealing lips tighter against the rotating shaft. This type of seal only operates effectively against fluid pressure from one direction. Leather also is used as a lip seal. In this configuration, the inside diameter of the seal is smaller than the shaft As the shaft is installed, the seal bows outward to form a lip seal.

- **WICK SEALS.** The wick seal (fig. 3-21) is made of graphite-impregnated asbestos. Wicking is sometimes used to control oil leakage. This seal conforms to the recess in which it is installed. When using this type of seal, use a knurl finish on the rotating shaft. The oil is contained between the knurls and seal, which rub together. As the shaft rotates, the oil is driven back by the propeller effect of the seal and knurl finish. An oil slinger sometimes is used with wick seals. The oil slinger is a raised washerlike area on the shaft. As oil meets the slinger, it is propelled outward by centrifugal force. A catch trough then is used to collect the oil and return it to the sump.

As you gain experience in the mechanical field, you will be able to recognize the different types of seals and how they work to prevent leaks. Other types of seals are discussed in a later module.

MOVING PARTS OF AN ENGINE

The moving parts of an engine serve an important function—turning heat energy into mechanical energy. They further convert reciprocal motion into rotary

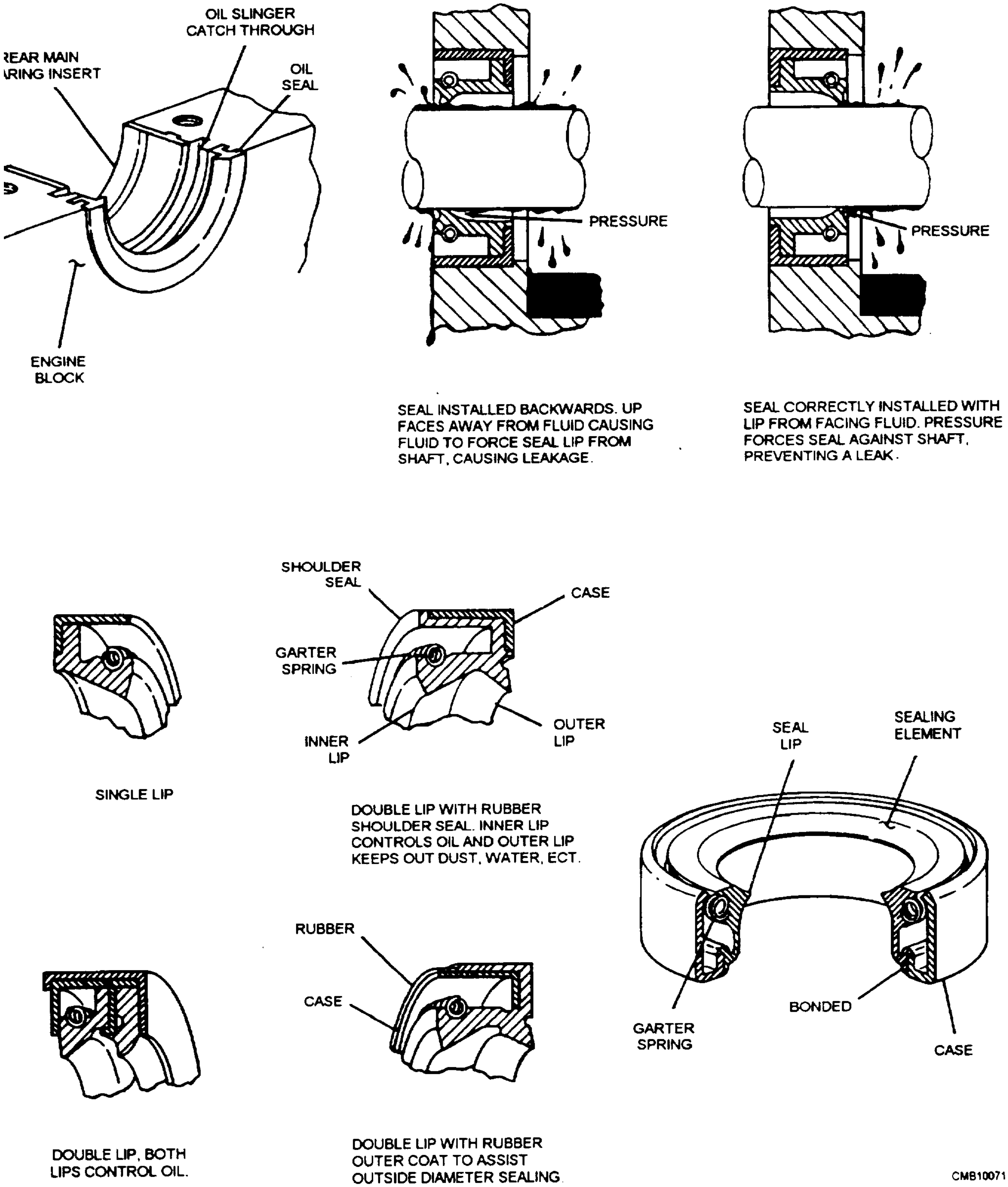


Figure 3-20.—Synthetic rubber oil seals.

motion. The principal moving parts are the piston assembly, the connecting rods, the crankshaft assembly (including flywheel and vibration dampener), the camshaft, the valves, and the gear train.

Burning of the air-fuel mixture within the cylinder exerts a pressure on the piston, thus pushing the cylinder down. The action of the connecting rod and crankshaft converts this downward motion to a rotary motion.

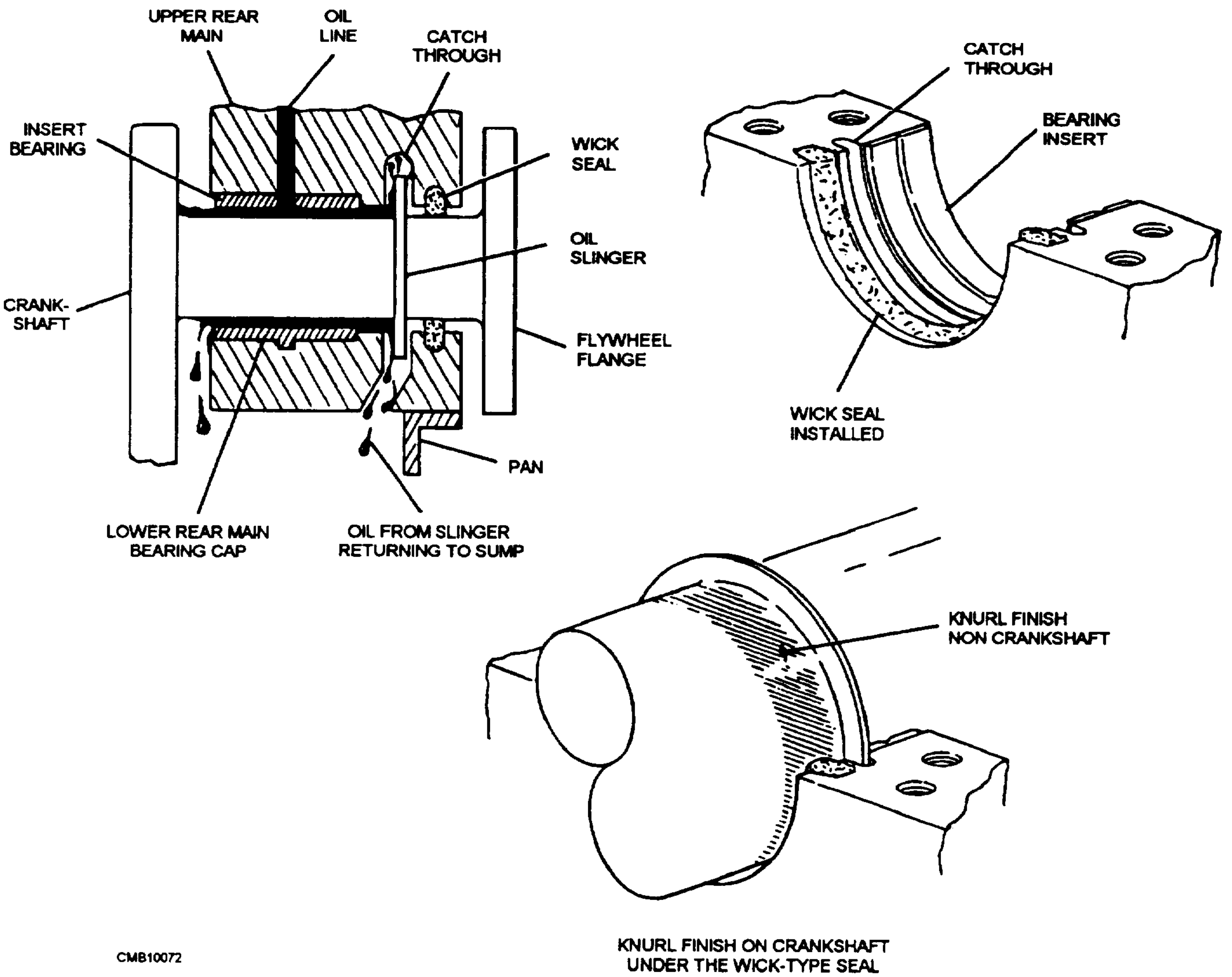


Figure 3-21.—Wick seals.

Piston Assembly

Pistons (fig. 3-22) are usually made of an aluminum alloy. They are a sliding fit in the cylinders. This serves several purposes as follows:

- Transmits the force of combustion to the crankshaft through the connecting rod.
- Acts as a guide for the upper end of the connecting rod.
- Serves as a carrier for the piston rings that are used to seal the compression in the cylinder.

The piston must withstand incredible punishment under temperature extremes. The following are

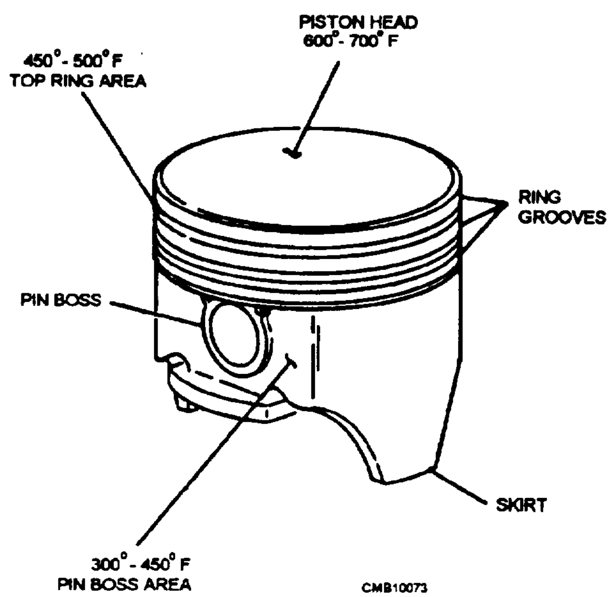


Figure 3-22.—Piston.

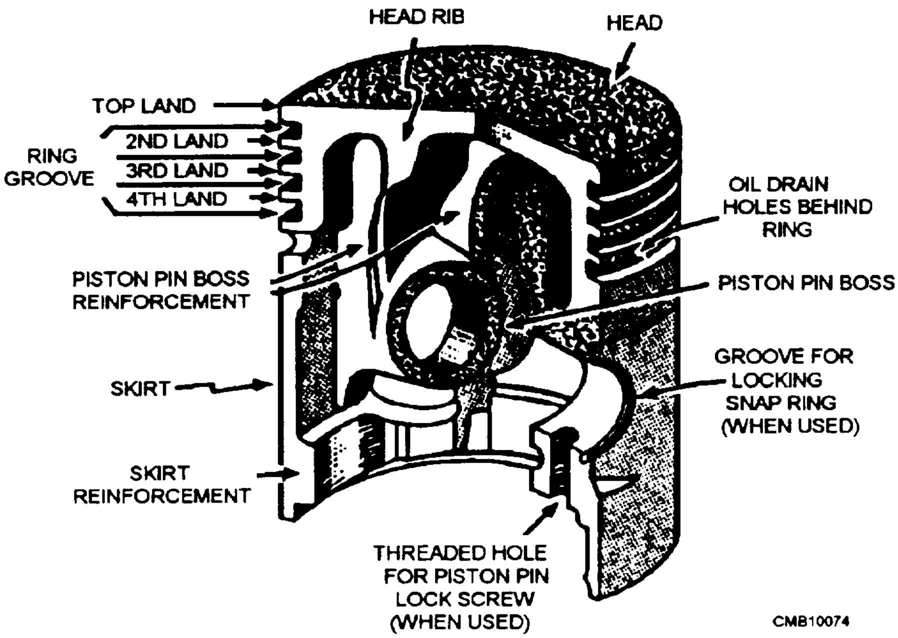


Figure 3-23.—The parts of a piston.

examples of conditions that a piston must withstand at normal highway speed:

- As the piston moves from the top of the cylinder to the bottom (or vice versa), it accelerates from a stop to a speed approximately 50 mph at midpoint, and then decelerates to a stop again. It does this approximately 80 times per second.
- The piston is subjected to pressures on its head in excess of 1,000 psi.
- The piston head is subjected to temperatures well above 600°F.

The structural components of the pistons are the **HEAD, SKIRT, RING GROOVES,** and **LANDS** (fig. 3-23); however, all pistons do not look like the typical one shown here. Some have differently shaped heads. Diesel engine pistons usually have more ring grooves and rings than the pistons of a gasoline engine. Some of these rings may be installed below as well as above the **WRIST** or **PISTON PIN** (fig. 3-24).

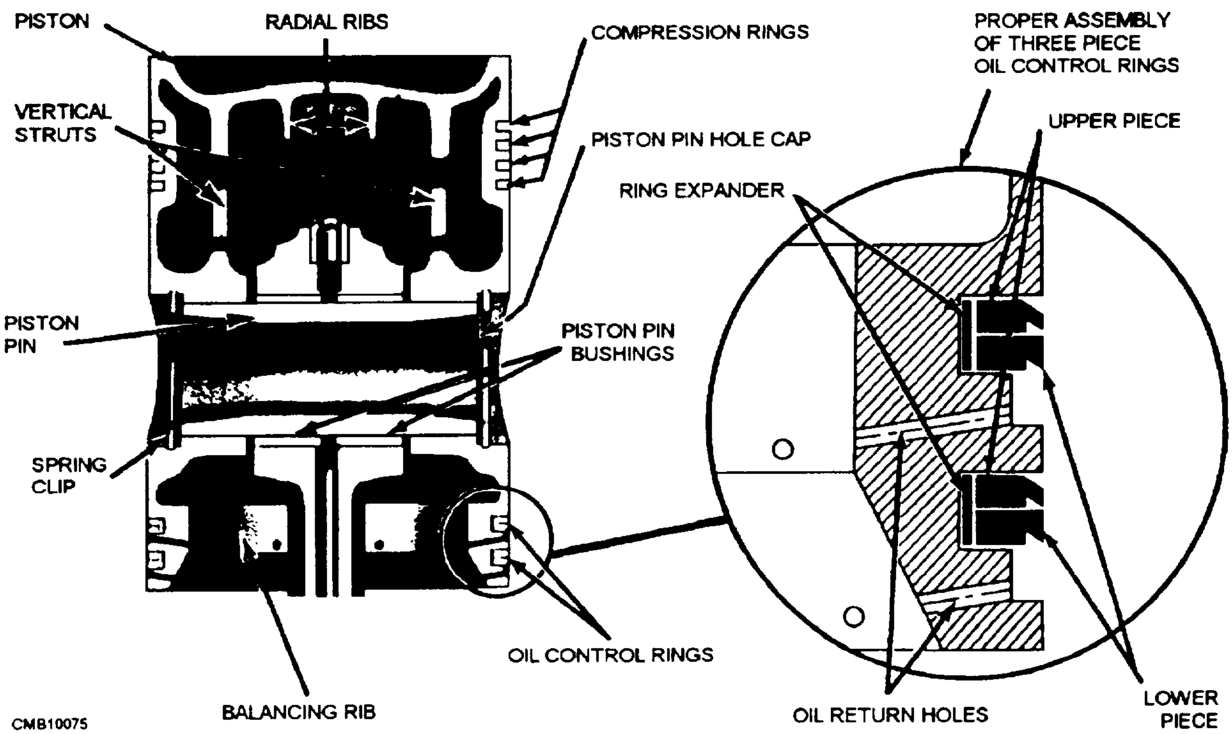


Figure 3-24.—Diesel piston assembly.

Fitting pistons into the cylinder properly is very important. Because metal expands when heated, space must be provided for lubricants between the pistons and the cylinder walls. Pistons must have features built into them to control expansion. Without these features, pistons would fit loosely in the cylinders when cold, and then bind in the cylinders, as they are warmed up. This is the problem with aluminum because it expands so much. The pistons (fig. 3-25) may be designed with the following features to control expansion:

- It is obvious that the crown of the piston gets hotter than the rest of the piston. To prevent it from expanding to a larger size than the rest of the piston, it is machined to a diameter that is approximately 0.03 to 0.04 of an inch smaller than the skirt area.
- One way to control expansion in the skirt area is to cut a slot up the side of the skirt. As a split-skirt piston warms up, the split merely closes, thereby keeping the skirt from expanding outward and binding the piston in the cylinder.
- Another variation of the split-skirt piston is the T-slot piston. The T-slot piston is similar to the split-skirt piston with the addition of a horizontal slot that retards heat transfer from the piston head to the piston skirt.
- Some aluminum pistons have steel braces cast into them to control expansion.

The skirt, or bottom part, of the piston runs much cooler than the top; therefore, it does not require as much clearance as the head.

The piston is kept in alignment by the skirt, which is usually **CAM-GROUND** (elliptical in cross section), as shown in figures 3-26 and 3-27. By making the piston egg-shaped, it is able to fit the cylinder better throughout its operational temperature range. Cam-ground pistons are machined so their diameter is smaller and more parallel to the piston pin axis than it is perpendicular to it. When the piston is cold, it is big enough across the larger diameter to keep from rocking. As it warms up, it expands across its smaller diameter at a much higher rate than at its larger diameter. This tends to make the piston round at operating temperature. The walls of the skirt are cut away as much as possible to reduce weight and to prevent excessive expansion during engine operation. Virtually all pistons in automotive applications are cam ground.

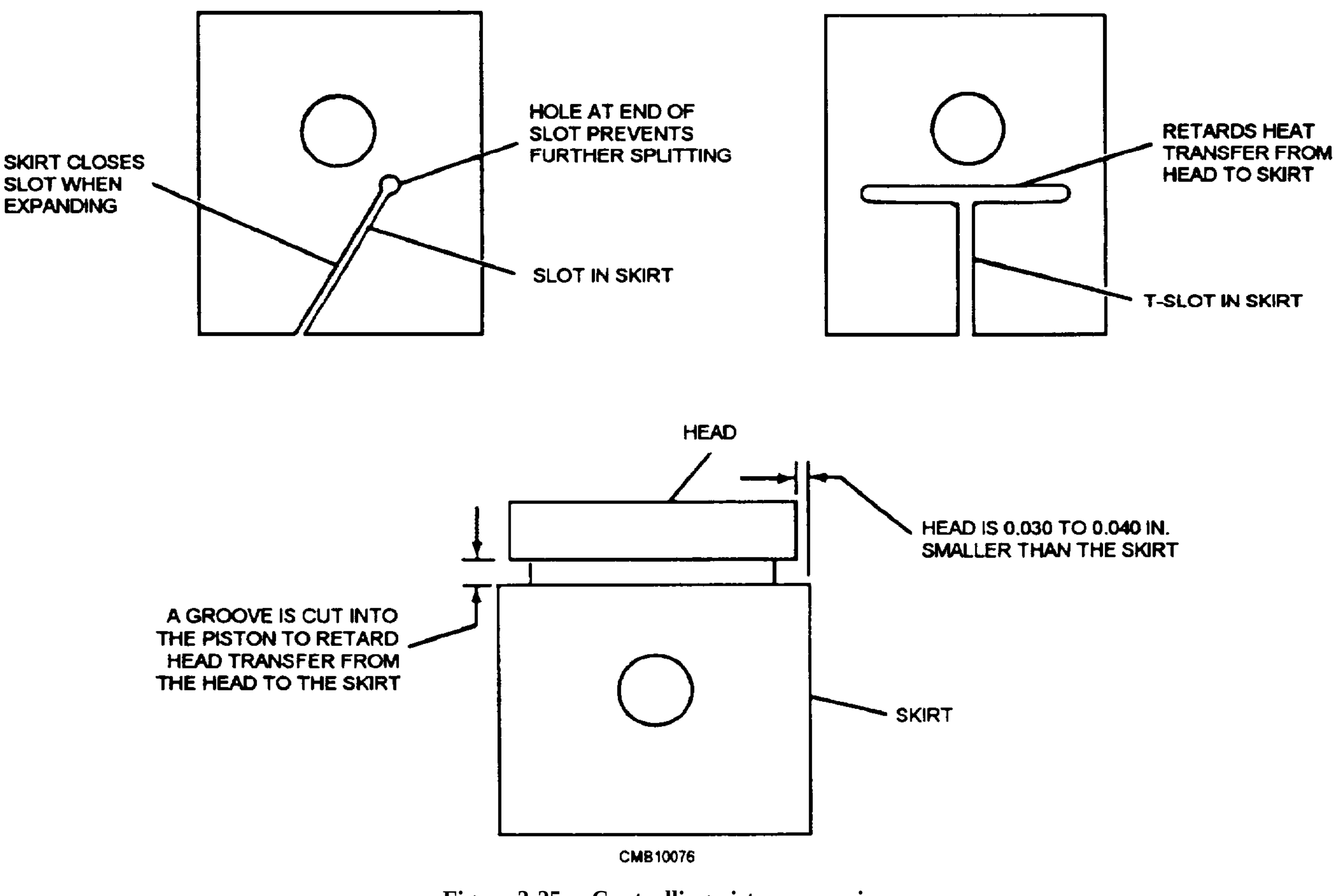


Figure 3-25.—Controlling piston expansion.

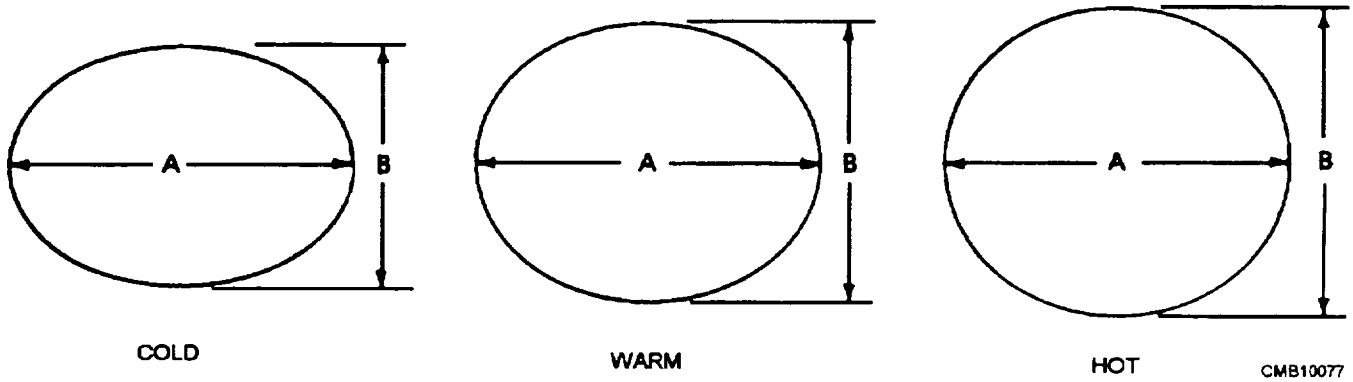


Figure 3-26.—Cam-ground piston action.

There are two types of piston skirts in most **engines—FULL TRUNK** and **PARTIAL SKIRTED (SLIPPER)** (fig. 3-28). The full trunk type of skirt has a full cylindrical shape with hearing surfaces parallel to those of the cylinder. This gives it more strength and better control of the oil film. The partial skirt or slipper skirt has considerable relief on the sides of the skirt. Removal of the skirt in these areas serves the following purposes:

- Lightens the piston, which, in turn, increases the speed range of the engine.
- Reduces the contact area with the cylinder wall, which reduces friction.
- Allows the piston to be brought down closer to the crankshaft without interference with its counterweights.

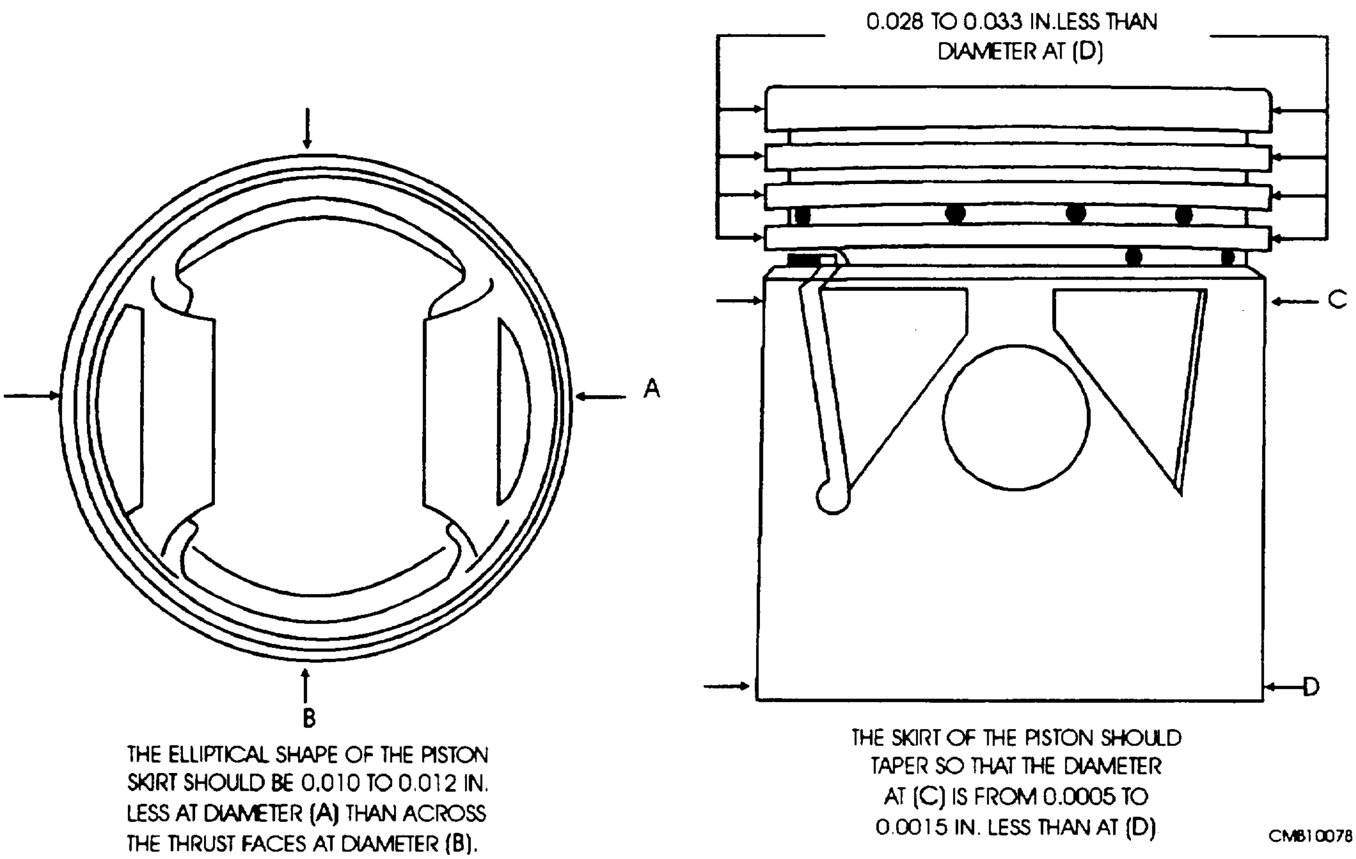


Figure 3-27.—Cam-ground piston.

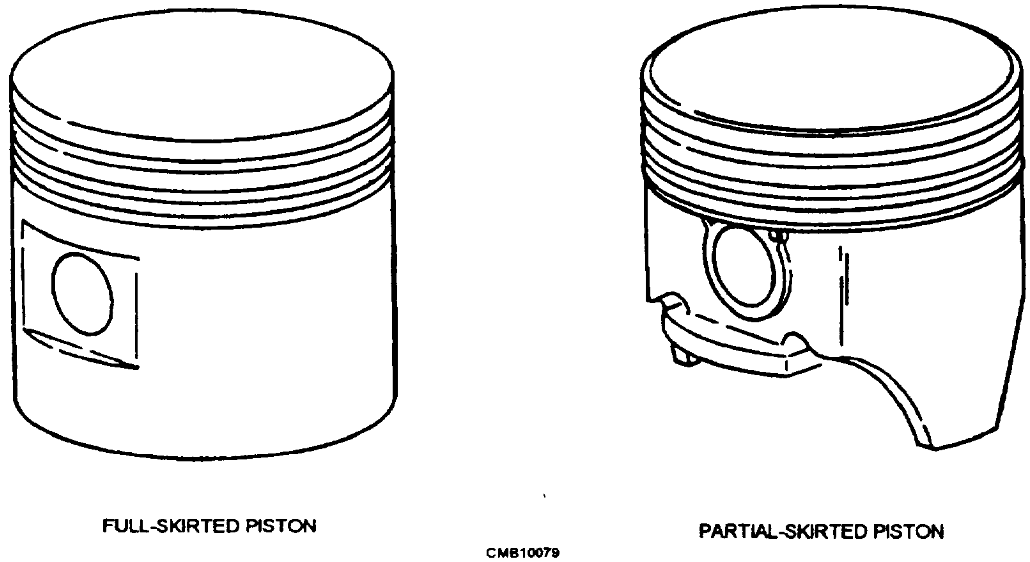


Figure 3-28.—Full- and partial-skirted pistons.

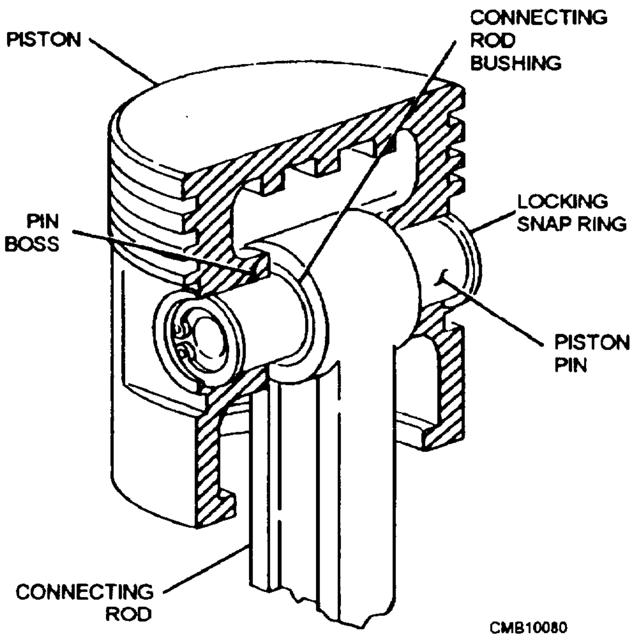


Figure 3-29.—Piston pin.

The piston pin (fig. 3-29) serves to connect the piston to the connecting rod. It passes through the pin bosses in the piston and the upper end of the connecting rod. The piston pin must be hard to provide the desired wearing qualities. At the same time, the piston pin must not be too brittle. A case-hardened steel pin is the best to satisfy the overall requirements of a piston pin. Case hardening is a process that hardens the surface of the steel to any desired depth. The pin is also hollow to reduce the overall weight of the reciprocating mass. They are lubricated by splash from the crankcase or by pressure through passages bored in the connecting rod.

There are three methods used for fastening a piston to the connecting rod. The following are the three different types of piston pins (fig. 3-30):

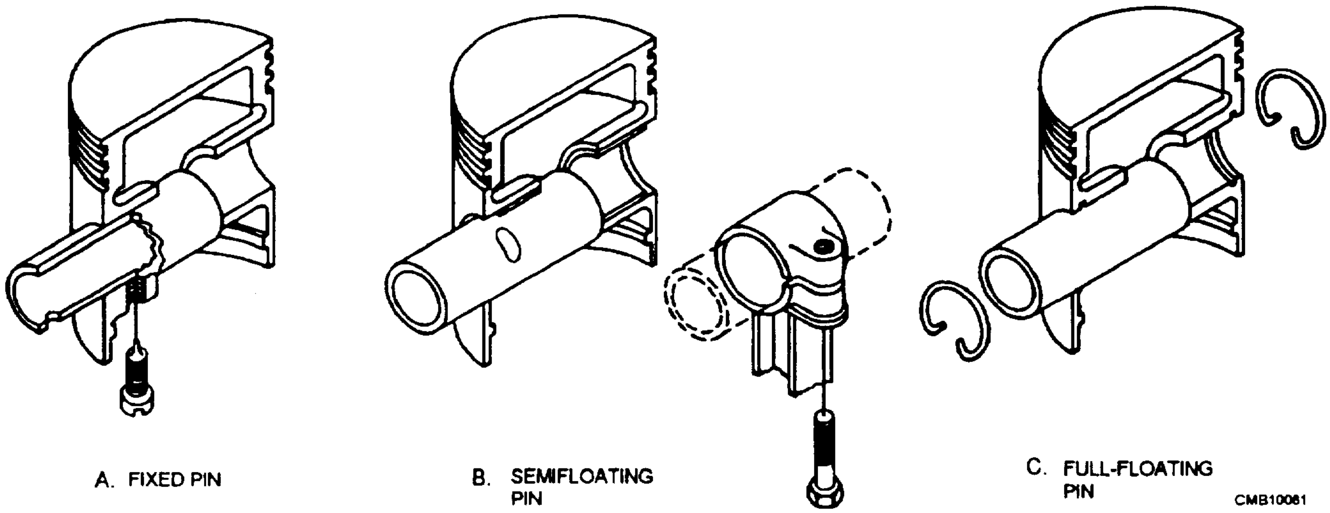


Figure 3-30.—Types of piston pins.

- An **ANCHORED,** or fixed, piston pin is locked into the piston pin bosses by a screw. The rod pivots freely on the connecting rod, which is fitted with a bronze bushing.
- A **SEMIFLOATING** pin is locked to the connecting rod by a screw or by friction. The pin pivots freely in the piston pin bosses.
- The **FULL-FLOATING** piston pin pivots freely in the connecting rod and piston pin bosses. The outer ends of the piston pins are fitted with lock rings to keep the pin from sliding out and contacting the cylinder walls.

Piston rings serve three important functions (fig. 3-31). They provide a seal between the piston and the cylinder wall to keep the force of the exploding gases from leaking into the crankcase from the combustion chamber. Blow-by is detrimental to engine performance because the force of the exploding gases merely bypasses the piston, rather than push down on it. It also contains the lubricating oil. They keep the lubricating oil from passing the piston and getting into the combustion chamber from the crankcase. Also, they provide a solid bridge to conduct heat from the piston to the cylinder wall. About one third of the heat absorbed by the piston passes to the cylinder wall through the piston rings.

Piston rings are secured to the piston by fitting into grooves. They are split to allow for installation and expansion, and they exert pressure on the cylinder walls when installed. They fit into grooves that are cut into the piston and are allowed to float freely in these grooves. A piston ring that is formed properly, working in a cylinder that is within limits for roundness and size, exerts an even pressure and a solid contact with the cylinder wall around the entire circumference. There are two basic classifications of piston rings. The **COMPRESSION RING** (fig. 3-32) that seals the force of the exploding mixture into the combustion chamber and the **OIL CONTROL RING** (fig. 3-32) that keeps engine lubricating oil from getting into the combustion chamber. These rings are arranged on the piston in three basic configurations (fig. 3-33). They are as follows:

- The three-ring piston has two compression rings from the top, followed by one oil control ring—the most common configuration.

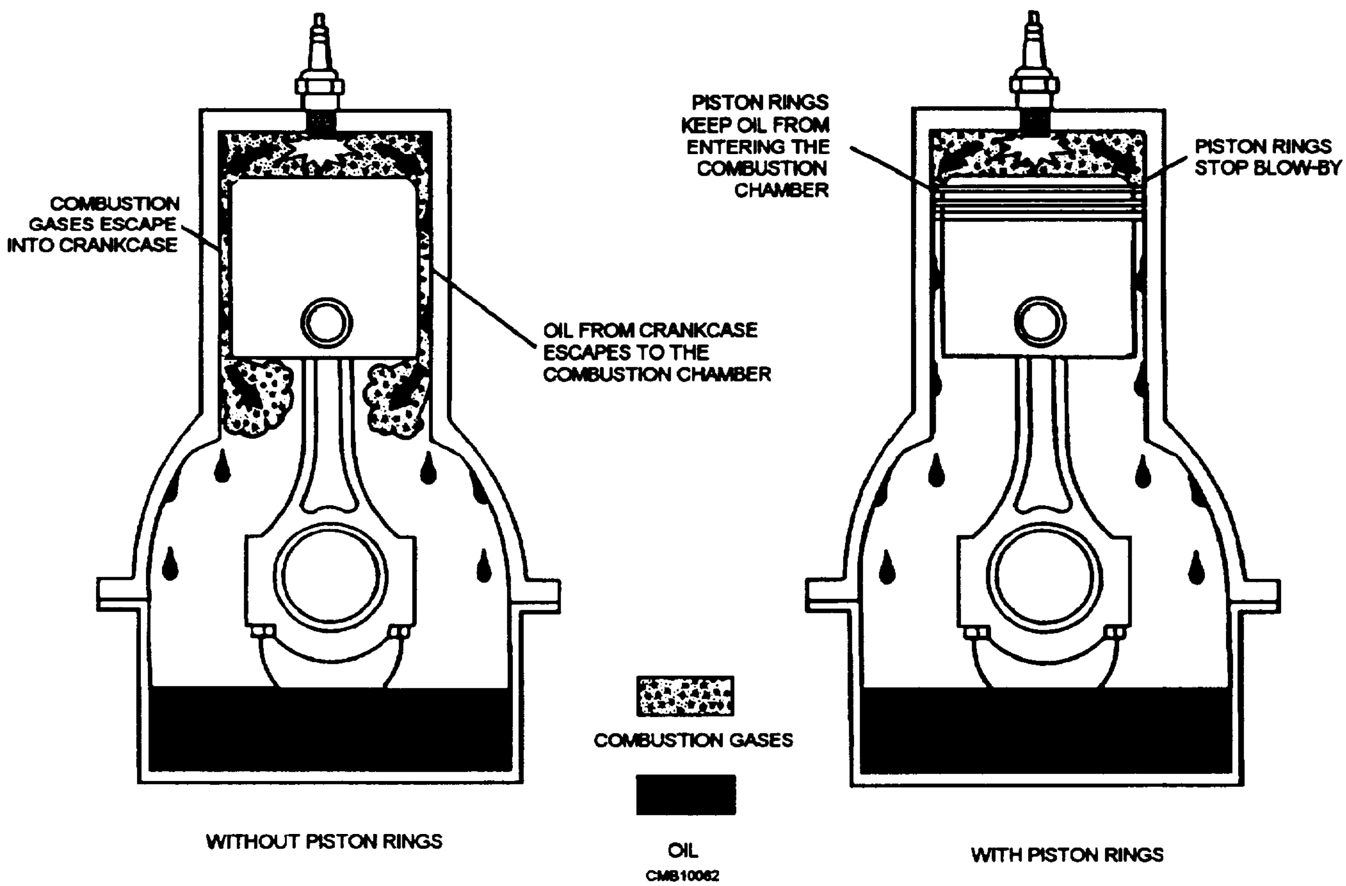


Figure 3-31.—Purpose of piston rings.

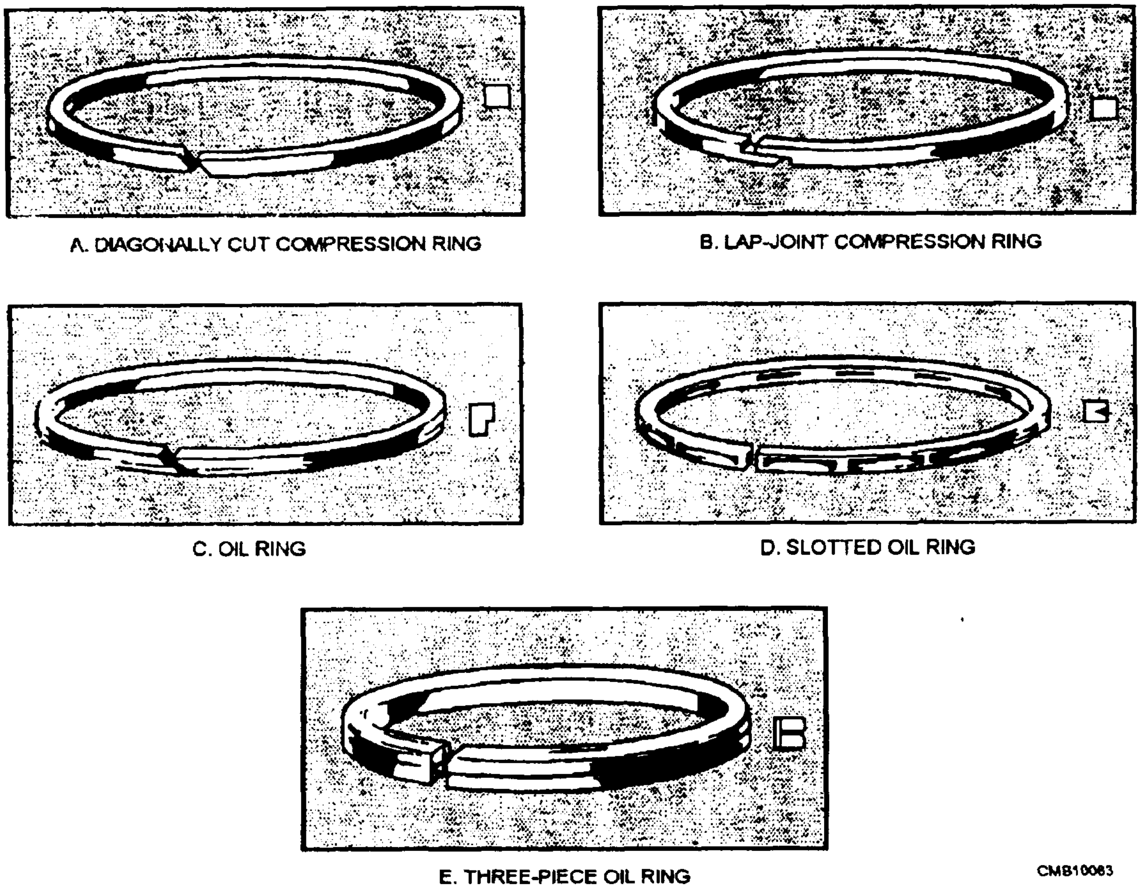


Figure 3-32.—Types of piston rings.

- The four-ring piston has three compression rings from the top, followed by one oil control ring. Commonly used on diesel engines because they are more prone to blow-by. This is due to the much higher pressures generated during the power stroke.
- The four-ring piston has two compression rings from the top, followed by two oil control rings. The bottom oil control ring may be located above or below the piston pin. This is not very common in current engine design.

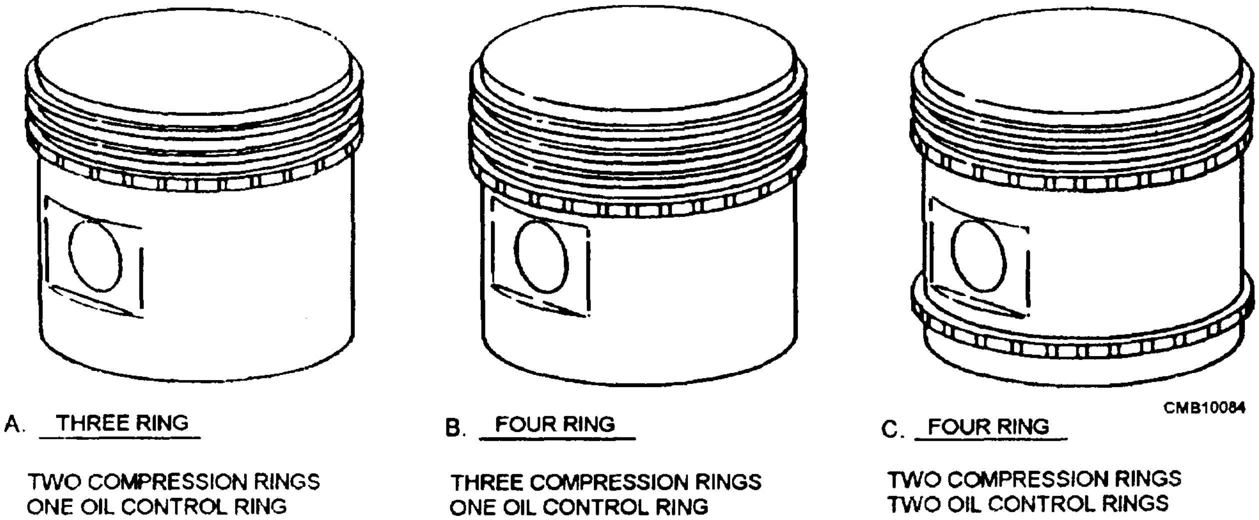


Figure 3-33.—Configurations of piston rings.

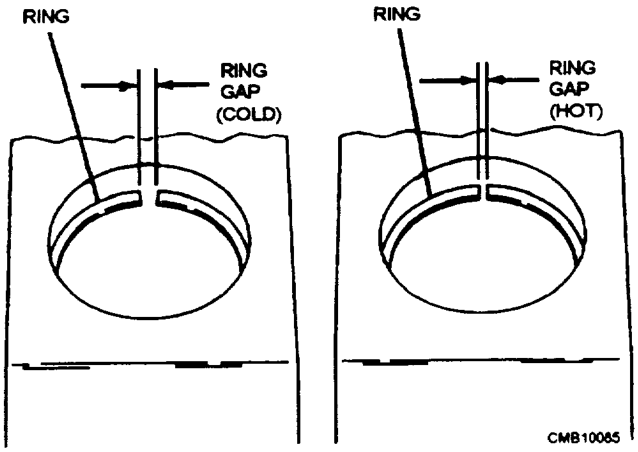


Figure 3-34.—Ring gap.

There is an additional groove cut into the piston just above the top ring groove. The purpose of this groove is to divert some of the intense heat that is absorbed by the piston head away from the top ring. This groove is called a **HEAT DAM.**

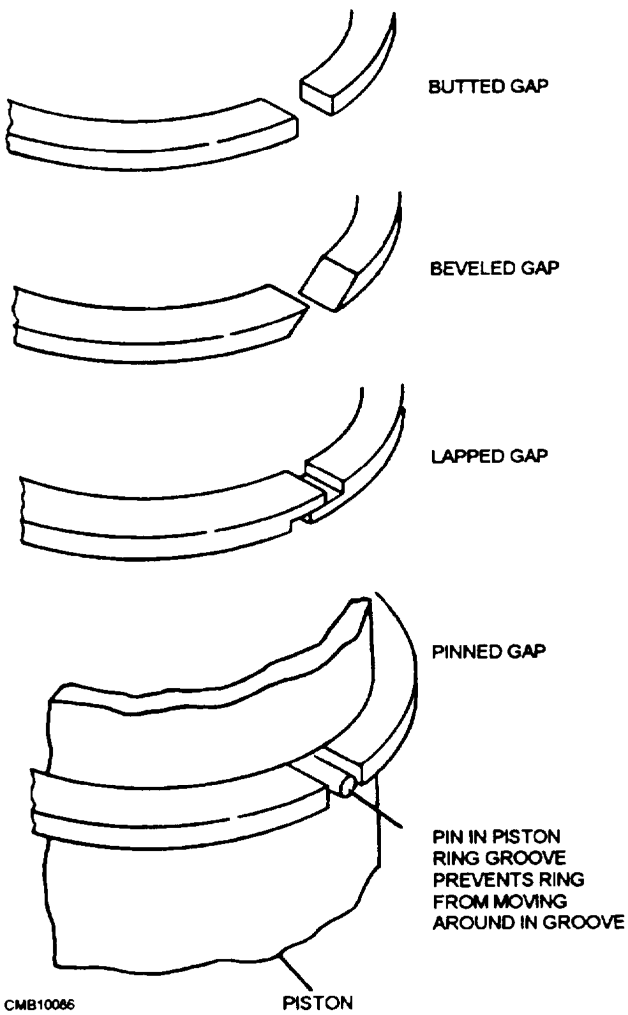


Figure 3-35.—Ring gap variations.

RING GAP (fig. 3-34) is the split in the piston ring. This is necessary for installing the ring on the piston and allowing for expansion from heating. The gap must be such that there is enough space so the ends do not come together, as the ring heats up. This would cause the rings to break. There are a few variations of ring gap joints (fig. 3-35). Two-cycle engines usually have pins in their ring grooves to keep the gap from turning. This is important because the ring would break if the ends were allowed to snap into the inlet or exhaust ports. Staggering the ring gap is also important as it prevents blow-by. A significant amount of total blow-by at the top ring will be from the ring gap. For this reason, the top and second compression rings are assembled to the piston with their gaps 60-degrees offset with the first ring gaps.

Rings must also be fitted for the proper side clearance (fig. 3-36). This clearance varies in different types and makes of engines; however, in a diesel engine, the rings must be given greater clearance than in a gasoline engine. If too much side clearance is given the rings, excessive wear on the lands will result. If there is too little side clearance, expansion may cause the lands to break.

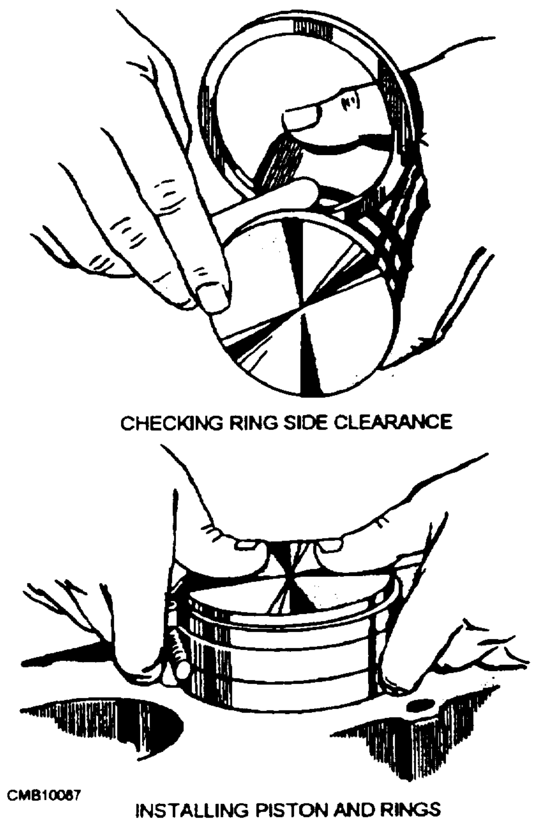


Figure 3-36.—Fitting piston ring and installing piston.

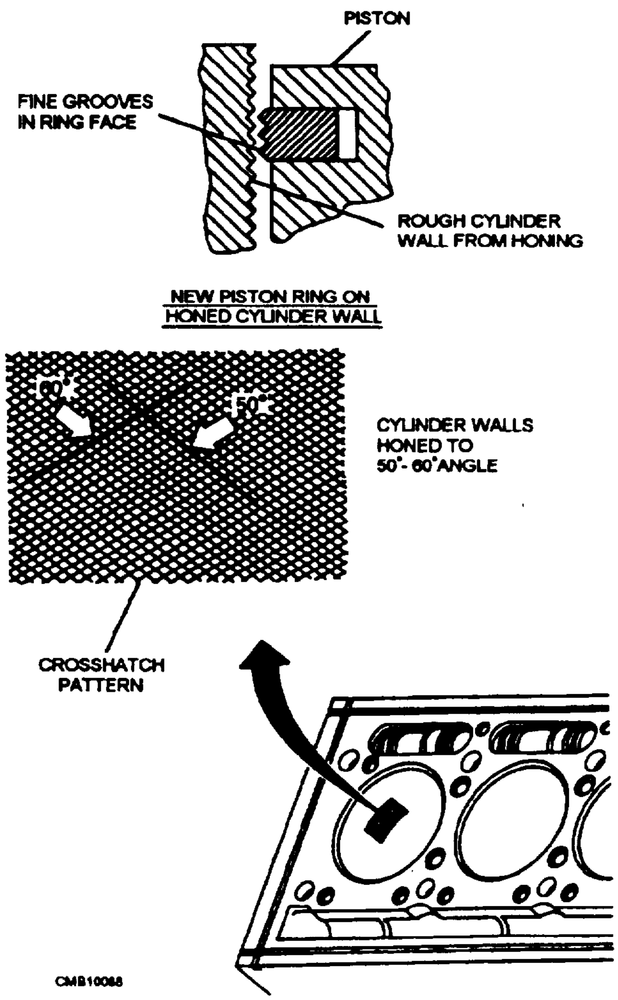


Figure 3-37.—Piston ring wear-in.

When piston rings are new, a period of running is necessary to wear the piston rings a small amount, so they conform perfectly to the cylinder walls. The cylinder walls are surfaced with a tool called a hone, which leaves fine scratches in the cylinder walls (fig. 3-37). The piston rings are made with grooves in their faces, which rub against the roughened cylinder walls, serving to accelerate ring wear during the initial stages. As the surfaces wear smooth, the rings wear in.

Extreme pressure may be applied to high spots on the piston rings during the wear-in period. This can cause the piston rings to overheat at these points and cause damage to the cylinder walls in the form of rough streaks. This condition is called **scuffing.** New piston rings are coated with a porous material, such as graphite, phosphate, or molybdenum. These materials absorb oil and serve to minimize scuffing. As the rings wear in, the coatings wear off.

Some piston rings are chrome-plated. Chrome-plated rings provide better overall wearing qualities. They also are finished to a greater degree of accuracy, which lets the piston rings wear in faster.

Connecting Rods

Connecting rods connect the pistons to the crankshaft. They must be strong enough to transmit the thrust of the pistons to the crankshaft and to withstand the internal forces of the directional changes of the pistons. The connecting rods (fig. 3-38) are in the form of an I-beam. This design gives the highest overall strength and lowest weight. They are made of forged

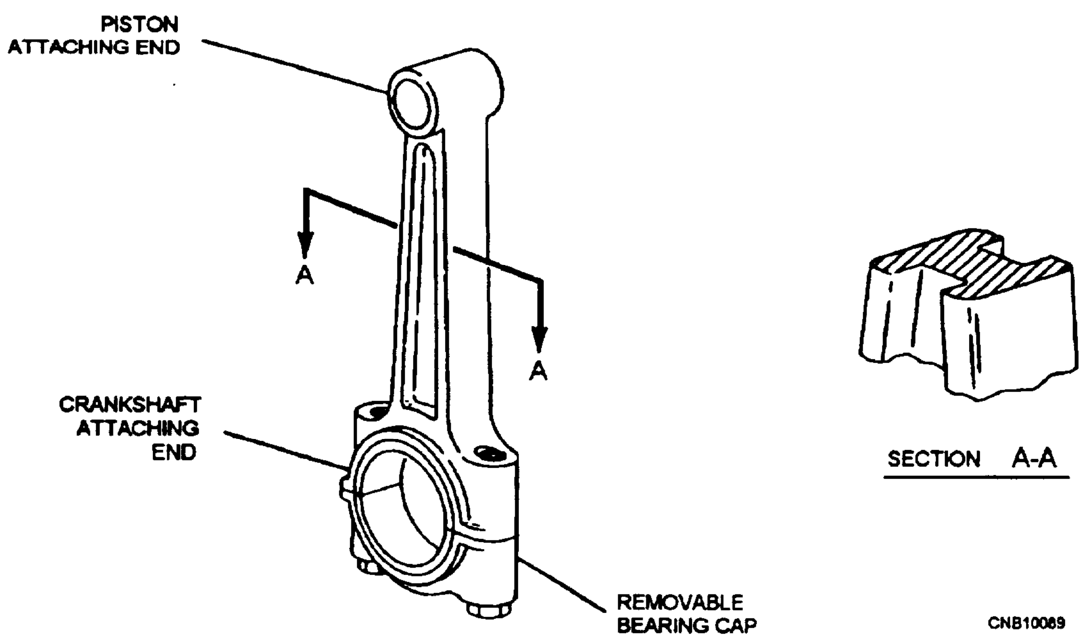


Figure 3-38.—Connecting rod construction.

steel but may also be made of aluminum in smaller engines.

The upper end of the connecting rod is connected to the piston by the piston pin. The piston pin is locked in the pin bosses, or it floats in both piston and connecting rod. The upper hole of the connecting rod has a solid bearing (bushing) of bronze or similar material. As the lower end of the connecting rod revolves with the crankshaft, the upper end is forced to turn back and forth on the piston pin. Although the movement is slight, the bushing is necessary because the temperatures and pressures are high. If the piston pin is semifloating, a bushing is not needed.

The lower hole in the connecting rod is split, so it can be clamped around the crankshaft. The bottom part, or cap, is made of the same type of material as the rod and is attached by two or more bolts. The surface that bears on the crankshaft is generally a bearing material in the form of a split shell, although, in a few cases, it may be spun or die-cast in the inside of the rod and cap during manufacture. The two parts of the separate bearing are positioned in the rod and cap by dowel pins and projections or by a short brass screw. The shell may be of Babbitt metal that is die-cast on a backing of bronze or steel. Split bearings may be of the precision or semiprecision type.

The **PRECISION** type of bearing is accurately finished to fit the crankpin and does not require further fitting during installation. It is positioned by projections on the shell that match relief in the rod and cap. The projections prevent the bearings from moving sideways and from rotary motion in the rod and cap.

The **SEMIPRECISION** type of bearing is fastened to or die-cast with the rod and cap. Before installation, it is machined and fitted to the proper inside diameter with the cap and rod bolted together.

The connecting rod bearings are fed a constant supply of oil through a hole in the crankshaft journal. A hole in the upper bearing half feeds a passage in the connecting rod to provide oil to the piston pin.

Connecting rod numbers are used to assure a proper location of each connecting rod in the engine. They all assure that the rod cap is installed on the rod body correctly. When connecting rod caps are being manufactured, they are bolted to the connecting rods. Then the lower end holes are machined in the rods. Since the holes may not be perfectly centered, rod caps must **NOT** be mixed up or turned around. If the cap is installed without the rod numbers in alignment, the bore will **NOT** be perfectly round. Connecting rod caps, crankshaft, and bearing damage will result.

In addition to the proper fit of the connecting rod bearings and the proper position of the connecting rod, the alignment of the rod itself must be considered. That is to say, the hole for the piston pin and the crankpin must be precisely parallel. Equipment of suitable accuracy is available for checking connecting rods (fig. 3-39). **EVERY** connecting rod should be checked for proper alignment just before it is installed in the engine. Misalignment of connecting rods causes many hard to locate noises in the engine.

Crankshaft

As the pistons collectively might be regarded as the heart of the engine, so the **CRANKSHAFT** (fig. 3-40) may be considered its backbone. The crankshaft is the part of the engine that transforms the reciprocating motion of the piston to rotary motion. It transmits power through the flywheel, the clutch, the transmission, and the differential to drive your vehicle.

Crankshafts are made from forged or cast steel. Forged steel is the stronger of the two and is used in commercial and military engines. The cast unit is primarily used in light- and regular-duty gasoline engines. After the rough forging or casting is produced, it becomes a finished product by going through the following steps:

- Each surface is rough machined
- Each hole is located and drilled.

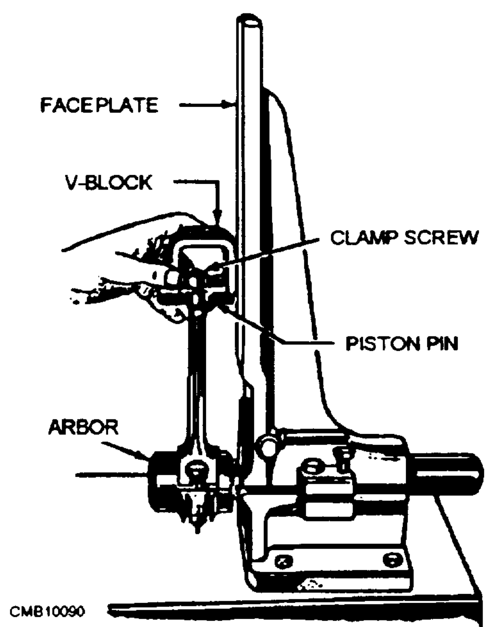


Figure 3-39.—Checking connecting rod alignment.

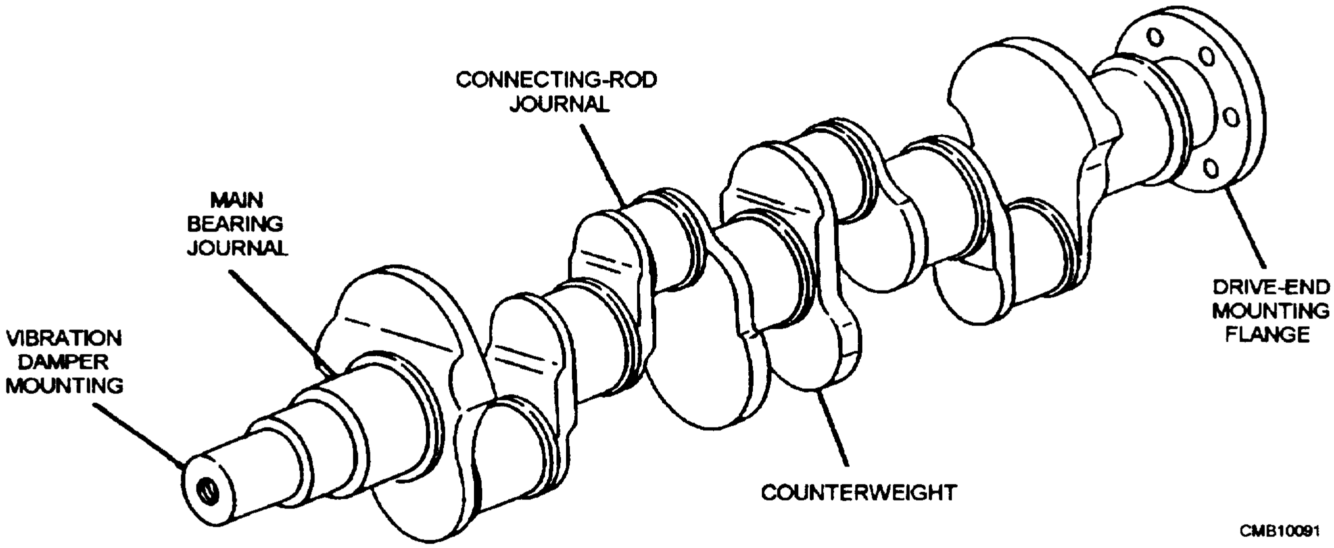


Figure 3-40.—Crankshaft construction.

- The crankshaft, with the exception of the bearing journals, is plated with alight coating of copper.
- The bearing journals are case-hardened.
- The bearing journals are ground to size.
- Threads are cut into necessary bolt holes.

Crank throw arrangements for four-, six-, and eight-cylinder engines are shown in figure 3-41. The arrangements of throws determine the firing order of the engine. The position of the throws for each cylinder arrangement is paramount to the overall smoothness of operation. For the various engine configurations, typical throws are arranged as follows:

- In-line four-cylinder engines have throws one and four offset 180 degrees from throws two and three.
- V-type engines have two cylinders operating off each throw. The two end throws are on one plane offset 180 degrees apart. The two center throws are on another common plane, which is also 180 degrees apart. The two planes are offset 90 degrees from each other.
- In-line six-cylinder engines have throws a-ranged on three planes. There are two throws on each plane that are in line with each other. The three planes are arranged 120 degrees apart.
- V-type twelve-cylinder engines have throw arrangements like the in-line six-cylinder engine. The difference is that each throw accepts two-engine cylinders.
- V-type six-cylinder engines have three throws at 120- degree intervals. Each throw accepts two-engine cylinders.

The crankshaft is supported in the crankcase and rotates in the main bearings (fig. 3-42). The connecting rods are supported on the crankshaft by the rod bearings. Crankshaft bearings are made as precision inserts that consist of a hard shell of steel or bronze with a thin lining of antifrictional metal or bearing alloy. Bearings must be able to support the crankshaft rotation and deliver power stroke thrust under the most adverse conditions.

The crankshaft rotates in the **MAIN BEARINGS** located at both ends of the crankshaft and at certain intermediate points. The upper halves of the bearing fit right into the crankcase and the lower halves fit into the caps that hold the crankshaft in place (fig. 3-43). These bearings often are channeled for oil distribution and may be lubricated with crankcase oil by pressure through drilled passages or by splash. Some main bearings have an integral thrust face that eliminates crankshaft end play. To prevent the loss of oil, place the seals at both ends of the crankshaft where it extends through the crankcase. When main bearings are replaced, tighten the bearing cap to the proper tension with a torque wrench and lock them in place with a cotter pin or safety wire after they are in place.

VIBRATION DUE TO IMBALANCE is an inherent problem with a crankshaft that is made with

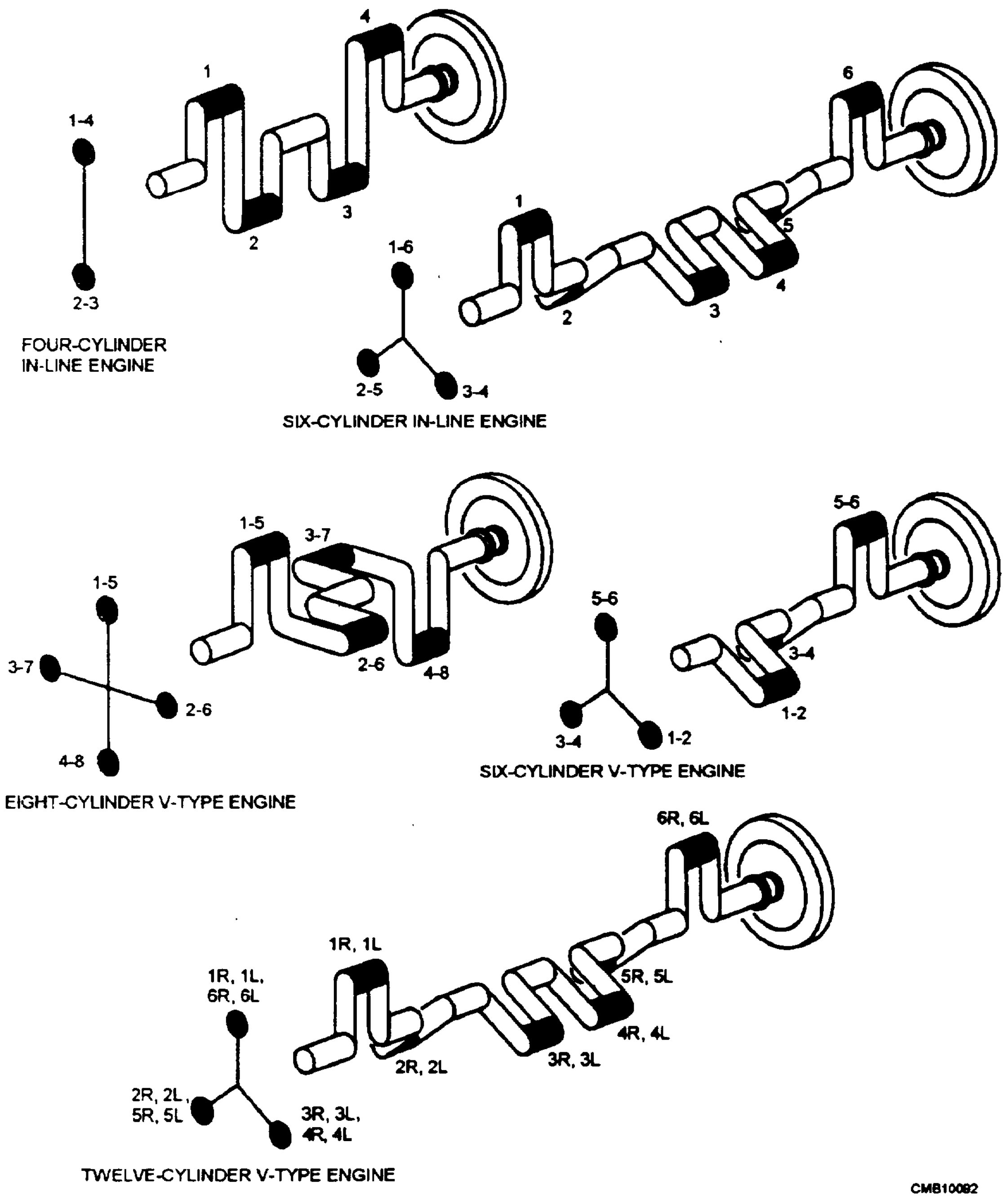


Figure 3-41.—Crankshaft throw arrangements.

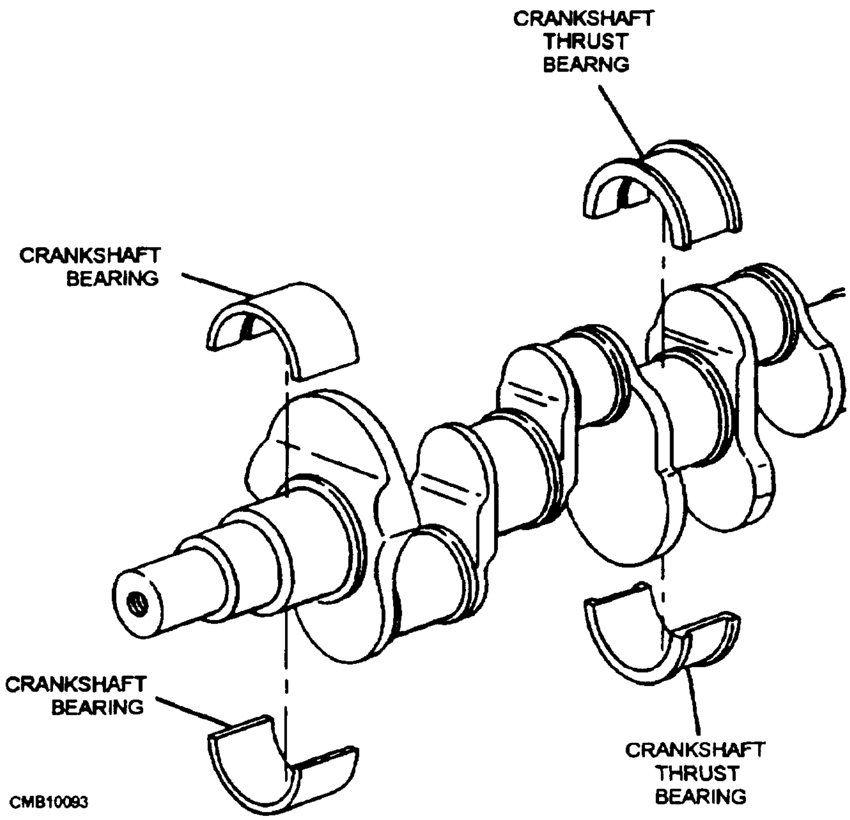


Figure 3-42.—Crankshaft bearings.

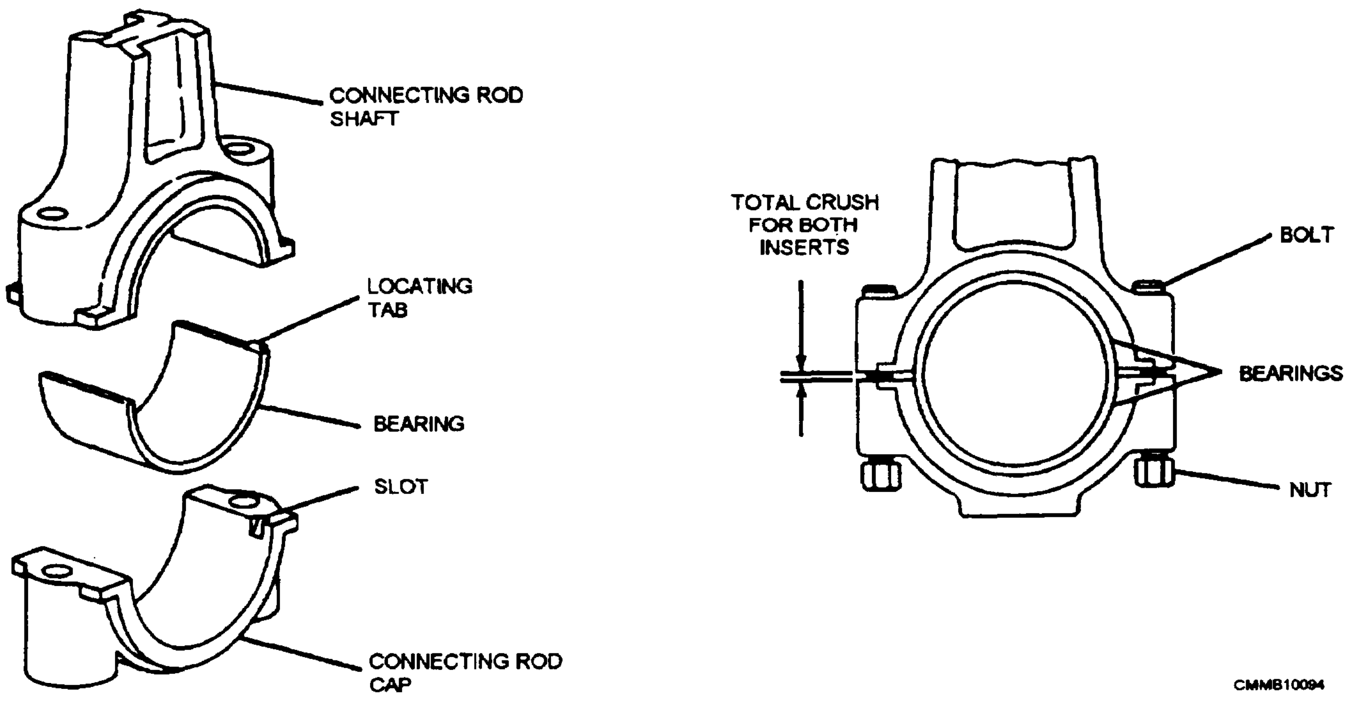


Figure 3-43.—Typical insert bearing installation.

offset throws. The weight of the throws tend to make the crankshaft rotate elliptically. This is aggravated further by the weight of the piston and the connecting rod. To eliminate the problem, position the weights along the crankshaft. One weight is placed 180 degrees away from each throw. They are called counterweights and are usually part of the crankshaft but may be a separate bolt on items on small engines.

The crankshaft has a tendency to bend slightly when subjected to tremendous thrust from the piston. This deflection of the rotating member causes vibration. This **VIBRATION DUE TO DEFLECTION** is minimized by heavy crankshaft construction and sufficient support along its length by bearings.

TORSIONAL VIBRATION occurs when the crankshaft twists because of the power stroke thrusts. It is caused by the cylinders furthest away from the crankshaft output. As these cylinders apply thrust to the crankshaft, it twists and the thrust decreases. The twisting and unwinding of the crankshaft produces a vibration. The use of a vibration damper at the end of the crankshaft opposite the output acts to absorb torsional vibration.

Vibration Damper

The power impulses of an engine tend to set up torsional vibration in the crankshaft. If this torsional vibration were not controlled, the crankshaft might actually break at certain speeds; a vibration damper mounted on the front of the crankshaft controls this vibration.

There are a few variations of the vibration damper (fig. 3-44), but they all accomplish their task basically in

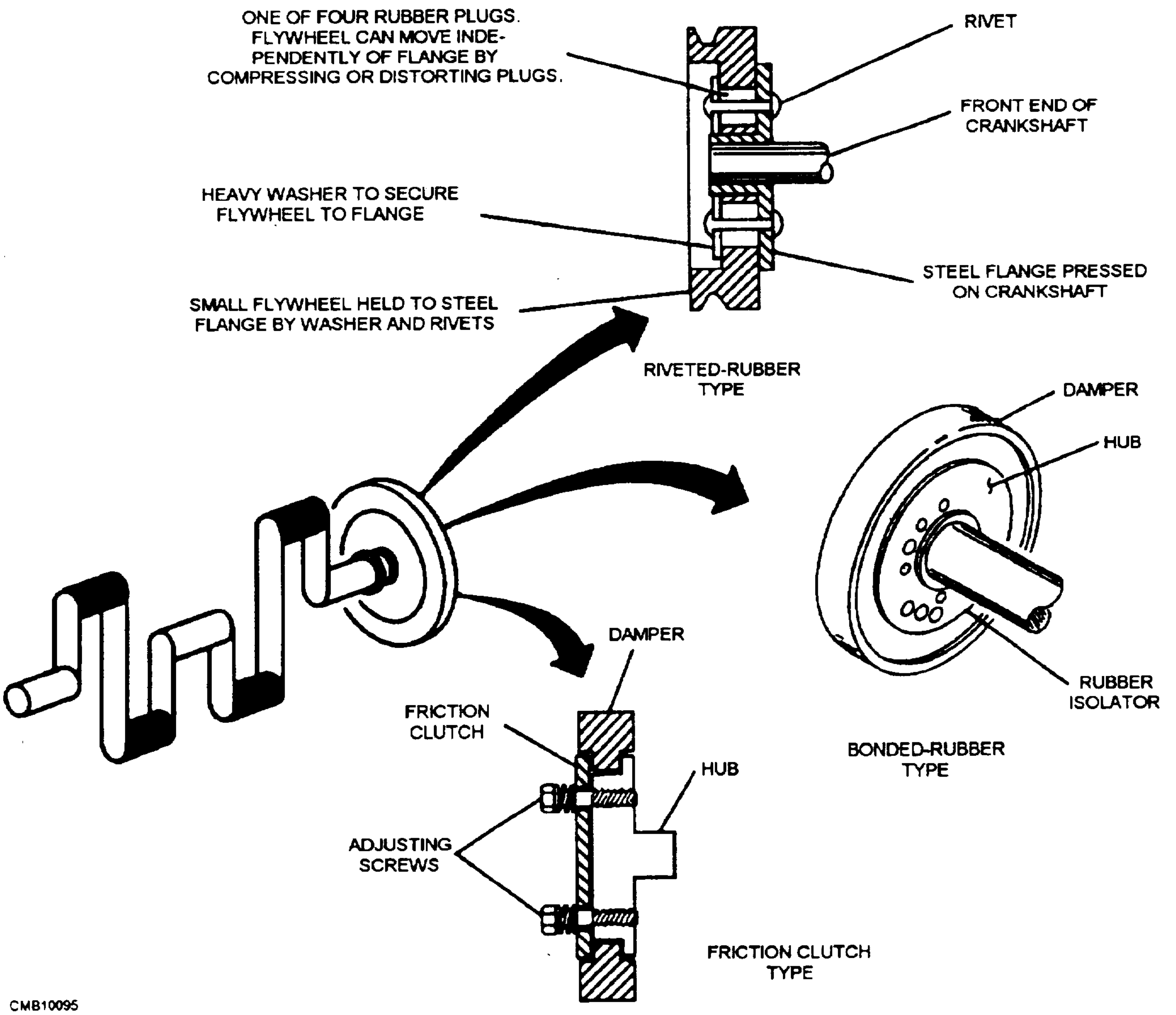


Figure 3-44.—Vibration damper.

the same manner. They all use a two-piece design The differences in design are in how the two pieces are linked together. One type of damper links the pieces together by an adjustable friction clutch. Whenever a suddenchange in crankshaft speed occurs, it causes the friction clutch to slip. This is because the outer section of the damper tends to continue at the same speed. The slippage of the clutch acts to absorb the torsional vibration. Another type of damper links the two pieces together with rubber. As the crankshaft speeds up, the rubber compresses, storing energy. This minimizes the effect of crankshaft speed increase. As the crankshaft unwinds, the damper releases energy stored in the compressed rubber to cushion the speed change in the other direction.

Flywheel

The flywheel (fig. 3-45) stores energy from the power strokes and smoothly delivers it to the drive train of the vehicle between the engine and the transmission. It releases this energy between power impulses, assuring fewer fluctuations in speed and smoother engine operation. The flywheel is mounted at the rear of the crankshaft near the rear main bearing. This is usually the longest and heaviest main bearing in the engine, as it must support the weight of the flywheel.

The flywheel on large, low-speed engines is usually made of cast iron. This is desirable because the heavy weight of the cast iron helps the engine maintain a steady speed. Small, high-speed engines usually use a forged steel or forged aluminum flywheel for the following reasons:

- The cast iron is too heavy, giving it too much inertia for speed variations necessary on small engines.
- Cast iron, because of its weight, pulls itself apart at high speeds due to centrifugal force.

When equipped with a manual transmission, the flywheel serves to mount the clutch With a vehicle that is equipped with an automatic transmission, the flywheel supports the front of the torque converter. In some configurations, the flywheel is combined with the torque converter. The outer edge of the flywheel carries the ring gear, either integral with the flywheel or shrunk on. The ring gear is used to engage the drive gear on the starter motor for cranking the engine.

VALVE AND VALVE MECHANISMS

There are two valves for each cylinder in most engines—one intake and one exhaust. Since these valves operate at different times, it is necessary that a separate operating mechanism be provided for each valve. Valves are held closed by heavy springs and by compression in the combustion chamber. The purpose of the valve actuating mechanism is to overcome spring pressure and open the valve at the proper time. The valve actuating mechanism includes the engine camshaft, the camshaft followers (tappets), the pushrods, and the rocker arms.

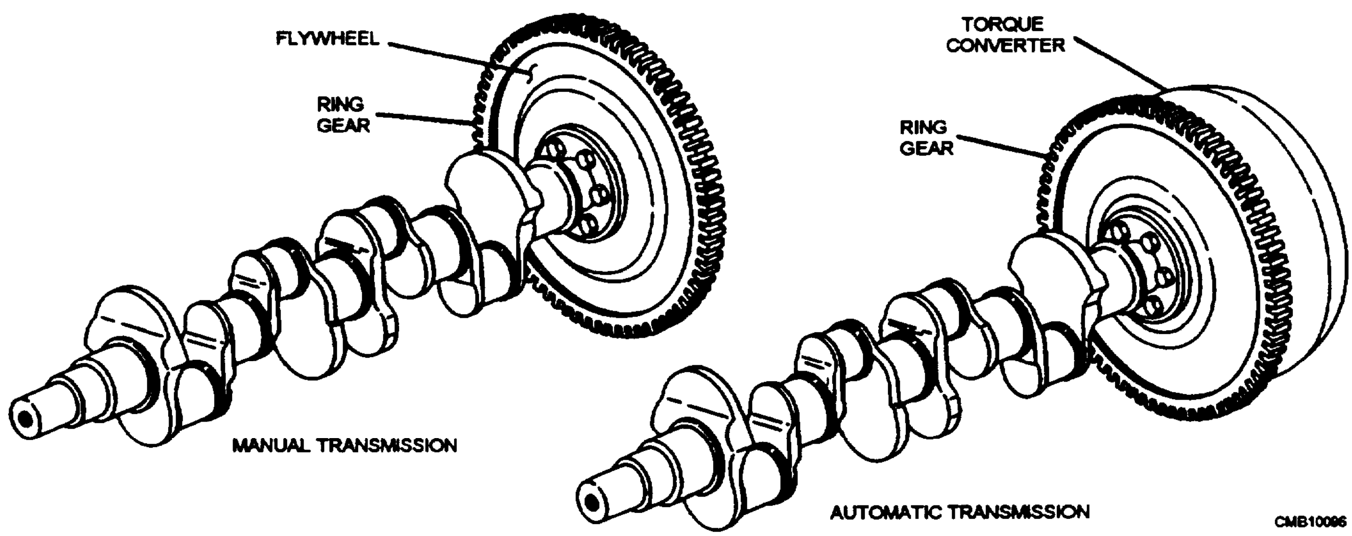


Figure 3-45.—Flywheel.

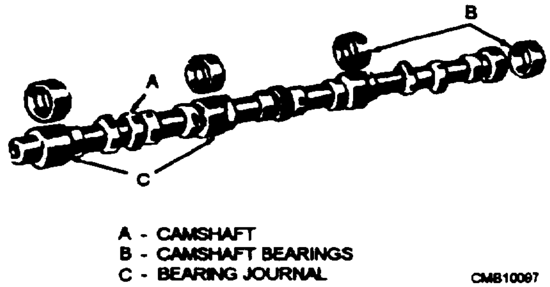


Figure 3-46.—Camshaft and bushings.

Camshaft

The camshaft provides for the opening and closing of the engine valves. The camshaft (fig. 3-46) is enclosed in the engine block. It has eccentric lobes (cams) ground on it for each valve in the engine. As the camshaft rotates, the cam lobe moves up under the valve tappet, exerting an upward thrust through the tappet against the valve stem or the pushrod. This thrust overcomes the valve spring pressure as well as the gas pressure in the cylinder, causing the valve to open. When the lobe moves from under the tappet, the valve spring pressure reseats the valve.

On L-, F-, or I-head engines, the camshaft is located to one side and above the crankshaft, while in V-type engines, it is located directly above the crankshaft On the overhead camshaft engine, the camshaft is located above the cylinder head

The camshaft of a four-stroke-cycle engine turns at one half of engine speed. It is driven off the crankshaft through timing gears or a timing chain. (The system of camshaft drive is dismissed later in this chapter.) In a two-stroke-cycle engine, the camshaft must turn at the same speed as the crankshaft, so each valve opens and closes once in each revolution of the engine.

In most cases, the camshaft does more than operate the valve mechanism. It may have external cams or gears that operate the fuel pumps, the fuel injectors, the ignition distributor, or the lubrication pump.

Camshafts are supported in the engine block by journals in bearings. Camshaft bearing journals are the largest machined surfaces on the shaft. The bearings are made of bronze and are bushings, rather than split bearings. The bushings are lubricated by oil circulating through drilled passages from the crankcase. The stresses on the camshaft are small; therefore, the bushings are not adjustable and require little attention. The camshaft bushings are replaced only when the engine requires a complete overhaul.

Followers

Camshaft followers are part of the valve actuating mechanism that contacts the camshaft. You will hear them called valve tappets or valve lifters. The bottom surface is hardened and machined to be compatible with the surface of the camshaft lobe. There are two basic type of followers—mechanical and hydraulic.

MECHANICAL (or solid) tappets (fig. 3-47) are simply barrel-shaped pieces of metal. When used in flathead engines, they have an adjusting screw mechanism to set the clearance between the tappets and the valve stems. Mechanical tappets may also come with a wider bottom surface. These are called

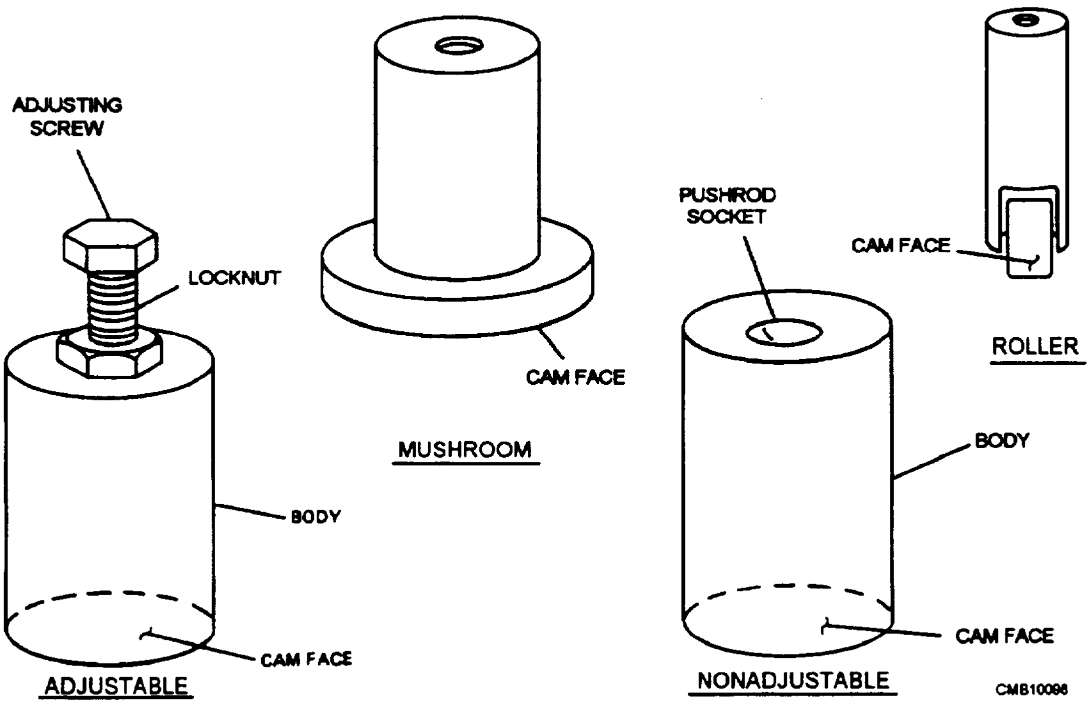


Figure 3-47.—Mechanical tappets

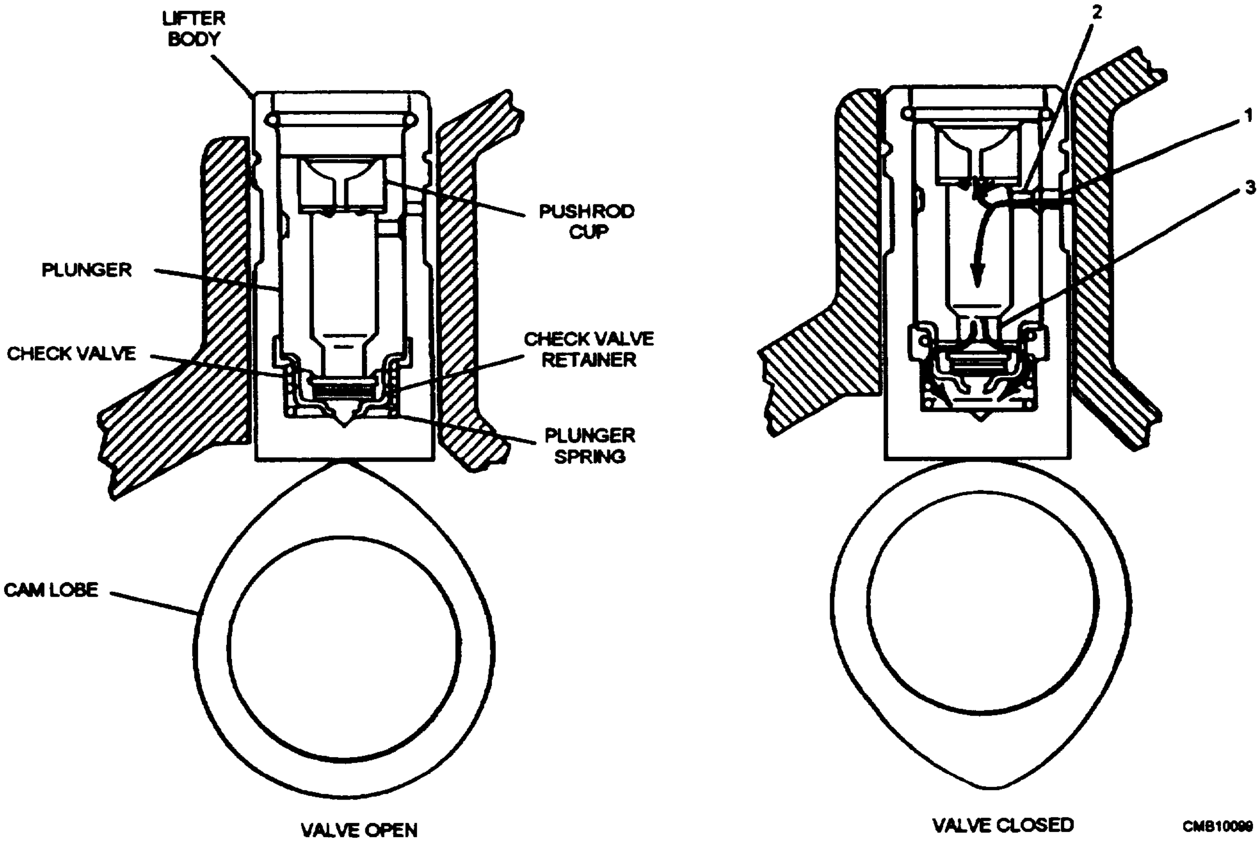


Figure 3-48.—Hydraulic tappets.

mushroom tappets. Another variation is the roller tappet. It has a roller contacting the camshaft and is used mostly in heavy-duty applications.

HYDRAULIC tappets are very popular in overhead valve engines. They use oil under pressure to maintain zero clearance in the valve mechanism automatically. The lifter body, which contacts the camshaft lobe, is hollow. Inside the lifter body, there is a plunger that operates the valve mechanism. Injecting oil into the cavity under the plunger regulates its height, thereby adjusting valve mechanism clearance. The hydraulic lifter operates as follows (fig. 3-48): oil, supplied by the engine lubrication system, reaches the lifter body and enters it through passage (1). The oil then passes through passage (2) to fill the plunger. The oil then passes through passage (3) where it pushes the check valve off its seat to enter the cavity under the plunger. As oil fills the cavity, it pushes the plunger up to where it contacts the valve mechanism. When the camshaft pushes the lifter body up, the oil is trapped in the cavity and cannot escape because the check ball seals the opening. This trapped oil then becomes a solid link between the lifter body and the plunger. The constant pressurized supply of oil will maintain zero clearance in the valve mechanism.

The face of the tappet and the lobe of the camshaft are designed so the tappet rotates during operation (fig. 3-49). The cam lobe is machined with a slight taper that

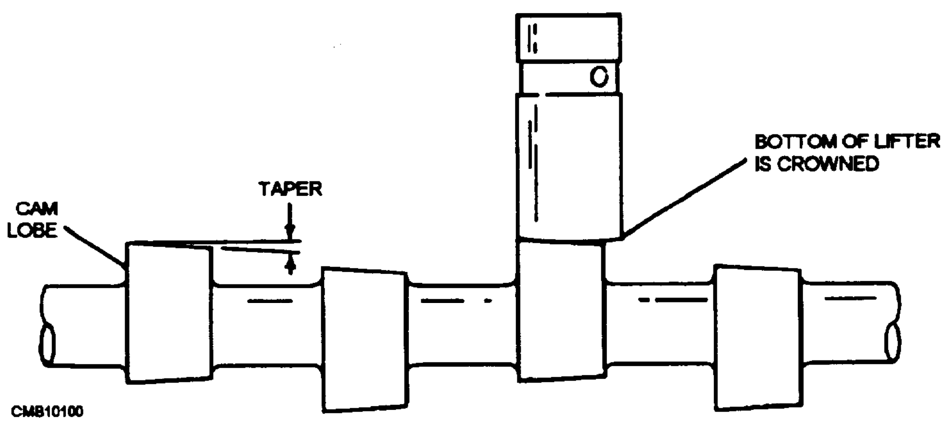


Figure 3-49.—Tappet-to-can lobe relationship.

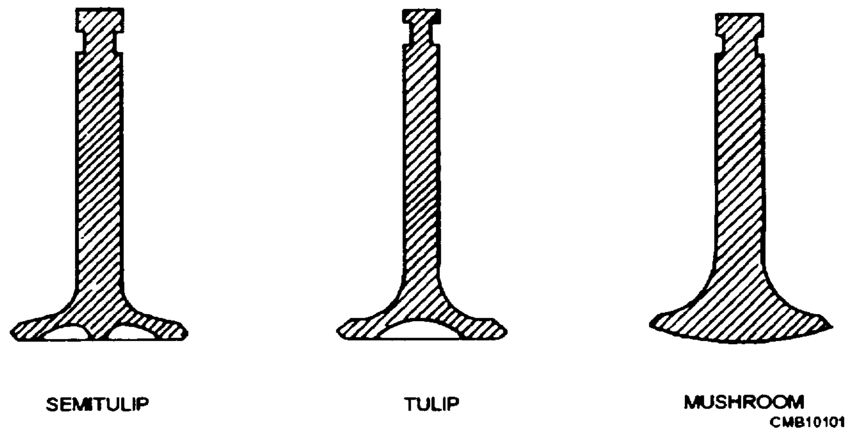


Figure 3-50.—Valve shapes.

mates with a crowned tappet face. The camshaft lobe does not meet the tappet in the center of its face. The design causes the tappet face to rotate on the cam lobe, rather than slide. This greatly increases component life.

Valve and Valve Seats

Each cylinder in a four-stroke-cycle engine must have one intake and one exhaust valve. The valves that are commonly used are of the poppet design. The word *poppet* is derived from the popping action of the valve. Poppet-type valves are made in the following three basic shapes: **semitulip, tulip,** and **mushroom** (fig. 3-50). The valve shape used in a given engine depends on requirements and shape of the combustion chamber.

Construction and design considerations are very different for intake and exhaust valves. The difference is based on their temperature operating ranges. Intake valves are kept cool by the incoming intake mixture. Exhaust valves are subject to intense heat from the burnt gases that pass by it. The temperature of an exhaust valve can be in excess of 1300°F. Intake valves are made of **nickel chromium alloy.** Whereas, exhaust valves are made from **silichrome alloy.** In certain heavy-duty and most air-cooled engines, the exhaust valves are **sodium filled.** During engine operation, the sodium inside the hollow valve melts. When the valve opens, the sodium splashes down into the valve head and collects heat. Then, when the valve closes, the sodium splashes up into the valve stem. Heat transfers out of the sodium, into the stem, valve guide, andengine coolant. In this way, the valve is cooled. Sodium-filled valves are light and allow high engine rpm for prolonged periods.

In vehicles that use unleaded fuel, a **stellite valve** is preferred. A stellite valve has a special hard metal coating on its face. Lead additives in gasoline, other than increasing octane, act as a lubricant. The lead coats the valve face and seat to reduce wear. With unleaded fuel, the wear of the valve seat and valve face is accelerated. To prevent this and prolong valve service life, use a stellite valve.

Valve seats are important, as they must match the face of the valve head to form a perfect seal. The seats are made so they are concentric with the valve guides; that is, the surface of the seat is an equal distance from the center of the guide all around Although some earlier engines were designed with flat contact surface for the valve and valve seat, most are now designed with valve seat angles of 30 to 45 degrees, as shown in figure 3-51. This angle helps prevent excessive accumulation

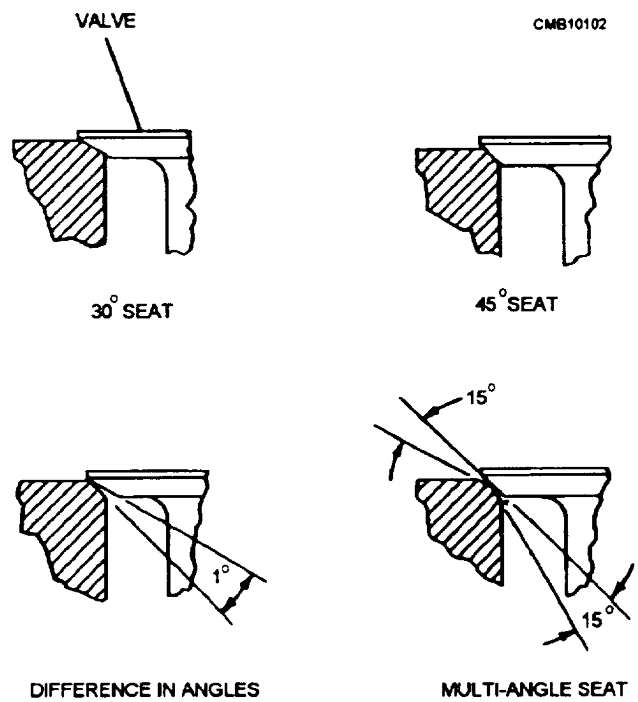


Figure 3-51.—Valve-to-valve seat relationship.

of carbon on the contact surface of the seat—a condition that keeps the valve from closing properly. To further reduce carbon build up, there is an interference angle (usually 1 degree) between the valve and seat. In some cases, a small portion of the valve seat has an additional 15-degree angle ground into it to narrow the contact area of the valve face and seat. When you reduce the contact area, the pressure between the mating parts is increased, thereby forming a better seal.

The valve seats may be an integral part of the cylinder head or an insert pressed into the cylinder head. Valve seat inserts are commonly used in aluminum cylinder heads. Steel inserts are needed to withstand the extreme heat. When a valve seat insert is badly worn from grinding or pitting, it must be replaced.

Valve Guides

The valve guides are the parts that support the valves in the cylinder head. They are machined to fit a few thousandths of an inch clearance with a valve stem, This close clearance is important for the following reasons:

- It keeps lubricating oil from getting sucked into the combustion chamber past the intake valve stem during the intake stroke.
- It keeps exhaust gases from getting into the crankcase area past the exhaust valve stem during the exhaust stroke.
- It keeps the valve face in perfect alignment with the valve seat.

Valve guides may be cast integrally with the head, or they may be removable (fig. 3-52). Removable guides are press-fit into the cylinder head.

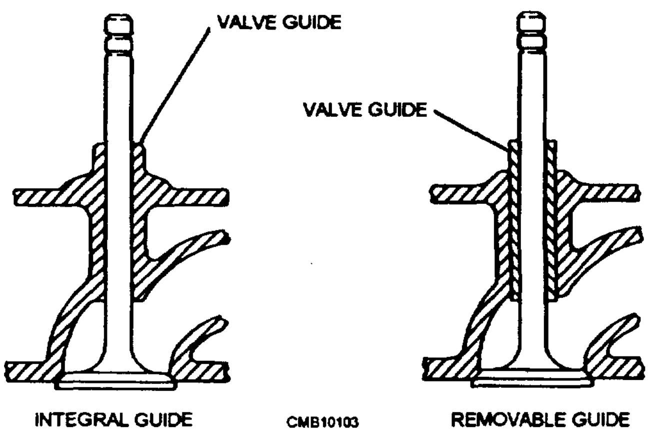


Figure 3-52.—Valve guides.

Valve Springs, Retainers, Seals, and Valve Rotators

The valve assembly is completed by the spring, the retainer, the seal, and the valve rotator (fig. 3-53). The spring, which keeps the valve in a normally closed position, is basically the same for all engines; however, the number and types of coils can vary. Most valves have only one spring, but, in some cases, there may be two—an inner spring and an outer spring. The second spring increases the pressure holding the valve closed. Low-spring tension can cause **valve float** (spring too weak to close the valve at high rpm).

A valve retainer and keepers lock the valve spring on the valve. The retainer is a specially shaped washer that fits over the top of the valve spring. The keepers, or locks, fit into the valve stem grooves, holding the retainer and spring in place.

The seal keeps the valve operating mechanism oil from running down the valve stem and into the combustion chamber. Valve seals come in two basic types—umbrella and O ring. Both are common on modern engines. The umbrella valve seal is shaped like a cup and can be made of neoprene plastic or rubber. An umbrella valve seal slides down over the valve stem before the spring and retainer. It covers the small

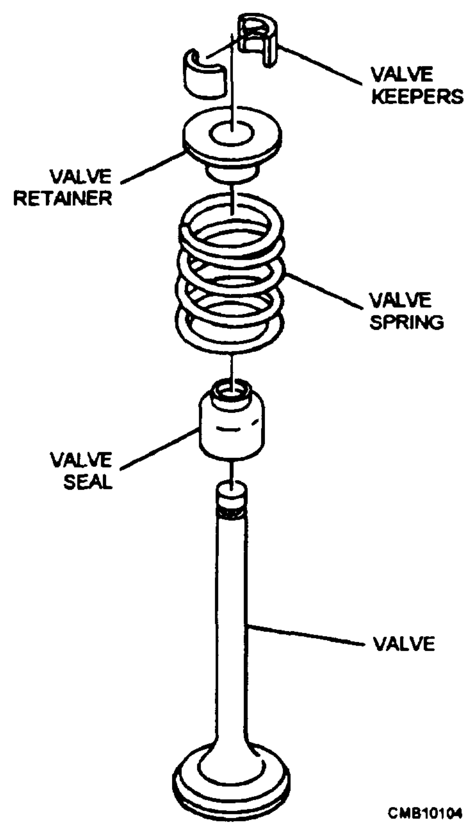


Figure 3-53.—Valve spring, retainer, and seal.

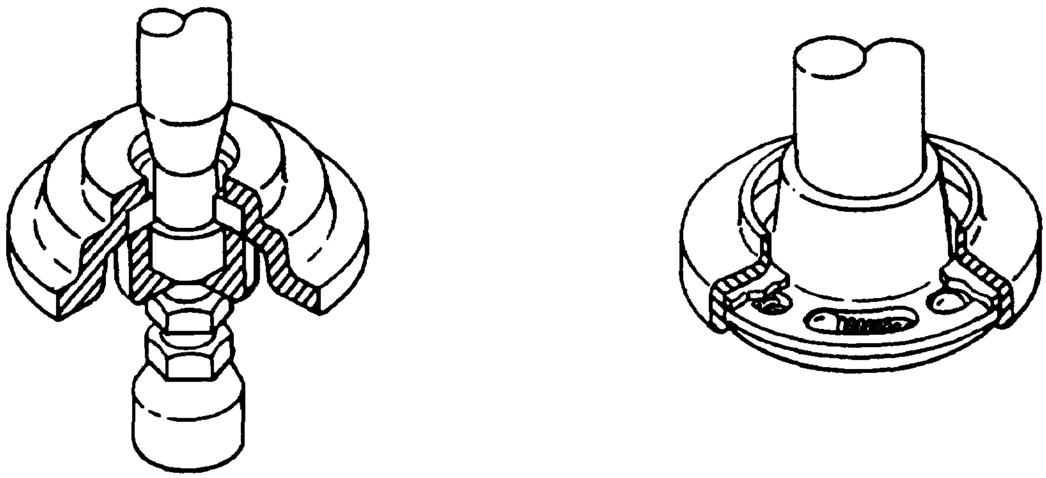


Figure 3-54.—Valve rotators.

clearance between the valve stem and guide. The O ring is a small, round seal that fits into an extra groove cut into the valve stem. It fits on the valve stem after the spring and retainer. Unlike the umbrella type, it seals the gap between the retainer and the valve stem, not the guide and stem. It stops oil from flowing through the retainer down the stem and into the guide.

A valve rotator (fig. 3-54) turns the valve to prevent a carbon buildup and hot spots on the valve face. There are two types of retainers—the release type and the positive type. The release type of rotator releases the spring tension from the valve while open; this allows the valve to rotate from engine vibration The positive rotator is a two-piece valve retainer with a flexible washer between the two pieces. A series of balls between the retainer pieces roll on machined ramps, as pressure is applied and released from the opening and closing of the valve. The movement of the balls up and down the ramps translates into rotations of the valve.

Reconditioning Valves

Valve reconditioning includes grinding valves and valve seats, adjusting valve tappet clearances, installing new valve seat inserts, and timing the valves. Together, these operations constitute the **VALVE SERVICE** necessary for smooth engine performance and maximum power output.

To recondition valves and valve seats, first remove the cylinder head from the engine. Once the cylinder head is off, remove the carbon from the head, the cylinder block, and the pistons. In cleaning the top of the piston, you must exercise care to prevent gouging and scratching, as rough spots collect carbon readily and lead to preignition and detonation during operation. Remove the valves using a valve spring compressor. Next, clean the valves with a wire brush or buffing wheel (fig. 3-55). When the buffing wheel is being used, make sure you wear proper eye protection to prevent wire and other foreign matter from flying into your eyes.

Be careful not to interchange the valves. Bach valve must be replaced in the same valve port from which it was removed. The valve stem moving up and down in the valve guide develops a wear pattern. And, if the valves are interchanged, a new wear pattern is developed. This causes excessive wear on the valve stem and guide.

To eliminate confusion, you should devise a system to identify a valve with the cylinder from which it was taken. The most common way to identify valves is to

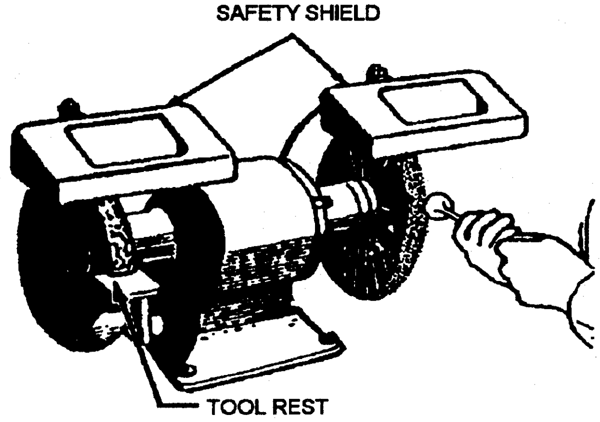


Figure 3-55.—Cleaning a valve with a wire buffing wheel.

place them on a piece of board with holes drilled and numbered to correspond with the cylinder each valve came from.

The next step is to resurface the valve face. This is done by using a valve grinding or refacing machine. **VALVE GRINDING** is done by machining a fresh, smooth surface on the face and stem tips. Valve faces suffer from burning, pitting, and wear caused by opening and closing millions of times during the service life of the engine. Valve stem tips wear because of friction from the rocker arms.

Although there are some variations in design, most valve grinding machines (fig. 3-56) are basically the same. They use a grinding stone and a precision chuck to remove a thin layer of metal from the valve and stem tip. The following steps are used in preparing to reface a valve:

- **DRESS THE STONE** by using a diamond cutter to true stone surface (fig. 3-57). Do this before grinding the valves. A diamond-tipped cutting attachment is provided with the machine for truing the stone. Follow the equipment manufacturer's instructions for that specific piece equipment.

CAUTION

Be careful when using a diamond tool to dress a stone. Wear eye protection and feed the diamond into the stone **SLOWLY.** If fed too fast, tool or stone breakage may result.

- **SET THE CHUCK ANGLE** by rotating the valve grinding machine chuck assembly. An **interference angle** (normally 1 degree difference in valve face angle and valve seat angle) is set on the machine. If the valve seat is 45 degrees, the chuck is set to 44 degrees. This allows for reduced break-in and sealing time.

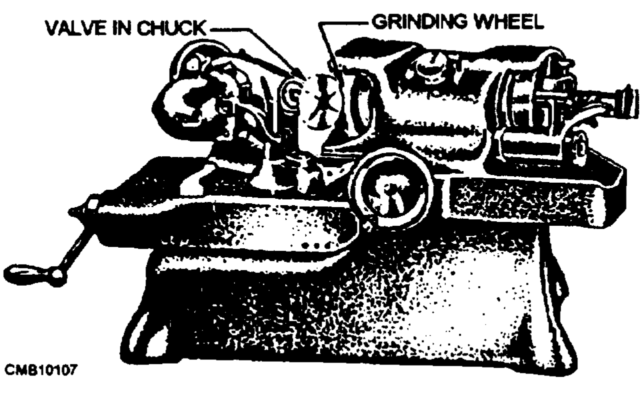


Figure 3-56.—Valve-refacing machine.

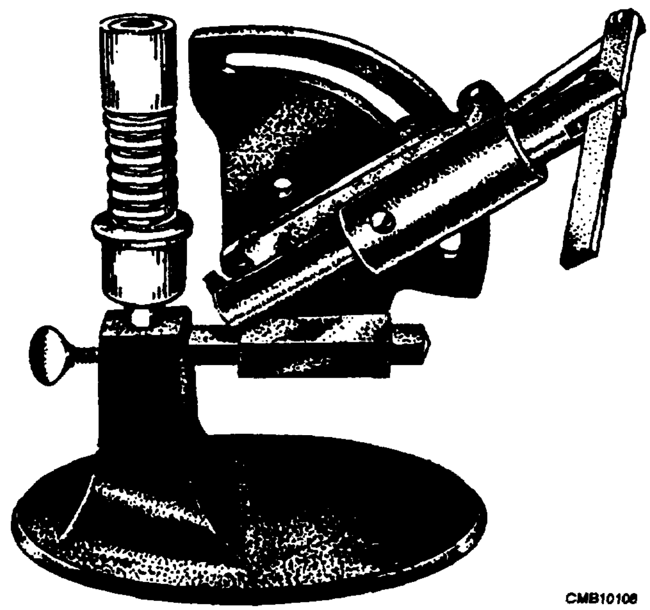


Figure 3-57.—Stone dresser.

- **CHUCK THE VALVE** in the valve grinding machine by inserting the valve stem into the chuck Make sure the stem is inserted so the chuck grasps the machine surface nearest the valve head.

WARNING

The chuck must **NOT** clamp onto an unmachined surface or runout will occur.

Before grinding, inspect each valve face for burning and each stem for wear. Replace valves that are badly worn or burned. Grind a new valve along with the old, used valves.

WARNING

Wear a face shield when grinding valves. The stone could shatter, throwing debris into your face.

To grind the valve face, turn on the machine and cooling fluid **SLOWLY** feed the valve into the stone. While feeding, slowly move the valve back and forth in front of the stone. Use the full face of the stone but do **NOT** let the valve face move out of contact with the stone while cutting. Grind the valve only long enough to clean up its face. When the full valve face looks shiny with no darken pits, shut the machine off and inspect the face.

Grinding, by removing metal from the face, makes the valve stem extend through the head more. This affects spring tension and rocker-arm geometry. Grind the face of the valve as little as possible. A **sharp valve margin** (fig. 3-58) indicates excessive valve face removal and requires valve replacement. If the margin is too thin, the valve can burn when returned to service. It may not be thick enough to dissipate heat fast enough. The head of the valve can actually begin to melt, burn, and blow out the exhaust port. Refer to the manufacturer's manual for specifications about minimum valve margin of thickness.

If the head of the valve wobbles as it turns on the valve grinding machine, the valve is either bent or chucked improperly. Turn off the machine and check for causes. If the valve is bent, replace it with a new one.

If a burned valve is not noticed during initial inspection, it will show up when excess grinding is required to clean up the valve face. A normal amount of grinding does not remove a deep pit or groove. Replace the valve if it is burned.

Another area on the valve that must be attended to is the valve stem. This is due to wear from the valve operating mechanisms. When the tip end of the valve stems is rough, smooth them by grinding lightly with a special attachment furnished with the valve grinding machine. Grind as little off the stem as possible. Many stems are hardened and too much grinding results in rapid wear when the valve is returned to service. Generally, cut the same amount of metal off the face and stem. This helps to keep the valve train geometry correct.

Valve Guide Service

Servicing of valve guides is an important, but often neglected, part of a good valve job. The guide must be clean and in good condition before a good valve seat can be made. Valve guide wear is a common problem; it allows the valve to move sideways in its guide during operation. This can cause oil consumption (oil leaks past the valve seal and through the guide), burned valves (poor seat to valve face seal), or valve breakage.

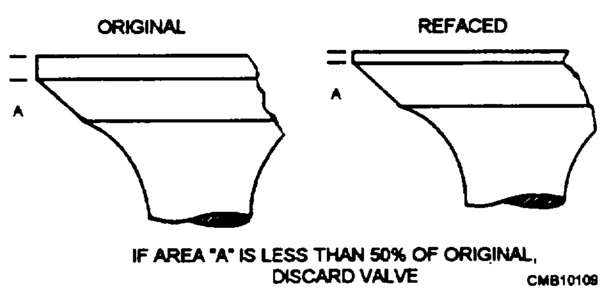


Figure 3-58.—Proper valve margin of thickness after refacing.

There are several satisfactory methods of checking for valve guide wear. One procedure for checking valve guide wear is to slide the valve into its guide. Full it open approximately 1/2 inch, then try and wiggle the valve sideways. If the valve moves sideways in any direction, the guide or stem is worn Another checking procedure involves the use of a small hole gauge to measure the inside of the guide and a micrometer to measure the valve stem; the difference in the readings is the clearance. Check the manufacturer's manual for the maximum allowable clearance. When the maximum clearance is exceeded the valve guide needs further servicing before you proceed with the rest of the job.

Servicing procedures depend on whether the guide is of the integral or replaceable type. If it is the integral type, it must be reamed to a larger size and a valve with an oversize stem installed. But if it is replaceable, it should be removed and a new guide installed

KNURLING of the valve guides has become more popular as a method of compensating for wear of the valve guides. Knurling is accomplished by attaching a special tool to an electric drill and inserting the tool in the worn guide. This method is not recommended if the guide has been worn excessively or knurled previously.

Valve guides should be removed and replaced with special drivers (fig. 3-59). When working on a valve in the cylinder head of an engine, you may use an arbor press to remove and replace the valve guides.

After the valve guides are serviced and the valve seats are ground, check the concentricity of the two with a valve seat dial indicator (fig. 3-60). Any irregularity in the seat will register on this dial.

Valve Seat Service

Valve seat service requires either replacement of the seat or reconditioning of the seat by grinding or cutting. Valve seat replacement is required when a valve seat is cracked, burned, or recessed (sunk) in the cylinder head Normally, valve seats can be machined and returned to service.

To remove a replaceable pressed-in seat, split the old seat with a sharp chisel. Then pry out the old seat. New seat inserts should be chilled in dry ice for about 15 minutes to shrink them, so they can be driven into place easily. The seat expands when returned to room temperature, which locks the seat in place.

In most cases, the valve seats are not replaceable, so they must be ground (fig. 3-61). Before operating the valve seat grinding equipment in your shop, be sure to study the manufacturer's manual for specific

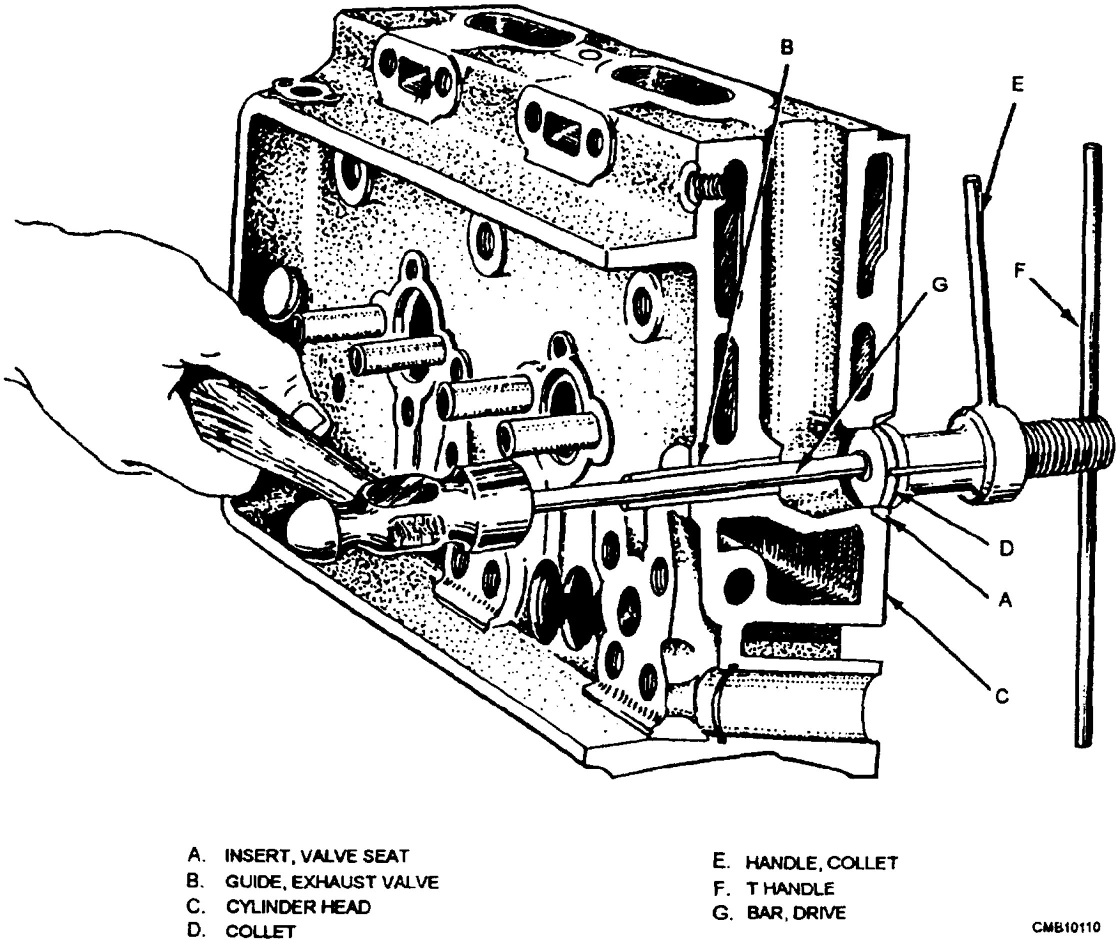


Figure 3-59.—Puller used in removing valve seat inserts.

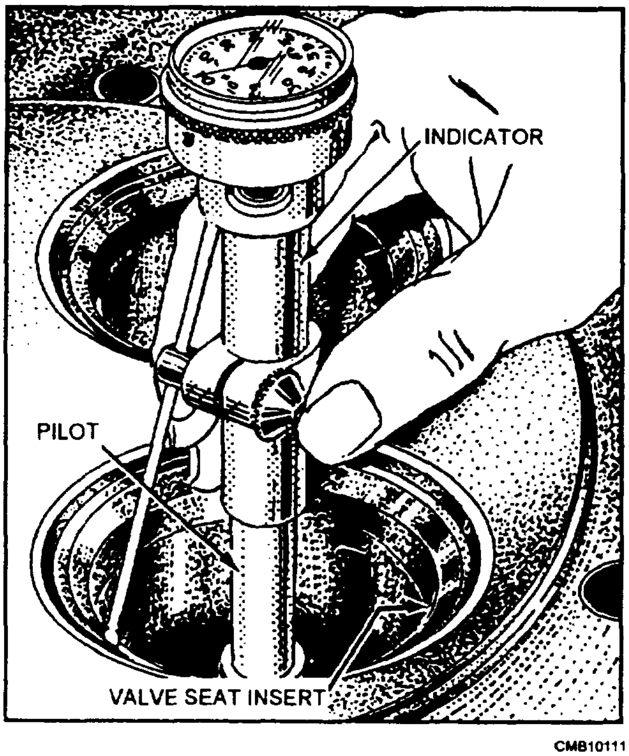


Figure 3-60.—Determining concentricity of the valve seat with a valve seat dial indicator.

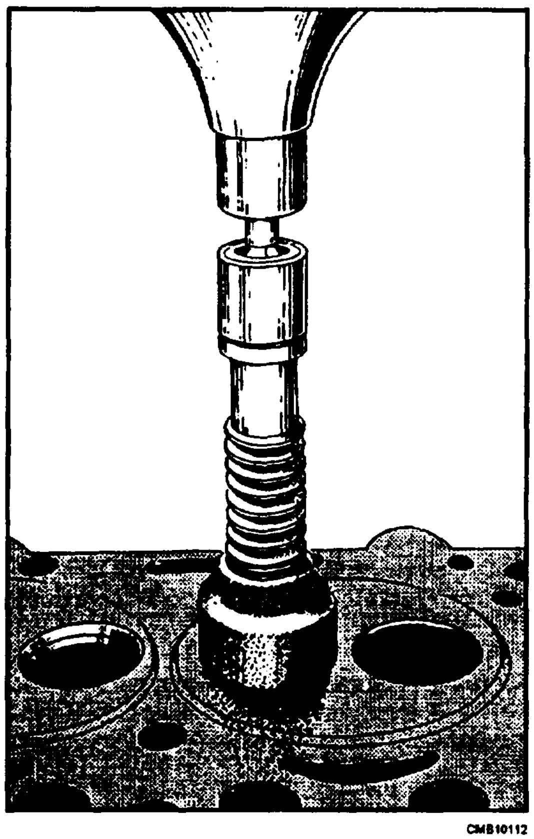


Figure 3-61.—Grinding valve seats using a concentric type of grinder.

Figure 3-62.—Self-centering pilot.

instructions. The following procedures are typical for grinding valve seats:

- Select and install the correct size pilot (metal shaft that fits into the guide and supports cutting stone or carbide cutter) (fig. 3-62). The pilot should fit snugly in the valve guide and not wiggle.

- Select the correct stone for the valve seat. It must be slightly larger in diameter than the seat and must have the correct face angle. Slip the stone-and-sleeve assembly over the pilot.

- Insert the power head into the sleeve assembly. Support the weight of the power head. Grind only long enough to clean up pits in the seat. Check the progress often to ensure that you do not remove more material than necessary to get a good seat.

After grinding valve seats, it is recommended that you lap the contact surfaces of the valve and valve seat. Lapping valves are done to check the location of the valve-to-seat contact point and to smooth the mating surfaces.

To lap the valve, dab grinding compound (abrasive paste) on the valve face. Install the valve into the cylinder head and rotate with a lapping stick (a wooden stick with a rubber plunger for holding the valve head). Rub your hands back and forth on the lapping stick to spin the valve on its seat. This rubs the grinding compound between the valve face and the seat. Remove the valve and check the contact point. A dull gray stripe around the seat and face of the valve indicates the valve-to-seat contact point. This helps you narrow or move the valve seat. A few manufacturers do **NOT** recommend valve lapping. Refer to the manufacturer's service manual for details.

WARNING

Make sure you clean all of the valve grinding compound off the valve and cylinder head. The compound can cause rapid part wear.

Another way to check valve-to-seat contact is by spreading a thin coat of prussian blue on the valve face or putting lead pencil marks on the valve seat. If, when turning the valve on its seat, an even deposit of coloring

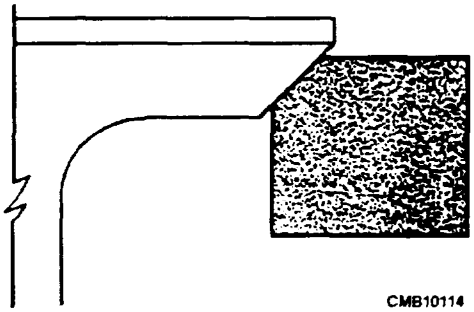


Figure 3-63.—Normal valve seat.

is seen on the valve seat or the pencil lines are removed, the seating is perfect. The valve should **NOT** be rotated more than one-eighth turn as a high spot could give a false indication if turned one full revolution.

Figure 3-63 shows a normal valve seat. This will vary according to the manufacturer's specification. The seat should touch near the center of the valve face with the correct contact width. Typically, an intake valve should have a valve-to-seat contact width of about 1/16 of an inch. An exhaust valve should have a valve-to-seat contact width of approximately 3/32 of an inch. Check the manufacturer's service manual for exact values.

When the valve seat does **NOT** touch the valve face properly (wrong width or location on the valve) (fig. 3-64), regrind the seat using different angles, usually 15-degree and 60-degree stones. This is known as narrowing or positioning a valve (fig. 3-65).

To move the seat in and narrow it, grind the valve seat with a 15-degree stone. This removes metal from around the top of the seat. The seat face moves closer to the valve stem.

To move the seat out and narrow it, grind the valve seat with a 60-degree stone. This cuts away metal from the inner edge of the seat. The seat contact point moves toward the margin *or* outer edge of the valve.

Rocker Arm Service

After disassembling the rocker arms, you should inspect them for wear, clogged oil holes, and damage.

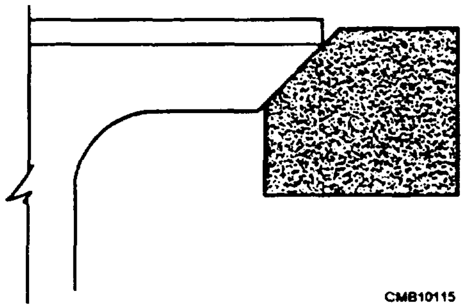


Figure 3-64.—Incorrect valve-to-seat contact.

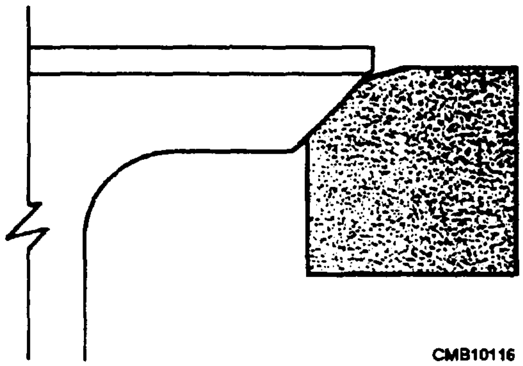


Figure 3-65.—Correct valve-to-seat contact after narrowing.

When wear is indicated inside the rocker bore, you can measure it with a telescoping gauge and a micrometer or a bore gauge. Rocker arms with bushings can be rebushed if the old bushing is worn On some rocker arms, worn valve ends can be ground down on the valve grinding machine. Excessively worn rocker arms should be replaced.

Also, inspect the rocker arm shaft for wear. A worn rocker arm shaft has indentions where the rocker arms swivel on the shaft. Wear on the shaft is usually greater on the bottom. Using a micrometer, check the shaft to determine whether wear is within the manufacturer's specifications.

When reinstalling rocker arms and shafts in the cylinder head, make sure that the oil holes (in the shaft if so equipped) are on the underside, so they can feed oil to the rocker arms. Ensure that all spring and rocker arms are restored to their original positions as you attach the shafts to the head.

Valve Spring Service

After prolonged use, valve springs tend to weaken, lose tension, or even break. During engine service, always test valve springs to make sure they are usable. Valve springs should be tested for uniformity and strength. The three characteristics to check are valve spring squareness, valve spring free height, and valve spring tension.

Valve spring squareness is easily checked with a combination square. Place each spring next to the square on a flat surface. Rotate the spring while checking for a gap between the side of the spring and the square. Replace any spring that is not square.

Valve spring free height can also be measured with a combination square or a valve spring tester. Simply measure the length of each spring in normal uncompressed condition. If it is too long or too short, replace the spring.

Valve spring tension, or pressure, is measured by using a spring tester. Compress the spring to specification height and read the scale on the tester. Spring pressure must be within specifications. If the reading is too low, the spring has weakened and must be replaced.

TIMING GEARS (GEAR TRAINS)

Because the crankshaft must rotate twice as fast as the camshaft, the drive member on the crankshaft must be exactly one half as large as the driven member on the camshaft So for the camshaft and crankshaft to work together, they must be in time with each other. This initial position between the two shafts is designated by marks that are called **timing marks.** To obtain the correct initial relationship of the components, align the corresponding marks at the time of assembly. Timing gears keep the crankshaft and the camshaft turning in proper relation to one another, so the valves open and close at the proper time. This is accomplished by gear-drive, chain-drive, or belt-drive gear trains (fig. 3-66).

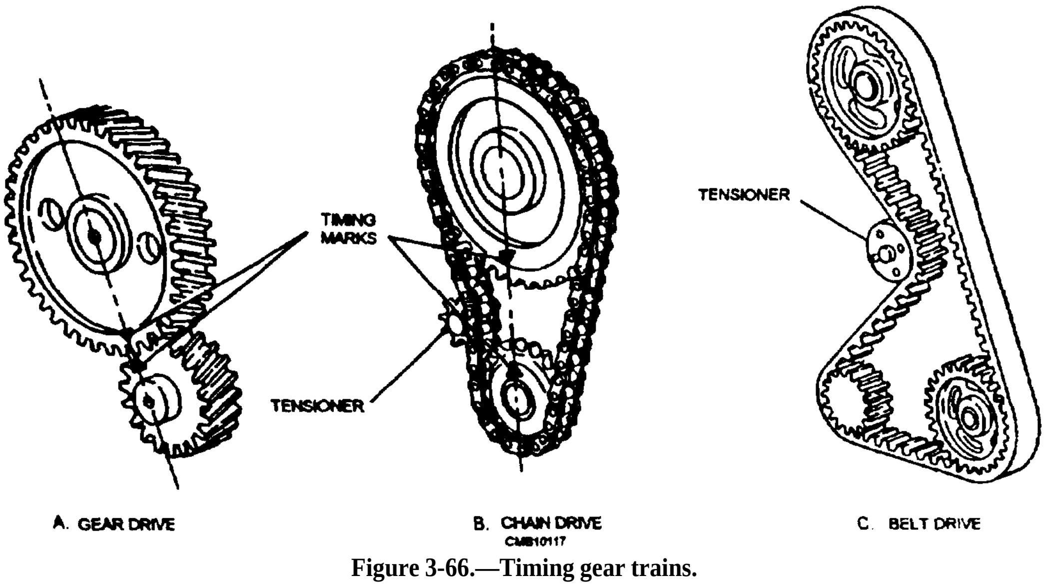


Figure 3-66.—Timing gear trains.

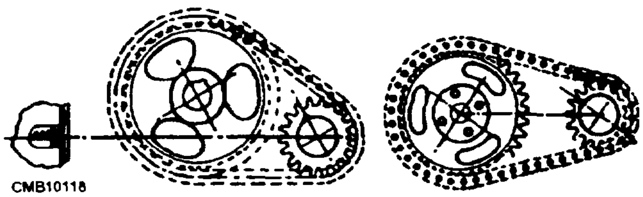


Figure 3-67.—Methods of valve timing with a chain drive.

In a gear drive setup (fig. 3-66), the timing gear on the crankshaft meshes directly with the gear on the camshaft. Timing gears are commonly used on heavy-duty applications due to their dependability; however, they are noisier than a chain or belt drive. Since they are keyed to their respective shafts, they can be replaced if they become worn. With directly driven gears, one gear usually has a mark on two adjacent teeth and the other mark on only one tooth. To time the valve properly, mesh the gears so the two marked teeth of one gear straddle the single marked tooth of the other.

A timing chain and sprockets can also be used to turn the camshaft (fig. 3-66). This is the most common type of gear train. There are two types of timing chains. One is a silent link type that is used in standard and light-duty applications. The other is the roller-link chain, which is used in heavy-duty applications. Like timing gears, the chain sprockets have timing marks. The correct timing may be obtained by hating a certain number of chain-link teeth between the marks or by lining up the marks with a straightedge, as shown in figure 3-67.

In a belt drive gear train, the sprockets on the crankshaft and the camshaft are linked by a continuous neoprene belt (fig. 3-66). The belt has square-shaped internal teeth that mesh with the teeth on the sprockets. The timing belt is reinforced with nylon or fiber glass to give it strength and prevent it from stretching. This drive configuration is limited to overhead camshaft engines.

Most engines with a chain drive and all belt-driven engines use a tensioner. The tensioner pushes against the belt or chain to keep it tight. This serves to keep it from slipping on the sprockets. This provides more precise valve timing and compensates for component wear and stretch. Engines with a belt drive usually use a spring-loaded idler wheel. Engines with a chain drive use a fiber-rubbing block that is either spring loaded or hydraulic.

NOTE

Always check the manufacturer's service manual when you are in doubt about the method of timing used for the engine you are overhauling.

ENGINE BEARINGS

Bearings are installed in an engine where there is relative motion between parts. Engine bearings are called sleeve bearings because they are in the shape of a

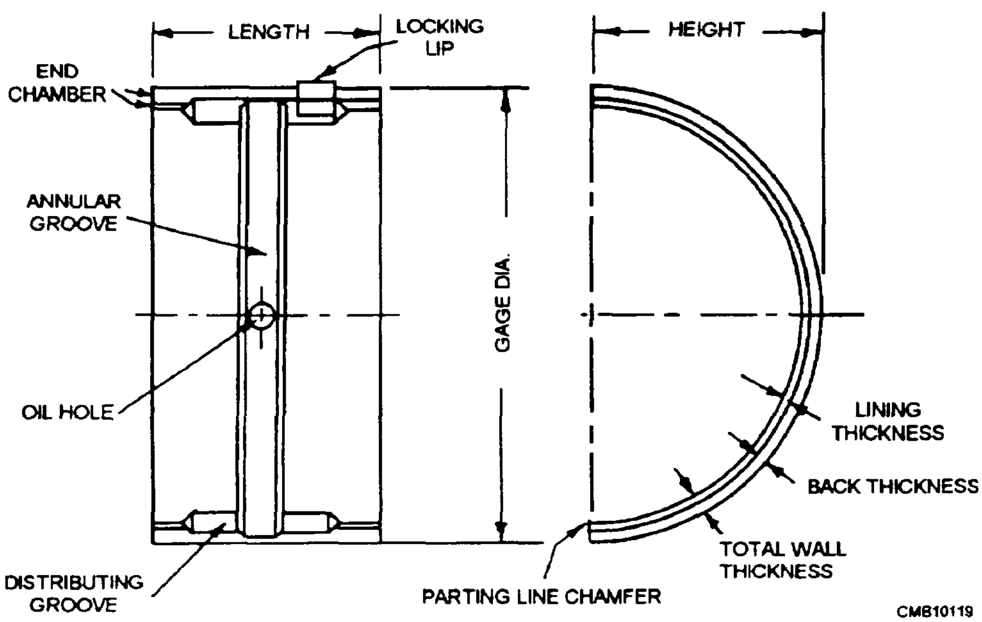


Figure 3-68.—Typical sleeve-type bearing half.

sleeve that fits around the rotating journal or shaft (fig. 3-68). Connecting rod or camshaft (main) bearings are of the split or half type (fig. 3-69). On main bearings, the upper half is installed in the counterbore in the cylinder block. The lower-bearing half is held in place by the bearing cap (fig. 3-70). On connecting rod bearings, the upper-bearing half is installed in the rod and the lower half is placed in the rod cap. The piston pin bearing in the connecting rod is of the full round or bushing type.

Bearing Lubrication

The lubrication of bearings is very important to engine service life because it forces oil to high friction points within the engine. Without lubrication between parts, bearings overheat and score from friction.

The journal or shaft must be smaller in diameter than the bearing (fig. 3-71), so there is clearance (called oil clearance) between the two parts; oil circulates through the clearance. The oil enters through the oil hole (fig. 3-66) and fills the oil groove in the bearing. From there, the rotating journal carries the oil around to all moving parts of the bearing. The oil works its way to the outer edges of the bearing. From there, it is thrown off and drops back into the oil pan. The oil thrown off helps to lubricate other engine parts, such as the cylinder walls, the pistons, and the piston rings.

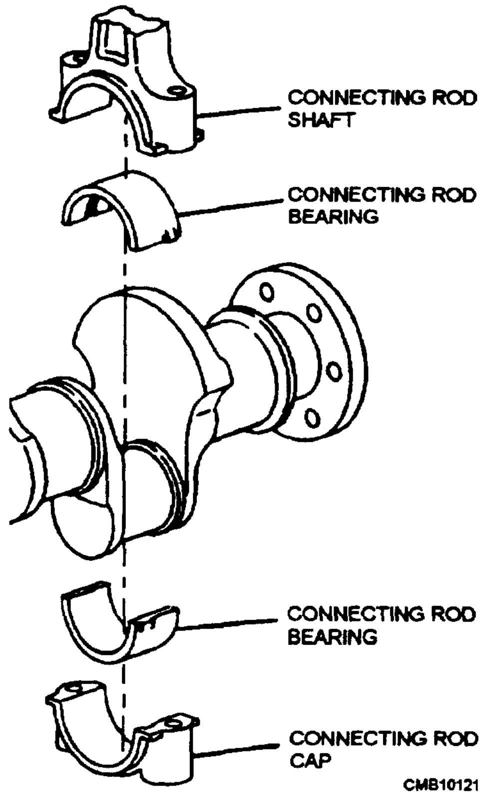


Figure 3-70.—Connecting rod bearings.

As the oil moves across the faces of the bearings, it not only lubricates them but also helps keep them cool. The oil is relatively cool, as it leaves the oil pan. It picks up heat in its passage through the bearing. This heat is

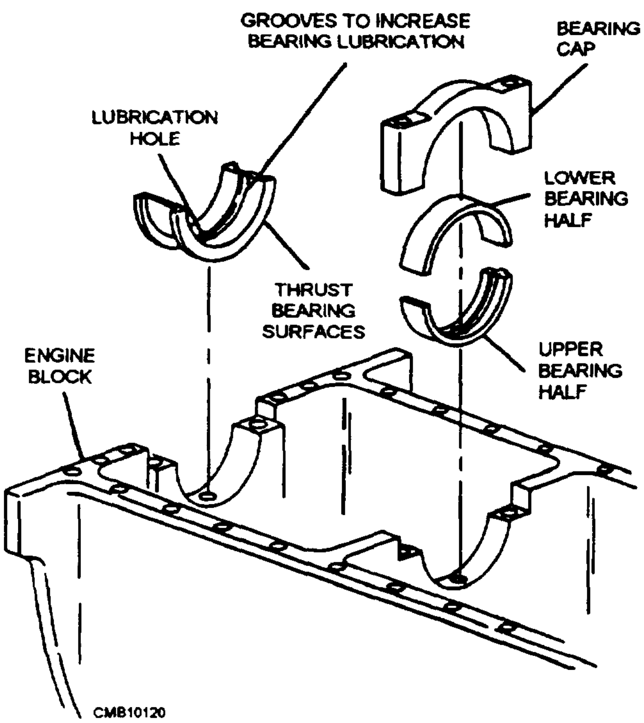


Figure 3-69.—Crankshaft main bearings.

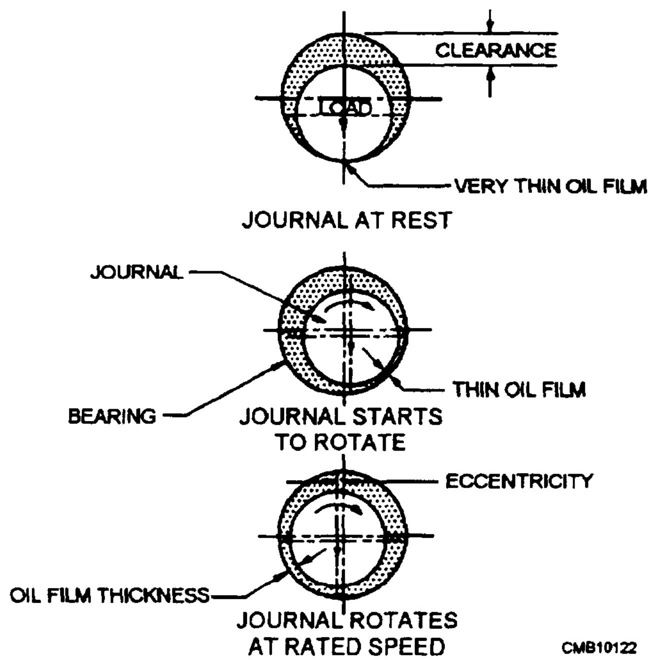


Figure 3-71.—Oil clearance between bearing and shaft.

carried down to the oil pan and released to the air passing around the oil pan. The oil also flushes and cleans the bearings. It tends to flush out particles of grit and dirt that may have worked into the bearing. The particles are carried back to the oil pan by the circulating oil. The particles then drop to the bottom of the oil pan or are removed from the oil by the oil screen or filter.

The greater the oil clearance, the faster the oil flows through the bearing; however, excessive oil clearance causes some bearings to fail from oil starvation. Here's the reason: If oil clearances are excessive, most of the oil passes through the nearest bearings. There is not enough oil for the most distant bearings; these bearings eventually fail from lack of oil. An engine with excessive bearing oil clearance usually has low oil pressure; the oil pump cannot build up normal pressure because of the excessive oil clearance in the bearings.

On the other hand, when the bearings have insufficient oil clearances, there is metal-to-metal contact between the bearings and the journal. Extremely rapid wear and quick failure is the end result. Also, there is not enough throw off for adequate lubrication of cylinder walls, pistons, and rings.

Bearing Characteristics

Engine bearings must operate under tremendous loads, severe temperature variations, abrasive action, and corrosive surroundings. Essential bearing characteristics include the following.

BEARING LOAD STRENGTH is the ability of a bearing to withstand pounding and crushing during engine operations. The piston and rod can produce several TONS of downward force. The bearing must not fatigue, flatten, or split under these loads. If the bearing load resistance is too low, the beating can smash, fail, and spin in its bore. This ruins the bore or the journal.

BEARING CONFORMABILITY is the ability of a bearing to move, shift, conform to variations in shaft alignment, and adjust to imperfections in the surface of the journal. Usually, a soft metal is placed over hard steel. This lets the bearing conform to the defects in the journal.

BEARING EMBEDABILITY refers to the ability of a bearing to permit foreign particles to become embedded in it (fig. 3-72). Dirt and metal are sometimes carried into the bearings. The bearing should allow the particles to sink beneath the surface into the bearing material. This prevents the particles from scratching, wearing, and damaging the surface of the crankshaft or camshaft journals.

BEARING CORROSION RESISTANCE is the ability of a bearing to resist corrosion from acid, water, and other impurities in the engine oil. Combustion blow-by gases cause engine oil contamination that can also corrode engine bearings. Aluminum-lead and other alloys are commonly being used because of their excellent corrosion resistance.

Bearing Materials

As discussed earlier, there are three basic types of engine bearings—connecting rod bearings, crankshaft main bearings, and camshaft bearings. The backing material (body of the bearing that contacts stationary parts) for engine bearings is normally steel. Softer alloys are bonded over the backing to form the bearing surface. Any one of three basic types of metal alloys can be plated over the top of the steel backing—Babbitt (lead-tin alloy), copper, or aluminum (fig. 3-73). These three metals may be used in different combinations to design bearings for either light-, medium-, or heavy-duty applications. The engine designer selects the combination of ingredients that will best suit the engine.

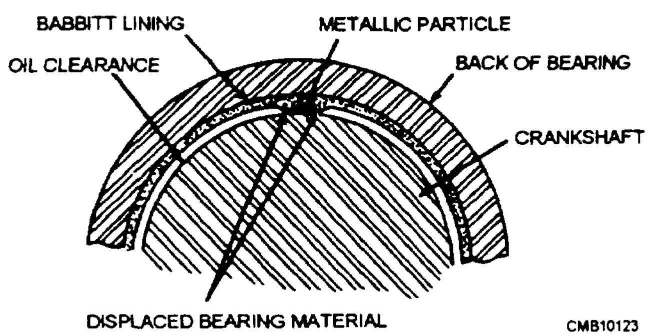


Figure 3-72.—Effect of a metallic particle embedded in bearing material (Babbitt lining).

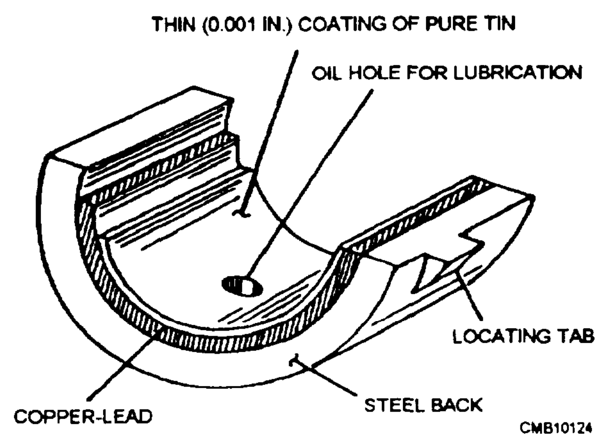


Figure 3-73.—Bearing materials

Q1. What material is commonly used to provide a wearing surface in a liquid-cooled engine for the pistons to ride against?

Q2. What are the two types of cylinder sleeves?

Q3. What are the two types of core hole plugs used in an internal combustion engine?

Q4. What is the basic foundation of all air-cooled engines ?

Q5. A properly made exhaust manifold results in what type of action to help an engine get rid of exhaust gases?

Q6. In an exhaust-heated intake manifold, gases diverted to the manifold are controlled by what valve?

Q7. What two basic types of oil seals are currently being used on engines?

Q8. What ate the structural components of a piston?

Q9. What are the three types of piston pin configurations?

Q1O. What three functions do piston rings serve?

Q11. What part is the backbone of an internal combustion engine?

Q12. The valve actuating mechanism is made up of what engine parts?

Q13. What are the three basic shapes of a poppet-type valve ?

Q14. What type of valve is preferred in a vehicle using unleaded fuel?

Q15. What are the two basic types of valve seals?

Q16. What three characteristics of a valve spring should you check?

ENGINE ADJUSTMENT AND TESTING

LEARNING OBJECTIVE: *Describe The techniques used in adjusting engine valves. Recognize basic engine testing procedures and required tools.*

Proper and uniform valve adjustments are required for a smooth running engine. Unless the clearance between the valve stems and rocker arms or valve lifters is adjusted according to the manufacturer's specifications, a valve does not open and close at the proper time, and engine performance is affected.

In most shops, the Navy provides accurate and dependable testing equipment. But having the testing equipment in the shop is **NOT** enough. The supervisor and crew must know how to use this equipment properly since it provides the quickest and surest means of determining what is wrong and where the fault lies.

VALVE ADJUSTMENT

Valve adjustment, also called tappet clearance adjustment or rocker adjustment, is critical to the performance and service life of an engine. If the valve train is too loose (too much clearance), it can cause valve train noise (tapping or clattering noise from the rocker striking the valve stems). This can increase part wear and cause part breakage. Valves that are adjusted too tight (inadequate clearance) may be held open or may not close completely. This can allow combustion heat to blow over and burn the valve.

When reassembling an engine after reconditioning the valves, make sure the adjusting screws are backed off before rotating the engine. A valve that is too tight could strike the piston and damage either the piston or the valve, or both. Adjust the valve according to manufacturer's specifications, following the recommended procedure.

On any engine, after valve adjustments have been made, be sure that the adjustment locks are tight and that the valve mechanism covers and gaskets are in place and fastened securely to prevent oil leaks.

Overhead Valves

Most overhead valves are adjusted **"HOT";** that is, valve clearance recommendations are given for an engine at operating temperature. Before valve adjustments can be made properly, the engine must be run and brought up to normal operating temperature.

To adjust a valve, remove the valve cover and measure the clearance between the valve stem and the rocker arm. Loosen the locknut and turn the adjusting screw in the rocker arm, as shown in figure 3-74. On engines with stud-mounted rocker arms, make the adjustment by turning the stud nut.

Valves in Block

This type of valve arrangement is not commonly seen in the field; however, the adjustment procedure is described in case you should happen to run across this type.

Valves within the block are adjusted **"COLD";** that is, recommended valve clearances are provided for a cold engine. These valves have mechanisms quite similar to overhead valves. They are adjusted by removing the side cover plate beneath the intake manifold on the side of the engine block (fig. 3-75). Since you must stop the engine to adjust the valves, the piston in the cylinder must be on TDC of the compression stroke. You can determine this by watching the valves of the piston that is paired with the one that is being set. As the cylinder that is being positioned is coming up on the compression stroke, the paired cylinder is coming up on the exhaust stroke; therefore, the exhaust valve is open. Just as the exhaust valve closed and the intake valve begins to open, the cylinder to be set is on TDC of the compression stroke, and you can set the two valves. Once the No. 1 cylinder is positioned, follow through according to the firing order of the engine, as this makes the job easier and faster. You may also use this procedure when adjusting valves on overhead engines.

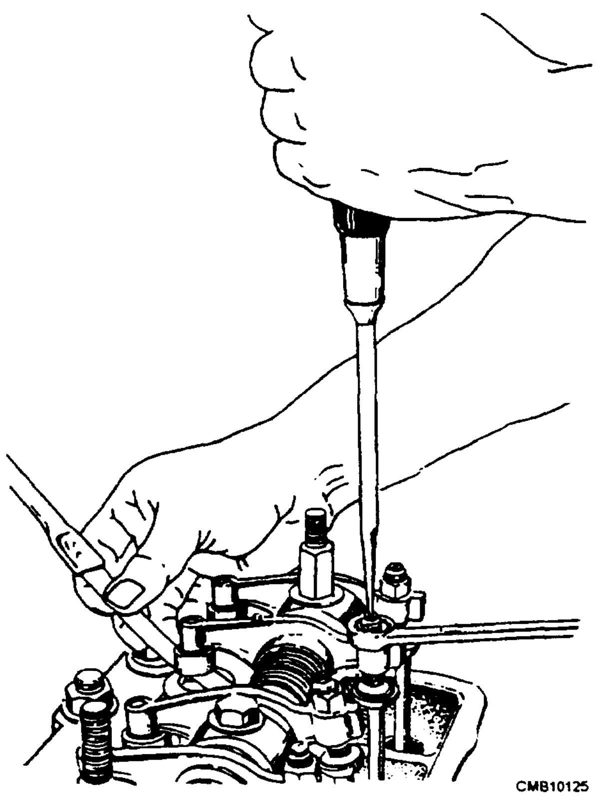


Figure 3-74.—Adjusting overhead valves.

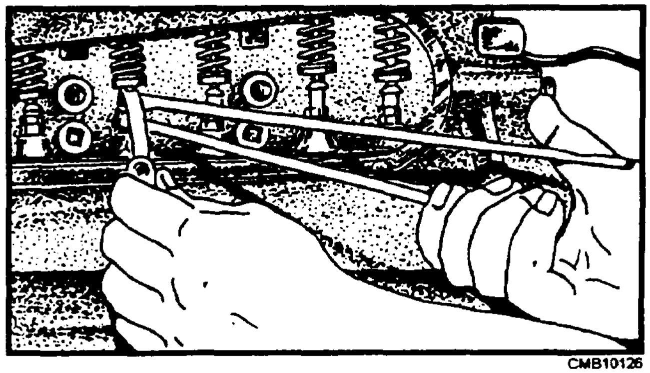


Figure 3-75.—Adjusting valve in block.

Hydraulically Operated Valves

On engines with hydraulic valve lifters, it is not necessary to adjust the valve periodically. The engine lubrication system supplies a flow of oil to the lifters at all times. These hydraulic lifters operate at zero clearance and compensate for changes in engine temperature, adapt automatically for minor wear at various points, and provide ideal valve timing.

To adjust hydraulic lifters with the engine off, turn the crankshaft until the lifter is on the camshaft base circle (not the lobe). The valve must be fully closed. Loosen the adjusting nut until you can wiggle the pushrod up and down. Then slowly tighten the rocker until all play is out of the valve train (cannot wiggle pushrod). Repeat the adjusting procedure on the other rockers.

To adjust hydraulic lifters with the engine running, install a special oil shroud or some other device for catching oil spray off the rocker. Start and run the engine until it reaches operating temperature. Tighten all rockers until they are quiet. One at a time, loosen a rocker until it clatters. Then tighten the rocker slowly until it quiets down. This is zero valve lash.

OHC Engine Valves

There are several different methods of adjusting the valves on an overhead cam (OHC) engine. Many are adjusted like mechanical lifters in a pushrod engine. The rocker arm adjuster is turned until the correct size feeler gauge fits between the rocker or cam lobe and the valve stem.

Valve adjusting shims may also be used on OHC engines for the cam-to-valve clearance. To determine whether shims are required, measure the valve clearance with a feeler gauge. Then, if needed remove or change the shim thickness as necessary.

Other OHC engines have an Allen adjusting screw in the cam followers. Turning the screw changes the valve clearance. Always refer to the manufacturer's manual for detailed instructions.

COMPRESSION TEST

A compression test is one of the most common methods for determining the mechanical condition of an engine. It should be done when symptoms (engine miss, rough idle, puffing noise in induction or exhaust) point to major engine problems. Measure compression pressures of all cylinders with a compression gauge (fig. 3-76). Then compare them with each other and with the manufacturer's specifications for a new engine. This provides an accurate indication of engine condition.

When gauge pressure is lower than normal, pressure is leaking out of the combustion chamber. Low engine compression can be caused by the following conditions:

- **BURNED VALVE** (valve face damaged by combustion heat).
- **BURNED VALVED SEAT** (cylinder head seat damaged by combustion).
- **PHYSICAL ENGINE DAMAGE** (hole in piston, broken valve, etc.).
- **BLOWN HEAD GASKET** (head gasket ruptured).

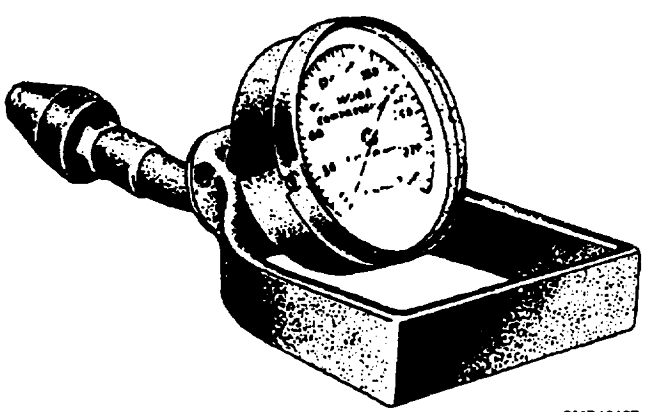


Figure 3-76.—Cylinder compression tester.

- **WORN RINGS OR CYLINDERS** (part wear that prevents a ring-to-cylinder seal).
- **VALVE TRAIN TROUBLES** (valve adjusted with insufficient clearance. This keeps the valve from fully closing. Also, broken valve spring, seal, or retainer).
- **JUMPED TIMING CHAIN OR BELT** (loose or worn chain or belt has jumped over teeth, upsetting valve timing).

To perform a compression test on a gasoline engine, use the following procedures:

- Remove all spark plugs so the engine can rotate easily. Block open the carburetor or fuel injection pump throttle plate. This prevents restricted air flow into the engine.
- Disable the ignition system to prevent sparks from arcing out of the disconnected spark plug wires. Usually, the feed wire going to the ignition coil can be removed to disable the system.
- If the engine is equipped with electronic fuel injection, it should also be disabled to prevent fuel from spraying into the engine. Check the manufacturer's manual for specific directions.
- Screw the compression gauge into one of the spark plug holes. Some gauges have a tapered rubber-end plug and must be held by hand securely in the spark plug opening until the highest reading is obtained.
- Crank the engine and let the engine rotate for about four to six compression strokes (compression gauge needle moves four to six times). Write down the gauge readings for each cylinder and compare them to the manufacturer's specifications.

The compression test for a diesel engine is similar to that of a gasoline engine; however, do not use the compression gauge intended for a gasoline engine. It can be damaged by the high-compression-stroke pressure. A diesel gauge must be used that reads up to approximately 600 psi.

To perform a diesel compression test, use the following procedures:

- Remove all injectors or glow plugs. Refer to the manufacturer's manual for instructions.

- Install the compression gauge in the recommended opening. A heat shield must be used to seal the gauge when it is installed in place of the injector.
- Disconnect the fuel shut-off solenoid to disable the fuel injection pump.
- Crank the engine and note the highest reading on the gauge.

A wet compression test should be used when cylinder pressure reads below the manufacturer's specifications. It helps you to determine what engine parts are causing the problem. Pour approximately 1 tablespoon of 30-weight motor oil into the cylinder through the spark plug or injector opening, then retest the compression pressure.

If the compression reading *GOES UP* with oil in the cylinder, the piston rings and cylinders may be worn and leaking pressure. The oil will temporarily coat and seal bad compression rings to increase pressure; however, if the compression reading *STAYS ABOUT THE SAME,* then engine valves or head gaskets may be leaking. The engine oil seals the rings, but does **NOT** seal a burned valve or a blown head gasket. In this way, a wet compression test helps diagnose low-compression problems.

Do **NOT** put too much oil into the cylinder during a wet compression test or a false reading may result. With excessive oil in the cylinder, compression readings go up even if the compression rings and cylinders are in good condition.

NOTE

Some manufacturers warn against performing a wet compression test on diesel engines. If too much oil is squirted into the cylinder, hydraulic lock and part damage may result, because oil does **NOT** compress in the small cylinder volume.

Compression readings for a gasoline engine should run around 125 to 175 psi. The compression should not vary over 15 to 20 psi from the highest to the lowest cylinder. Readings must be within 10 to 15 percent of each other. Diesel engine compression readings average approximately 275 to 400 psi, depending on the design and compression ratio. Compression levels must not vary more than about 10 to 15 percent (30 to 50 psi). Look for cylinder variation during an engine compression check. If some cylinders have normal pressure readings and one or two have low readings, engine performance is reduced. If two adjacent cylinders read low, it might point to a blown head gasket between the two cylinders. If the compression pressure of a cylinder is low for the first few piston strokes and then increases to near normal, a sticking valve is indicated. Indications of valve troubles by compression test may be confirmed by taking vacuum gauge readings.

VACUUM GAUGE TEST

When an engine has an abnormal compression reading, it is likely that the cylinder head must be removed to repair the trouble. Nevertheless, the mechanics should test the vacuum of the engine with a gauge. The vacuum gauge provides a means of testing intake manifold vacuum, cranking vacuum, fuel pump vacuum, and booster pump vacuum. The vacuum gauge does **NOT** replace other test equipment, but rather supplements it and diagnoses engine trouble more conclusively.

Vacuum gauge readings are taken with the engine running and must be accurate to be of any value; therefore, the connection between the gauge and the intake manifold must be leakproof. Also, before the connection is made, see that the openings to the gauge and the intake manifold are free of dirt or other restrictions.

When a test is made at an elevation of 1,000 feet or less, an engine in good condition, idling at a speed of about 550 rpm, should give a steady reading from 17 to 22 inches on the vacuum gauge. The average reading will drop approximately 1 inch of vacuum per 1,000 feet at altitudes of 1,000 feet or higher above sea level.

When the throttle is opened and closed suddenly, the vacuum reading should first drop about 2 inches with the throttle open, and then come back to a high of about 24 inches before settling back to a steady reading as the engine idles, as shown in figure 3-77. This is normal for an engine in good operating condition.

If the gauge reading drops to about 15 inches and remains there, it would indicate compression leaks between the cylinder walls and the piston rings or power loss caused by incorrect ignition timing. A vacuum gauge pointer indicating a steady 10 inches, for example, usually means that valve timing of the engine is incorrect. Below-normal readings that change slowly between two limits, such as 14 and 16 inches, could indicate a number of problems. Among them are improper carburetor idling adjustment, maladjusted or

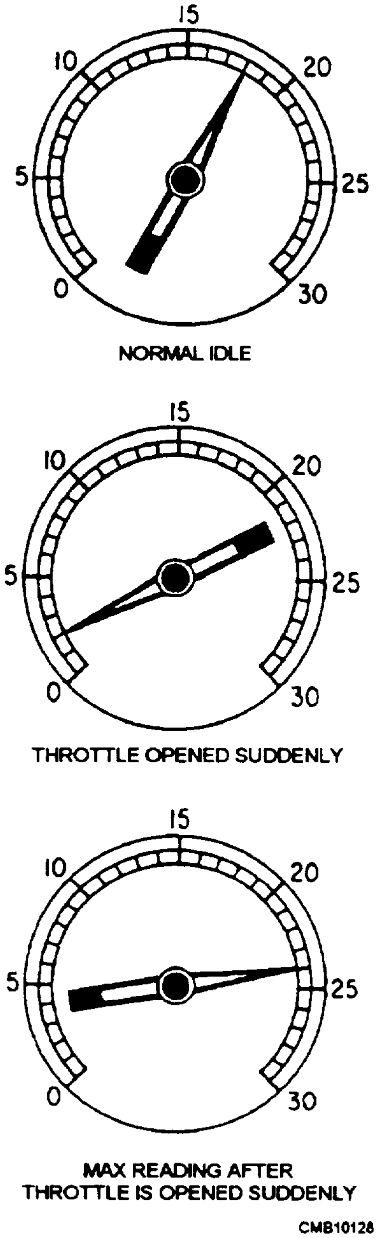


Figure 3-77.—Approximate vacuum gauge readings on a normal operating engine.

burned breaker points, and spark plugs with the electrodes set too closely.

A sticking valve could cause the gauge pointer to bounce from a normal steady reading to a lower reading and then bounce back to normal. A broken or weak valve spring can cause the pointer to swing widely, as the engine is accelerated. A loose intake manifold or leaking gasket between the carburetor and manifold shows a steady low reading on the vacuum gauge.

A vacuum gauge test only helps to locate the trouble. It is not conclusive, but as you gain experience in interpreting the readings, you can usually diagnose engine behavior.

CYLINDER LEAKAGE TEST

Another aid in locating compression leaks is the cylinder leakage tester. The principle involved is that of simulating the compression that develops in the cylinder during operation. Compressed air is introduced into the cylinder through the spark plug or injector hole, and by listening and observing at certain key points, you can make some basic deductions.

The commercial testers, such as the one shown in figure 3-78, have a gauge indicating a percentage of air loss. The gauge is connected to a spring-loaded diaphragm. The source of air is connected to the instrument and counterbalances the action of the spring against the diaphragm. By adjusting the spring tension, you can calibrate the gauge properly against a variety of air pressure sources within a given tolerance.

In making a cylinder leakage test, remove all spark plugs, so each piston can be positioned without the resistance of compression of the remaining cylinders. Next, place the piston at TDC or "rock" position between the compression and power strokes. Then you can introduce the compressed air into the cylinder. Note that the engine tends to spin. Now, by listening at the carburetor, the exhaust pipe, and the oil filler pipe (crankcase), and by observing the coolant in the radiator, when applicable, you can pinpoint the area of

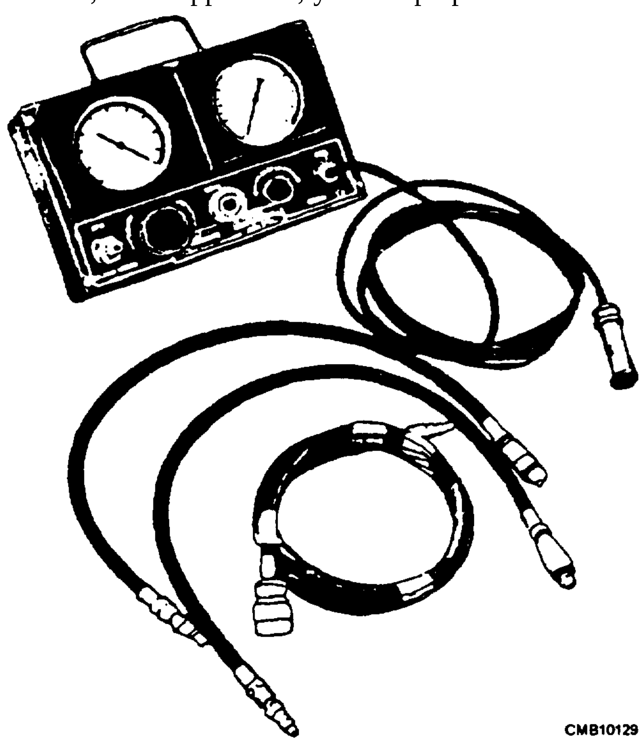


Figure 3-78.—Cylinder leakage tester.

air loss. Aloud hissing of air at the carburetor indicates a leaking intake valve, or valves. Excessive hissing of air at the oil filler tube (crankcase) indicates an excessive air leak past the piston rings. Bubbles observed in the coolant at the radiator indicates a leaking head gasket

As in vacuum testing, indications are not conclusive. For instance, a leaking head gasket may prove to be a cracked head, or bad rings may be a scored cylinder wall. The important thing is that the source of the trouble has been pinpointed to a specific area, and a fairly broad, accurate estimate of repairs or adjustments required can be made without dismantling the engine.

Q17. Overhead valves are adjusted with the engine in what condition ?

Q18. When you perform a wet compression test and the reading goes up, what is the most likely problem?

Q19. You make a vacuum gauge test at sea level with the engine idling at 550 rpm, and you get a reading of 10 inches. What is the most probable cause?

Q20. When performing a cylinder leakage test, you notice a loud hissing of air from the carburetor. This is an indication of what type of problem?

CHAPTER 4

GASOLINE FUEL SYSTEMS

LEARNING OBJECTIVE: *Describe the different types of gasoline fuel systems, how the components function to provide fuel to the engine in proper quantities, and servicing of the gasoline fuel system.*

The purpose of the fuel system of the internal combustion engine is to provide a combustible mixture of fuel and air to the engine cylinders. The ratio of fuel to air must always be in correct proportions regardless of the speed and load of the engine.

GASOLINE FUEL SYSTEMS

LEARNING OBJECTIVE: *Identify the properties of gasoline and the components of a fuel system.*

The function of both the carburetor fuel system and the fuel injection system is to supply a combustible mixture of air and fuel to the engine. Major elements of the gasoline fuel supply system include the following: fuel tank and cap, fuel system emission controls, fuel lines, fuel pump, fuel filter, carburetor or fuel injection system, air cleaner, and exhaust system. Before discussing the components of a gasoline fuel system, you should understand the composition and properties of gasoline.

GASOLINE

Gasoline is a highly volatile flammable liquid hydrocarbon mixture used as a fuel for internal-combustion engines. Acomparatively economical fuel, gasoline is the primary fuel for automobiles worldwide. Chemicals, called additives, such as lead, detergents, and anti-oxidants, are mixedinto gasoline to improve its operating characteristics.

Antiknock additives are used to slow down the ignition and burning of gasoline. This action helps to prevent engine ping or knock (knocking sound produced by abnormal and excessively rapid combustion). Leaded gasoline has lead antiknock additives. The lead allows a higher engine compression ratio to be used without the fuel igniting prematurely. Leaded gasoline is designed to be. used in older vehicles that have little or no emission controls.

The fuel used today is unleaded gasoline. Unleaded gasoline, also called no-lead or lead-free, does NOT contain lead antiknock additives. Congress has passed laws requiring that all vehicles meet strict emission levels. As a result, manufacturers began using catalytic converters and unleaded fuel.

The properties a good gasoline should have are as follows:

- Proper volatility (how quickly the gasoline vaporizes)
- Resistance to spark knock, or detonation
- Oxidation inhibitors to prevent formationof gum in the fuel system
- Antirust agents to prevent rusting of metal parts in the fuel system
- Anti-icers to retard icing and fuel-line freezing
- Detergents to help keep the fuel system clean
- Dye for identification

PROPERTIES OF GASOLINE

For a gasoline fuel system to function properly, it is necessary that the fuel have the right qualities to burn evenly no matter what the demands of the engine are. To help you recognize the qualities required of gasoline used for fuel, let’s examine some of the properties of gasoline and their effects on the operation of the engine.

Volatility

The ease with which gasoline vaporizes is called VOLATILITY. A high volatility gasoline vaporizes very quickly. A low volatility gasoline vaporizes slowly. A good gasoline should have the right volatility for the climate in which the gasoline is used.

If the gasoline is too volatile, it will vaporize in the fuel system. The result will be a condition called VAPOR LOCK. Vapor lock is the formation of vapor in the fuel lines in a quantity sufficient to prevent the flow of gasoline through the system. Vapor lock causes the vehicle to stall from lack of fuel. In the summer and in hot climates, fuels with low volatility lessen the tendency toward vapor lock.

Antiknock Quality

In modern high compression gasoline engines, the air-fuel mixture tends to ignite spontaneously or to explode instead of burning rather slowly and uniformly. The result is a knock, a ping, or a detonation. For this reason, gasoline refiners have various ways to make gasoline that does not detonate easily.

Octane Rating

Agasoline that detonates easily is called low octane gasoline. A gasoline that resists detonation is called high octane gasoline.

The octane rating of a gasoline is a measurement of the ability of the fuel to resist knock or ping. A high octane rating indicates the fuel will NOT knock or ping easily. It should be used in a high compression or turbo-charged engine. A low octane gasoline is suitable for a low compression engine.

Octane numbers give the antiknock value of gasoline. A higher octane number (91) will resist ping better than a gasoline with a low octane number (83). Each manufacturer recommends an octane number for their engine.

AIR-FUEL RATIO

For proper combustion and engine performance, the right amounts of air and fuel must be mixed together. If too much fuel or too little fuel is used, engine power, fuel economy, and efficiency are reduced.

For a gasoline engine, the perfect air to fuel ratio is 15:1 (15 parts air to 1 part fuel by weight). Under constant engine conditions, this ratio can help assure that all fuel is burned during combustion. The fuel system must change the air-fuel ratio with the changes in engine-operating conditions.

Lean Air-Fuel Mixture

A lean air-fuel mixture contains a large amount of air. For example, 20:1 would be a very lean mixture. A slightly lean mixture is desirable for high gas mileage and low exhaust emissions. Extra air in the cylinder ensures that all the fuel will be burned; however, too lean of a mixture can cause poor engine performance (lack of power, missing, and even engine damage).

Rich Air-Fuel Mixture

A rich air-fuel mixture contains a little more fuel mixed with the air. For gasoline, 8:1(8 parts air to 1 part fuel) is a very rich mixture. A slightly rich mixture tends to increase power; however, it also increases fuel consumption and exhaust emissions. An overly rich mixture will reduce engine power, foul spark plugs, and cause incomplete burning (black smoke at engine exhaust).

GASOLINE COMBUSTION

For gasoline or any other fuel to burn properly, it must be mixed with the right amount of air. The mixture must then be compressed and ignited. The resulting combustion produces heat, expansion of the gases, and pressure.

Normal Combustion

Normal gasoline combustion occurs when the spark plug ignites the fuel and burning progresses smoothly through the fuel mixture. Maximum cylinder pressure should be produced after a few degrees of crank rotation after the piston passes TDC on the power stroke.

Normal combustion only takes about 3/1,000 of a second. This is much slower than an explosion. Dynamite explodes in about 1/50,000 of a second. Under some undesirable conditions, however, gasoline can be made to bum quickly, making part of the combustion like an explosion.

Abnormal Combustion

Abnormal combustion occurs when the flame does NOT spread evenly and smoothly through the combustion chamber. The lean air-fuel mixture, high-operating temperatures, low octane, and unleaded fuels used today make abnormal combustion a major problem that creates unfavorable conditions, such as the following:

• DETONATION results when part of the unburned fuel mixture explodes violently. This is the most severe engine damaging type of abnormal combustion. Engine knock is a symptom of detonation because pressure rises so quickly that parts of the engine vibrate. Detonation sounds like a hammer hitting the side of the engine. It can crack cylinder heads, blow head gaskets, burn pistons, and shatter spark plugs.

• PRE-IGNITION results when an overheated surface in the combustion chamber ignites the fuel mixture. Termed surface ignition, a hot spot (overheated bit or carbon, sharp edge, hot exhaust valve) causes the mixture to burn prematurely. A ping or mild knock is a light tapping noise that can be heard during pre-ignition. Pre-ignition is similar to detonation, but the action is reversed. Detonation begins after the start of normal combustion, and pre-ignition occurs before the start of normal combustion. Pre-ignition is common to modern vehicles. Some manufacturers say that some pre-ignition is normal when accelerating under a load.

• DIESELING, also called after-running or run-on, is a problem when the engine keeps running after the key is turned off. A knocking, coughing, or fluttering noise may be heard, as the fuel ignites and the crankshaft spins. When dieseling, the engine ignites the fuel from heat and pressure, somewhat like a diesel engine. With the key off, the engine runs without voltage to the spark plugs. The most common causes of dieseling are high idle speed, carbon deposits in the combustion chambers, low octane fuel, overheated engine, or spark plugs with too high of a heat range.

• SPARK KNOCK is another combustion problem caused by the spark plug firing too soon in relation to the position of the piston. The spark timing is advanced too far, causing combustion to slam into the upward moving piston. This causes maximum cylinder pressures to form before TDC, not after TDC as it should. Spark knock and pre-ignition both produce about the same symptoms—pinging under load. To find its cause, first check ignition timing. If ignition timing is correct, check other possible causes.

GASOLINE FUEL SYSTEM COMPONENTS

A gasoline fuel system (fig. 4-1) draws fuel from the tank and forces it into the fuel-metering device (carburetor, gasoline injectors), using either a mechanical (engine-driven) or electric fuel pump. The basic parts of a fuel supply system include the following:

- FUEL TANK (stores gasoline)
- FUEL PUMP (draws fuel from the tank and forces it to the fuel-metering device)
- FUEL FILTERS (removes contaminants in the fuel)

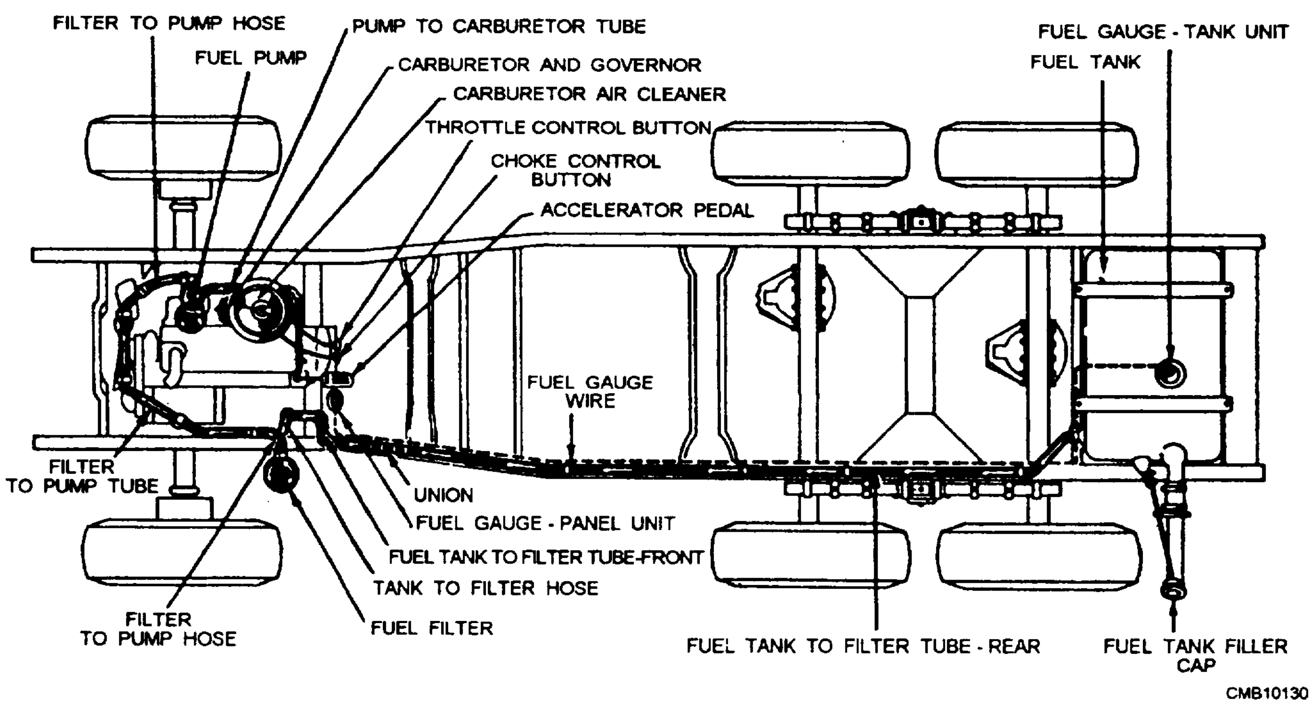


Figure 4-1.—Typical fuel system for a gasoline engine.

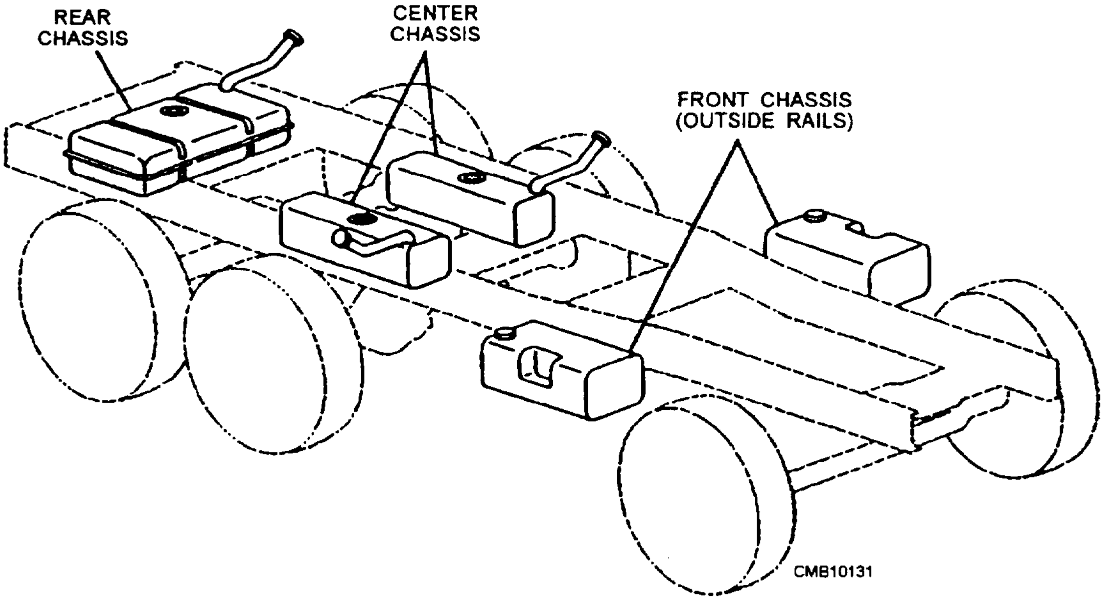


Figure 4-2.—Common fuel tank locations.

- FUEL LINES (carries fuel between the tank, the pump, and other parts)

Fuel Tank

An automotive fuel tank must safely hold an adequate supply of fuel for prolonged engine operation. The location of the fuel tank (fig. 4-2) should be in an area that is protected from flying debris, shielded from collision damage, and one that is not subject to bottoming. A fuel tank can be located just about anywhere in the vehicle that meets these requirements.

Figure 4-3 shows the general construction of a fuel tank used on automotive equipment. Fuel tanks are usually made of thin sheet metal or plastic. The main body of a metal tank is made by soldering or welding two formed pieces of sheet metal together. Other parts (filer neck, fuel tank cap, and baffles) are added to the form to complete the fuel tank assembly. A lead-tin alloy is normally plated to the sheet metal to prevent the tank from rusting.

The fuel tank filler neck is an extension on the tank for filling the tank with fuel. The filler cap fits on the end of the filler neck. The neck extends from the tank through the body of the vehicle. A flexible hose is normally used as part of the filler neck to allow for tank vibration without breakage.

In vehicles requiring unleaded fuel, a fuel neck restrictor is used inside the filler neck. This prevents the accidental use of leaded gasoline in an engine designed for unleaded. The restrictor is too small to accept the larger leaded fuel type pump nozzle.

WARNING

If the restrictor is removed and leaded fuel is used in a vehicle designed for unleaded fuel, the catalytic converter will be damaged. This action is a violation of federal law; therefore, NEVER remove the filler neck restrictor.

Modern fuel tank caps are sealed to prevent escape of fuel and fuel vapors (emissions) from the tank. The cap has pressure and vacuum valves that only open under abnormal conditions of high pressure or vacuum.

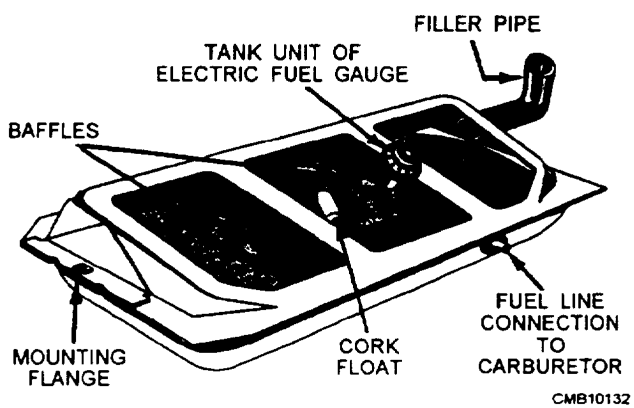


Figure 4-3.—Fuel tank with top cut away.

Fuel tank baffles are placed inside the tank to prevent the fuel from sloshing or splashing around in the tank. The baffles are metal plates that restrict fuel movement when the vehicle accelerates, decelerates, or turns comers.

Fuel tanks give little or no trouble, and generally require no servicing other than an occasional draining and cleaning.

WARNING

If a fuel tank is punctured or develops leaks, it should NOT be welded or repaired with or near an open flame until all traces of fuel and fuel vapors have been completely removed from the tank. Before attempting to make any repairs to a fuel tank, consult with the shop supervisor for specific instructions on all safety precautions to be observed.

Fuel Gauges

The fuel gauge is a signaling system that indicates the amount of fuel in the tank. Most fuel gauges are composed of two units—the gauge that is mounted on the instrument panel and the sending unit located on the tank

There are two types of gauges—magnetic and thermostatic. Each of these gauges has a sending unit and an instrument panel unit.

1. Magnetic Gauge (fig. 4-4). The sending unit in this fuel gauge contains a sliding contact. As the fuel level in the tank changes, the position of the contact changes on a rheostat winding, varying circuit resistance and resulting current flow. The unit on the instrument panel contains two magnetic coils (limiting coil and operating coil) and a permanent magnet that is attached to the gauge needle. When the fuel tank is empty, the limiting coil is stronger than the operating coil, thus the magnet is drawn toward it and the needle reads EMPTY on the gauge. As the tank is filled, the operating coil becomes stronger, attracting the magnet and moving the needle toward the FULL position.

2. Thermostatic Gauge (fig. 4-5). It has a sending unit similar to the magnetic system. The sending unit has a float and sliding contact that moves on a resistor. As the fuel level in the tank changes, the position of the contact changes on a rheostat winding, varying circuit resistance and resulting current flow. When the fuel is low in the tank, most of the resistance is in the circuit and very little current can flow. As the tank is filled, the float moves up and the sliding contact cuts most of the resistance out of the circuit. This action increases current flow and as the current flows through the heater coil in the gauge on the instrument panel, the current heats the thermostat. The thermostatic blade bends because of the heat. This moves the needle to the FULL mark. As the fuel level in the tank drops, resistance

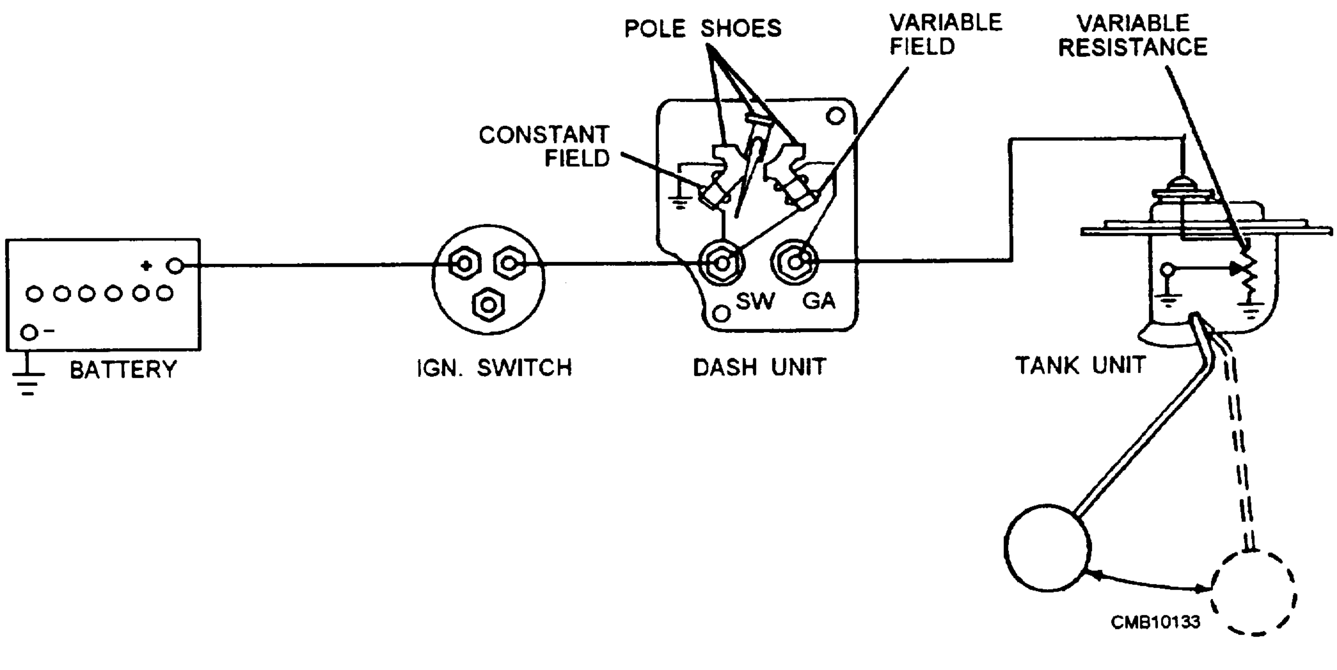


Figure 4-4.—Magnetic fuel gauge.

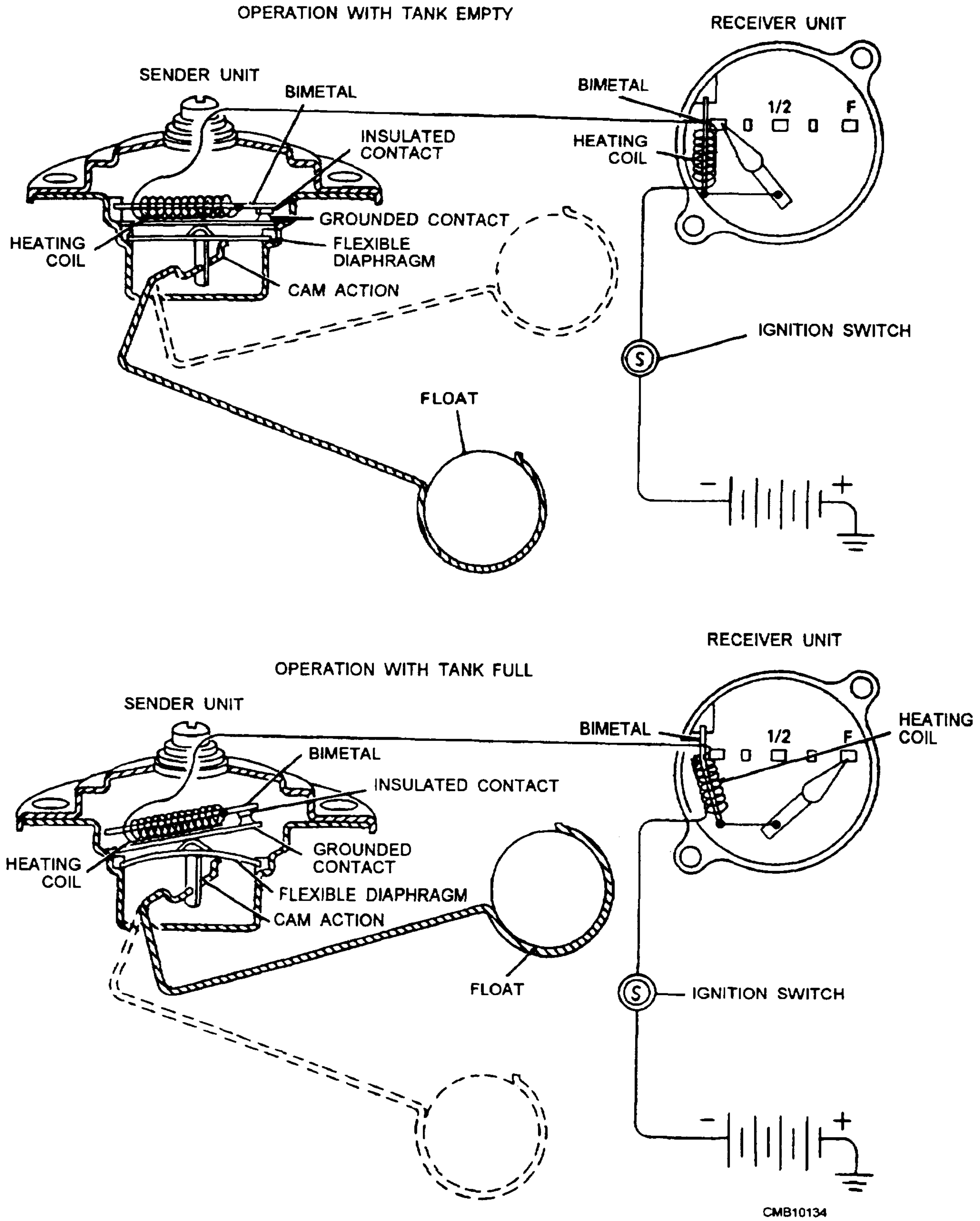


Figure 4-5.—Thermostatic fuel gauge: self-regulating.

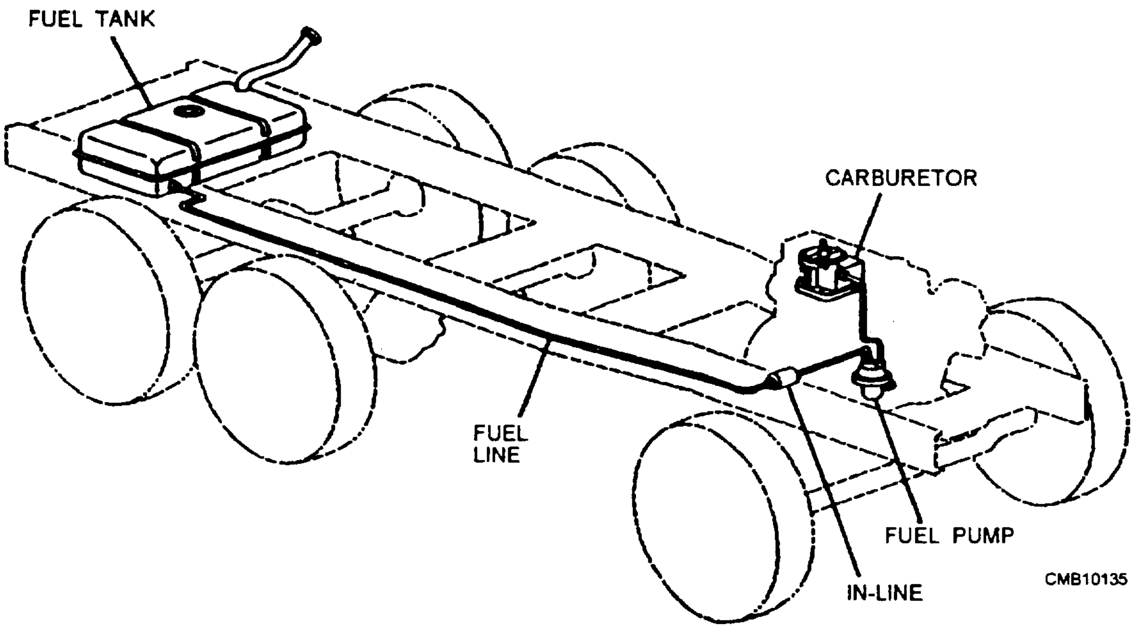


Figure 4-6.—Typical fuel filter locations.

increases, resulting in lower current flow through the heater coil, thus producing less heat to bend the thermostatic blade.

Fuel Filters

Fuel filters stop contaminants (rust, water, corrosion, and dirt) from entering the carburetor, throttle body, injectors, injections pumps, and any other parts that may be damaged by foreign matter. Fuel filters can be located in the following locations (fig. 4-6):

- In the fuel line before the carburetor or fuel injectors.
- Inside the fuel pump.
- In the fuel line right after the electric fuel pump.
- Under the fuel line fitting in the carburetor.
- A fuel strainer is also located in the fuel tank on the end of the pickup tube.

When in doubt about the location of the fuel filter, refer to the service manual.

Fuel filters operate by passing the fuel through a porous filtering medium (fig. 4-7). The openings in the porous material are very small, and, therefore, any particles in the fuel that are large enough to cause problems are blocked. In addition to the filtering medium, the filter, in some cases, also serves as a sediment bowl. The fuel, as it passes through the filter, spends enough time in the sediment bowl to allow large particles and water to settle out of it.

Several types of fuel filters are used today. They are the replaceable in-line, the replaceable in-line in the

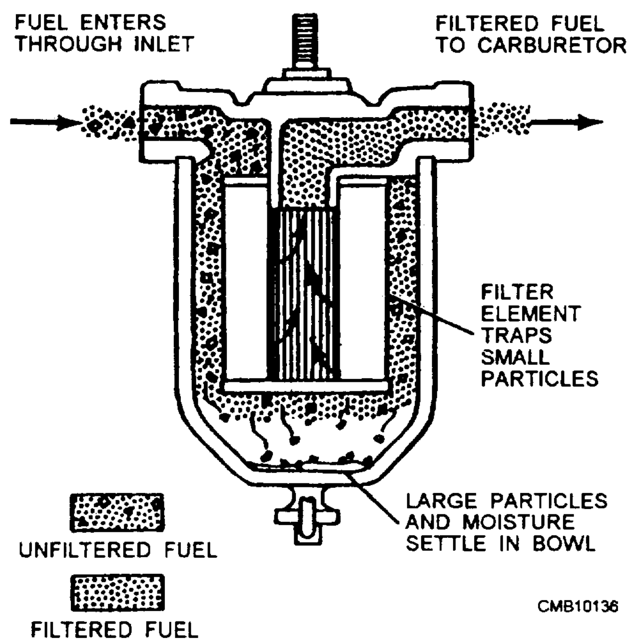


Figure 4-7.—Fuel filter operation.

carburetor, and the glass bowl (fig. 4-8). The most common configuration is the replaceable in-line filter. these are in-line filter elements that fit in the carburetor inlet or inside the fuel tank.

Fuel filter elements can be made from treated paper, ceramics, sintered bronze, or metal screen (fig. 4-9). However, there is one filter element that differs from the others. It consists of a stacked pile of laminated disks that are spaced 0.0003 inches apart. As the fuel passes between the disks, foreign matter is blocked out. These filters are replaced when the flow of fuel is restricted.

Fuel filter service involves periodic replacement or cleaning of system filters. It may also include locating clogged fuel filters that are upsetting fuel system operations. Paper elements must be replaced when clogged or after prolonged use. Sintered bronze fuel filters can usually be cleaned and reinstalled. A clogged fuel filter can restrict the flow of fuel to the carburetor or injectors. Engine Performance problems will show up at higher speeds.

Some fuel filters have a check valve that opens when the filter becomes clogged. This will allow fuel contaminants to flow into the system. When contaminants are found in the filters and system, the tank, the pump, and the lines should be flushed with clean fuel.

Always refer to the service manual for information concerning service intervals, cleaning, and replacement of all system filters.

Fuel Pump

The fuel pump delivers fuel from the tank to the engine under pressure. There are two basic types of fuel pumps—mechanical fuel pump and electrical fuel pump.

Mechanical fuel pumps are commonly used with carburetor type fuel systems. They are the oldest type of fuel pump, but they are still found on many vehicles. The mechanical fuel pump is mounted on the side of the engine block, using a gasket between the pump and the block to prevent oil leakage. Since the mechanical

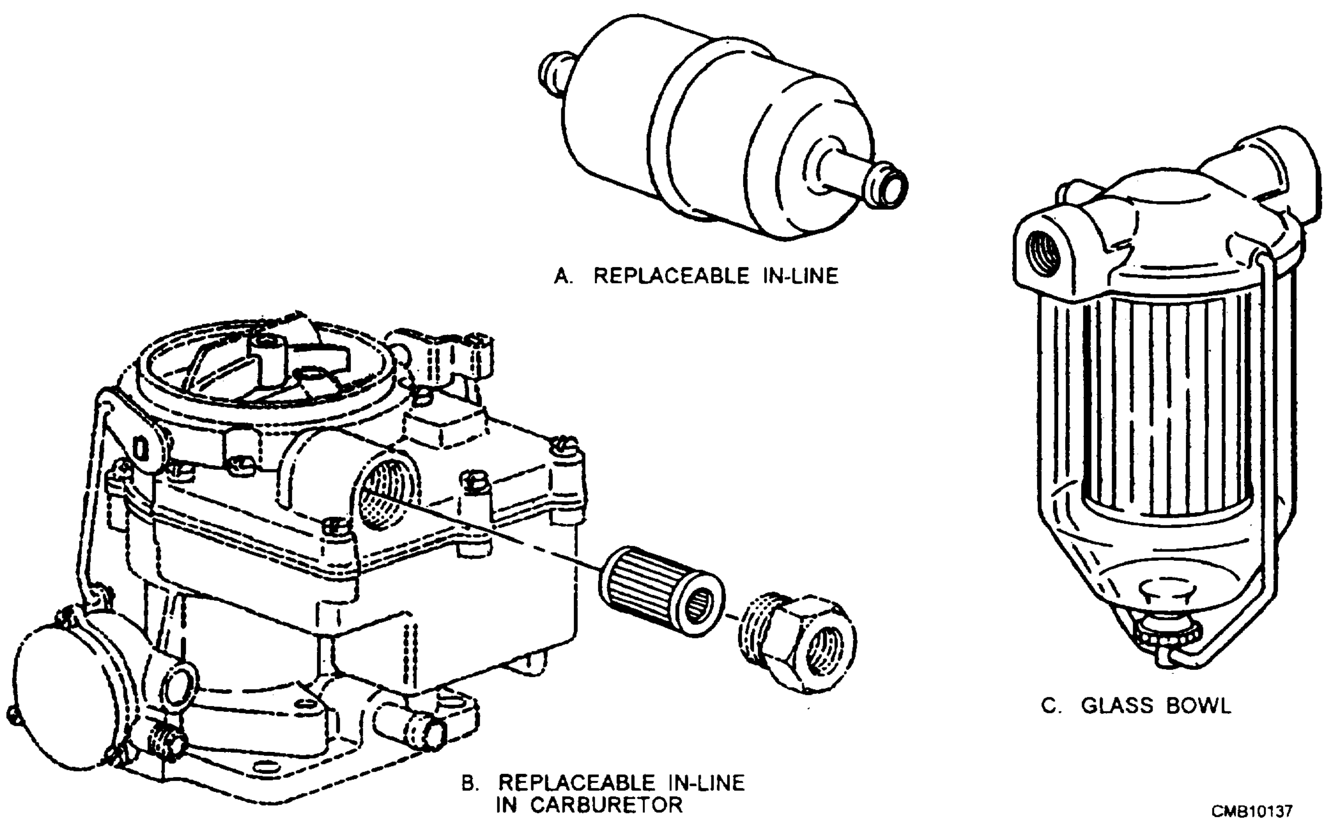


Figure 4-8.—Fuel filter configurations.

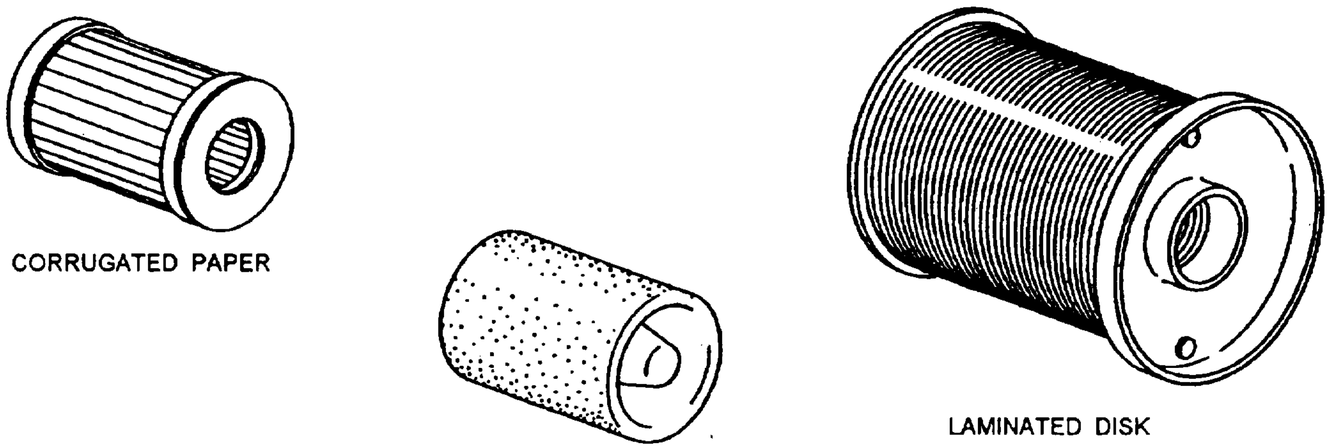


Figure 4-9.—Fuel filter elements.

pump uses a back-and-forth motion, it is a reciprocating pump. They are usually powered by an eccentric (egg-shaped lobe) on the engine camshaft.

The parts of a basic mechanical fuel pump are the rocker arm, the return spring, the diaphragm, the diaphragm spring, and the check valves.

- The ROCKER ARM, also called an actuating lever, is a metal arm hinged in the middle. A small pin passes through the arm and fuel pump body. The outer end of the arm rides on the camshaft eccentric and the inner end operates the diaphragm.

- The RETURN SPRING keeps the rocker arm pressed against the eccentric. Without a return spring, the rocker arm would make a loud clattering sound, as the eccentric lobe hits the rocker arm.

- The DIAPHRAGM is a synthetic rubber disc clamped between two halves of the pump body. The core of the diaphragm is usually cloth that adds strength and durability. A metal pull rod is mounted on the diaphragm to connect the diaphragm with the rocker arm.

- The DIAPHRAGM SPRING, when compressed, pushes on the diaphragm to produce fuel pressure and flow. This springs fits against the back of the diaphragm and against the pump body.

- The CHECK VALVES are used in a mechanical fuel pump to make the fuel flow through the pump. The check valves are reversed. This causes the fuel to enter one valve and exit through the other.

The basic operation of a mechanical fuel pump operation is as follows:

- INTAKE STROKE. The eccentric lobe pushes on the rocker arm. This action pulls the diaphragm down and compresses the diaphragm spring. Since the area in the pumping chamber increases, a vacuum pulls fuel through the inlet check valve.

- OUTPUT STROKE. The eccentric lobe rotates away from the pump rocker arm. This action releases the diaphragm. The diaphragm spring then pushes on the diaphragm and pressurizes the fuel in the pumping chamber. The amount of spring tension controls the fuel pressure. The fuel is then forced to flow out of the outlet check valve.

Mechanical fuel pumps are classified as positive and nonpositive diaphragm types. The POSITIVE type

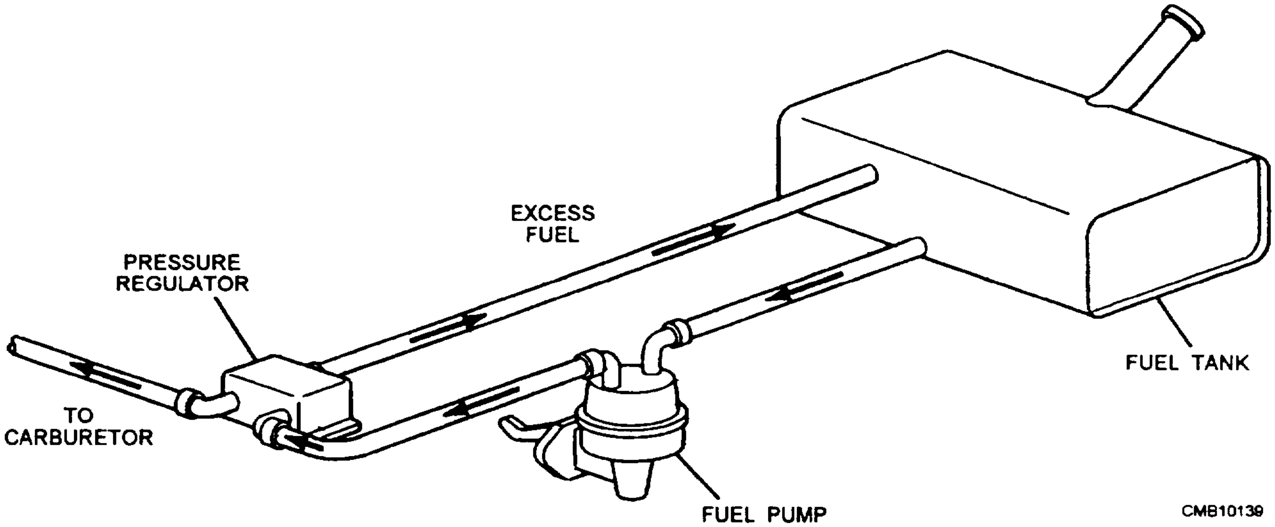


Figure 4-10.—Mechanical positive fuel pump installation.

(fig. 4-10) continues to pump fuel even when the carburetor bowl is filled; therefore, a method of bypassing the fuel back to the tank is required. The NONPOSITIVE type (fig. 4-11) is the one usually found in a gasoline engine. It delivers fuel to the carburetor only when it is needed for the requirements of the engine.

An electric fuel pump, like the mechanical pump, produces fuel pressure and flow for the fuel-metering section of a fuel system.

Electric fuel pumps are commonly used in gasoline fuel systems. They can be located inside the fuel tank as part of the fuel pickupsending unit. Also, it can be located in the fuel line between the tank and the engine.

The advantages an electric fuel pump has over the mechanical fuel pump are as follows:

- An electric fuel pump can produce almost instant fuel pressure. A mechanical pump slowly builds pressure as the engine is cranked for starting.

- Most electric fuel pumps are a rotary type. This produces a smoother flow of fuel (less pressure pulsations) than a reciprocating, mechanical pump.

- Since most electric pumps are located away from the engine, they help prevent vapor lock. An electric fuel pump pressurizes all of the fuel line near the engine heat. This helps avoid vapor lock because pressure makes it more difficult for bubbles to form in the fuel.

Electric rotary fuel pumps include the impeller, the roller vane, and the sliding vane types. They use a circular or spinning motion to produce pressure.

An impeller electric fuel pump is a centrifugal pump, normally located inside the fuel tank. This pump used a small motor to spin the impeller (fan blade). The impeller blades cause fuel to fly outward due to centrifugal force. This produces enough pressure to move the fuel through the fuel lines.

A roller vane electric fuel pump (fig. 4-12) is a positive displacement pump (each pump rotation moves a specific amount of fuel). This pump is located in the main fuel line. Small rollers and an offset mounted rotor disc produce fuel pressure in the pump. When the rotor disc and rollers spin, they pull fuel to one side. The fuel is then trapped and pushed to a smaller area on the opposite side of the pump housing. This action squeezes the fuel between the rollers and the fuel flows

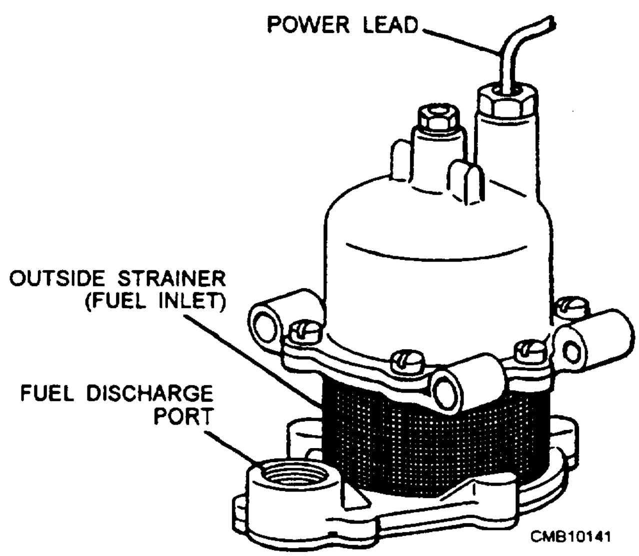


Figure 4-12.—Vane-type electric pump.

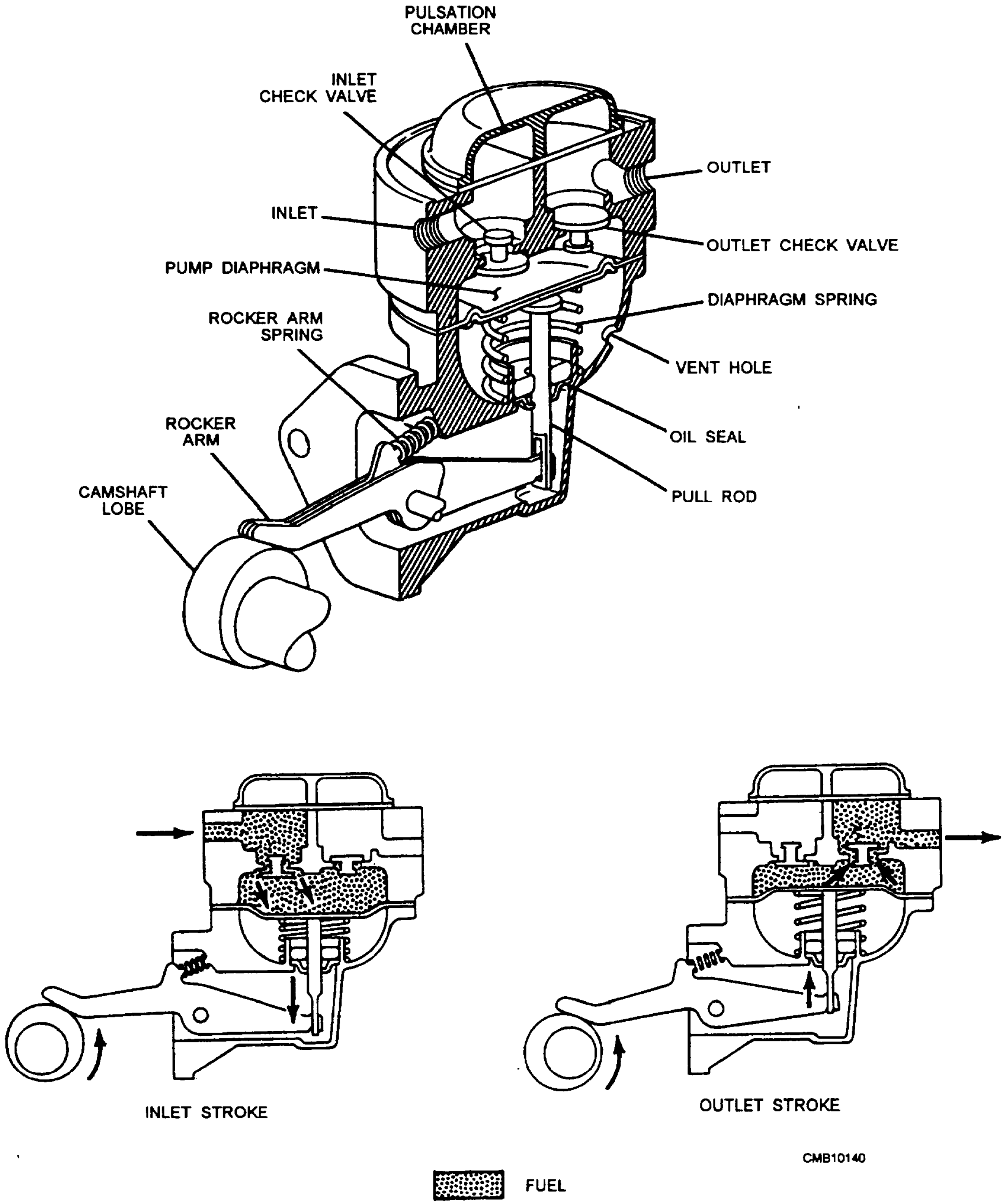


Figure 4-11.—Mechanical nonpositive fuel pump.

out under pressure. The sliding vane electric fuel pump is similar to the roller vane pump, except vanes (blades) are used instead of rollers.

Most rotary fuel pumps also have check valves and relief valves. The check valves keep the fuel from draining out of the fuel line when the pump is not in operation. A relief valve limits the maximum output pressure.

Another type of electric fuel pump is the reciprocating electric fuel pump. This pump has the same basic action as a mechanical fuel pump; however, it uses a solenoid instead of a rocker arm to produce a plunger action. The reciprocating pump uses either bellows (fig. 4-13) or a plunger. The solenoid turns on and off to force the bellows or plunger up and down. This action pushes fuel through the check valves and the fuel system.

Both mechanical and electric fuel pumps can fail after prolonged operation. Indications of fuel pump problems are as follows:

- LOW FUEL PUMP PRESSURE can be caused by a weak diaphragm spring, ruptured diaphragm, leaking check valves, or physical wear of moving parts. Low fuel pressure can make the engine starve for fuel at higher engine speeds.

- HIGH FUEL PUMP PRESSURE, more frequent with electric fuel pumps, indicates an inoperative pressure relief valve. If the valve fails to open, both pressure and volume can be above normal. High fuel pump pressure can produce a rich fuel mixture or even flood the engine.

- MECHANICAL FUEL PUMP NOISE (clacking sound from inside the pump) is commonly caused by weak or broken rocker arm return spring or by wear of the rocker arm pin or arm itself. This noise can be easily confused with valve or tappet clatter. To verify mechanical pump noise, use a stethoscope.

- FUEL PUMP LEAKS are caused by physical damage to the pump body or deterioration of the diaphragm and gaskets. Most mechanical fuel pumps have a small vent hole in the pump body. When the diaphragm is ruptured, fuel will leak out of this hole.

Fuel pump testing commonly involves measuring pump pressure and volume. Since exact procedures vary depending on the type of fuel system, refer to the manufacturer's manual for exact testing methods. Sometimes, fuel pump vacuum is measured as another means of determining pump and line condition. Always remember that there are several other problems that can produce symptoms similar to those caused by a fuel

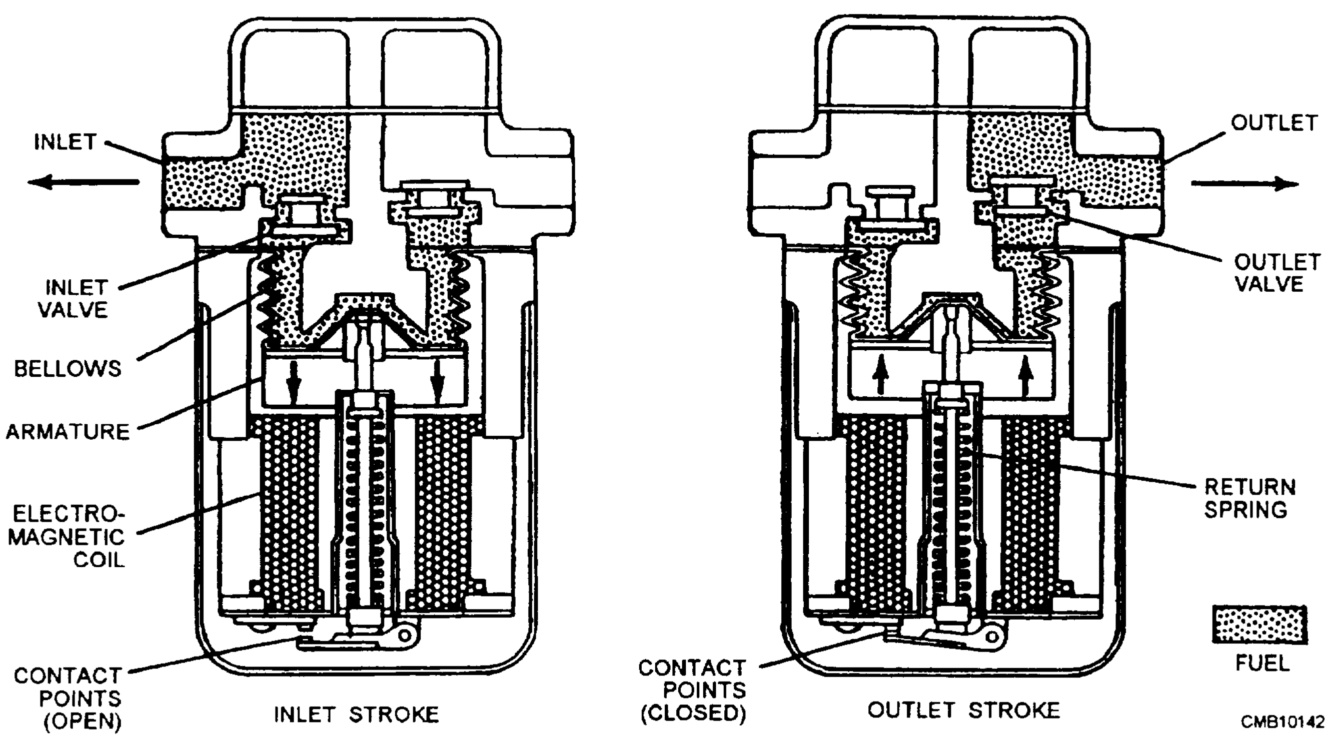


Figure 4-13.—Bellows-type electric fuel pump.

pump. Before testing a fuel pump, check for the following:

- Restricted fuel filters
- Smashed or kinked fuel line or hoses
- Air leak into the vacuum side of pump or line
- Carburetor or injection system problems
- Ignition system problems
- Low engine compression

To measure fuel pump pressure, connect a pressure gauge to the output line of the fuel pump. Start and idle the engine at the rpm specified by the manufacturer with a mechanical fuel pump. With an electric fuel pump, you may only need to activate the pump motor. Compare your pressure reading to the manufacturer's specifications. Fuel pressure for a carburetor type system is approximately 4 to 6 psi. A gasoline injection system will usually have a high-pressure output, varying from 15 to 40 psi. If fuel pump pressure is NOT within specifications. check the pump volume, the lines, and the filters before replacing the pump.

Fuel pump volume is the amount of fuel the pump can deliver in a specific amount of time. It is measured by allowing the fuel to pour into a graduated (marked) container for a certain amount of time (normally 30 seconds). Route an output line from the fuel pump to a measuring container. For safety, a valve or clip should be installed to control fuel flow into the container. With the engine idling at a set speed, allow the fuel to pour into the container for the prescribed amount of time. Close off the clip or the valve and compare volume output to the specifications. Output should be a minimum of 1 pint in 30 seconds for carburetor systems. Fuel injection systems have a slightly higher output from the supply pump. Always refer to the service manual specifications for the particular fuel pump and vehicle. If the fuel pump fails both pressure and volume test, then check the fuel pump vacuum.

A vacuum test will eliminate possible problems in the fuel lines, the hoses, the filters, and the pickup screen in the tank. For example, a clogged fuel pickup screen could make the fuel pump fail the volume test. To measure vacuum, connect a vacuum gauge to the inlet side of the pump, leaving the fuel hose from the volume test in the graduated container. Open the control valve on the hose and start the engine and allow it to run on the fuel in the carburetor, or connect voltage, to an electric pump. Compare your reading with the manufacturer’s specifications. Normally, fuel pump vacuum should be about 7 to 10 in/hg. A good reading indicates a good fuel pump. If the pump failed the pressure or volume test but passed the vacuum test, the fuel supply lines and filter may be at fault.

Fuel Lines and Hoses

Fuel lines and hoses carry fuel from the tank to the engine. The main fuel line allows the fuel pump to draw fuel out of the tank. The fuel is pulled through this line to the pump and then to the carburetor, or metering section of the injection system.

Fuel lines are normally made of double wall steel tubing. For fire safety, a fuel line must be able to withstand the constant and severe vibration produced by the engine and road surface. Lines are placed away from exhaust pipes, mufflers, and manifolds, so that excessive heat will not cause vapor lock. They are attached to the frame, the engine, and other units, so the effects of vibration will be minimized.

Fuel hoses, made of synthetic rubber, are used where severe movement occurs between parts. A flexible hose can absorb movement without breaking. Hose clamps are required to secure fuel hoses to the fuel lines or to metal fittings.

Faulty fuel lines and hoses are a common source of fuel leaks. Fuel hoses can become hard and brittle after being exposed to the engine heat and the elements. Engine oil can soften and swell them. Always inspect hoses closely and replace any in poor condition. Metal fuel lines rarely cause problems; however, they should be replaced if they become smashed, kinked, rusted, or leaking. Remember these rules when working with fuel lines and hoses:

- Place a rag around the fuel line fitting during removal. This action will keep fuel from spraying on you or on a hot engine. Use a flare nut or tubing wrench on fuel line fittings.

- Use only approved double wall steel tubing for fuel lines. NEVER use copper or plastic tubing.

- Make smooth bends when forming a new fuel line. Use a bending spring or bending tool.

- Form double lap flares on the ends of fuel lines. A single lap flare is NOT approved for fuel lines.

- Reinstall fuel line hold-down clamps and brackets. If not properly supported, the fuel line can vibrate and fail.

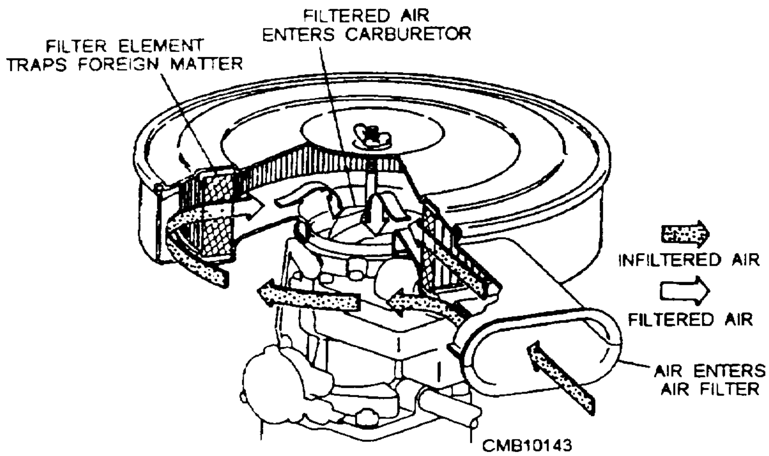


Figure 4-14.—Air cleaner.

- Route all fuel lines and hoses away from hot or moving parts. Double-check the clearance after installation.

- Only use approved synthetic rubber hoses in a fuel system. Vacuum hose is NOT to be used as fuel hose.

- Make sure fuel hoses completely cover its fitting or line before installing clamps. Pressure in the fuel system could force the hose off if not installed properly.

- Double-check all fitting for leaks. Start the engine and inspect the connections closely.

NOTE

Most fuel injection systems have very high fuel pressure. Follow recommended procedures for bleeding or releasing pressure before disconnecting a fuel line or fitting. This action will prevent fuel spray from possibly causing injury or a fire.

AIR CLEANER

The fuel system mixes air and fuel to produce a combustible mixture. A large volume of air passes through the carburetor or fuel injection system and engine, as much as 100,000 cubic feet of air every 1,000 miles. Air always contains a lot of floating dust and grit. The dust and grit could cause serious damage if they entered the engine. To prevent this, mount an air cleaner (fig. 4-14) at the air entrance of the carburetor or fuel injection system. The two types of cleaners currently used are the wet and dry types.

The wet-type. or oil bath, air cleaner consists of the main body, the filter element that is made of woven copper gauze, and the cover (fig. 4-15). Operation is as follows:

- Incoming air enters between the cover and the main body. The air is pulled down to the bottom of the main body where it must make a 180-degree turn, as it passes over the oil reservoir.

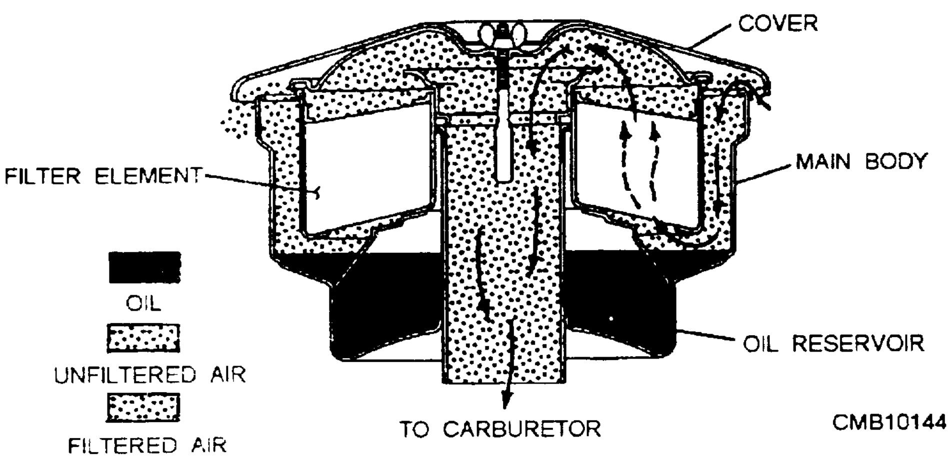


Figure 4-15.—Wet-type air filter.

- As the air passes over the oil reservoir, most of the particles will not be able to make the turn, and they will hit the oil and be trapped.

- As the air continues upward and passes through the filter element, the smaller particles that bypassed the oil will be trapped.

- The air keeps the element soaked with oil by creating a fine spray, as it passes the reservoir.

- The air then makes another 180-degree turn and enters the carburetor.

The dry-type air cleaner passes the incoming air through a filtering medium before it enters the engine. The air filter contains a ring of filter material (fine-mesh metal threads or ribbons, pleated paper, cellulose fiber, or polyurethane), as shown in figure 4-16. These types of filter materials provide a fine maze that traps most of the airborne particles.

The air cleaner also muffles the noise of the intake air through the carburetor or fuel injection system, manifold, and valve ports. This noise would be very noticeable if it were not for the air cleaner. In addition the air cleaner acts as a flame arrester in case the engine backfires through the intake manifold. The air cleaner prevents the flame from escaping and igniting gasoline fumes outside the engine.

Q1. What fuel additive is used to prevent engine ping or knock?

Q2. What is the measurement of *the ability of gasoline* to *resist knock or ping?*

Q3. What device is used to prevent the accidental use of leaded fuel in a vehicle designedfor unleaded fuel?

Q4. What are the two types of air cleaners currently being used?

PRINCIPLES OF CARBURETION

LEARNING OBJECTIVE: *Describe the operating systems and principles of a simple carburetor and a computerized controlled carburetor. Identify the different carburetor accessories and their functions. Identify and describe possible carburetor troubles and quick system checks.*

The principles of carburetion are presented so you may better understand the inner workings of a carburetor and how the other components of the fuel system function to provide a combustible mixture or air and fuel to the engine cylinders.

Air is composed of various gases, mostly nitrogen and oxygen (78 percent nitrogen and 21 percent oxygen by volume). These gases are, in turn, made up of tiny particles called molecules. All substances, whether solid, liquid, or gas, are made up of molecules. In solids, such as ice or iron, the particles are held closely together so that they seem to have no motion. In liquids, the molecules are not held together tightly, so they can move freely with respect to each other. In gases, there is still less tendency for the molecules to bond; therefore, the molecules can move quite freely. The molecules of gas are attracted to the earth by gravity or by their weight. It is the combined weight of the countless molecules in the air that make up atmospheric pressure.

Evaporation is the changing of a liquid to a vapor. The molecules of the liquid not being closely tied together are constantly moving among themselves. Any molecule that moves upward with sufficient speed will jump out of the liquid and into the air. This process will cause the liquid to evaporate over a period of time. The rate of evaporation is dependent on the following:

- TEMPERATURE. The rate of movement of the molecules increase with temperature. Because of this,

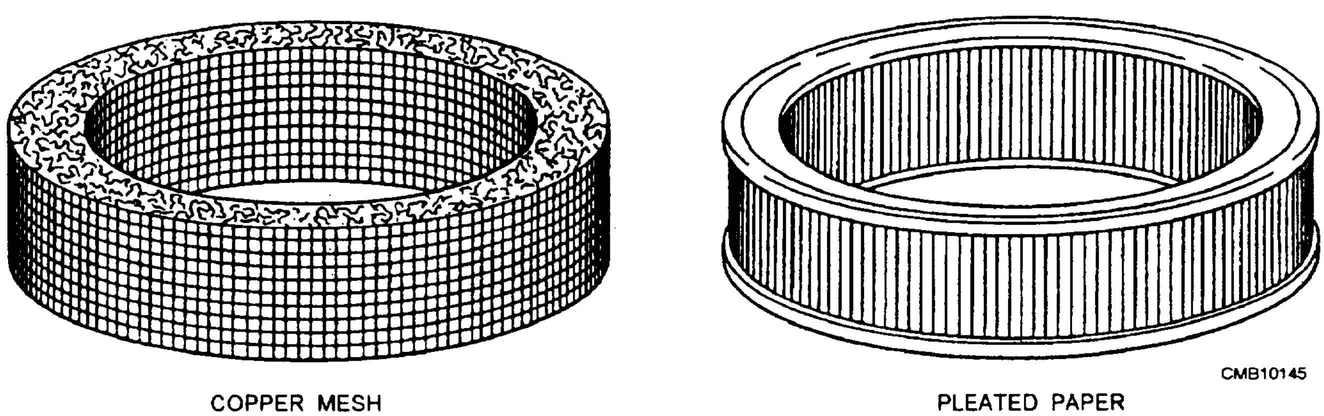


Figure 4-16.—Dry-type air filter.

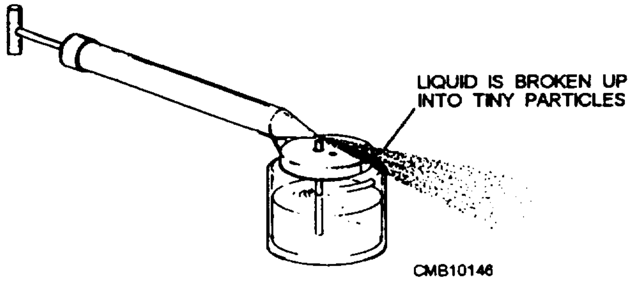


Figure 1-17.—Example of atomization.

the amount of molecules leaving the liquid for a given time will increase, as the temperature increases.

- ATMOSPHERIC PRESSURE. As atmospheric pressure increases, the amount of air molecules present over the liquid also increases. The increased presence of air molecules will slow the rate of evaporation. This is because the molecules of liquid will have more air molecules to collide with. In many cases, they will fall back into the liquid after the collision

- CLOSED CHAMBER. As evaporation takes place in a closed container, the space above the liquid will reach a point of saturation. When this happens, every molecule of liquid that enters the air will cause another airborne molecule of liquid to fall back.

- VOLATILITY. The term volatility refers to how fast a liquid vaporizes. Some liquid vaporizes easily at room temperature. Alcohol, for instance, vaporizes more easily than water. A highly volatile liquid is one that is considered to evaporate easily.

- ATOMIZATION (fig. 4-17). Atomization is the process of breaking up a liquid into tiny particles or droplets. When a liquid is atomized, the droplets are all exposed individually to the air. For this reason, atomization greatly increases evaporation by increasing the exposed surface area of the liquid.

The venturi effect (fig. 4-18) is used by the carburetor to mix air with the gasoline. The basic carburetor has an hourglass-shaped tube called a throat. The most constricted part of the throat is called the venturi. A tube, called the discharge nozzle, is positioned in the venturi. The discharge nozzle is connected to a reservoir of gasoline called the float bowl. The negative pressure that exists in the combustion chamber is due to the downward intake stroke of the piston, causing atmospheric pressure to create an air flow through the throat. This air flow must increase temporarily in speed, as it passes through the venturi due to its deceased size. The increased speed of air flow results in a corresponding decrease in pressure within the venturi and at the end of the discharge nozzle. This action permits the atmospheric pressure on the surface of the gasoline in the float bowl to force the gasoline out through the discharge nozzle. This gasoline then sprays and atomizes in the passing air flow to form the air-fuel mixture.

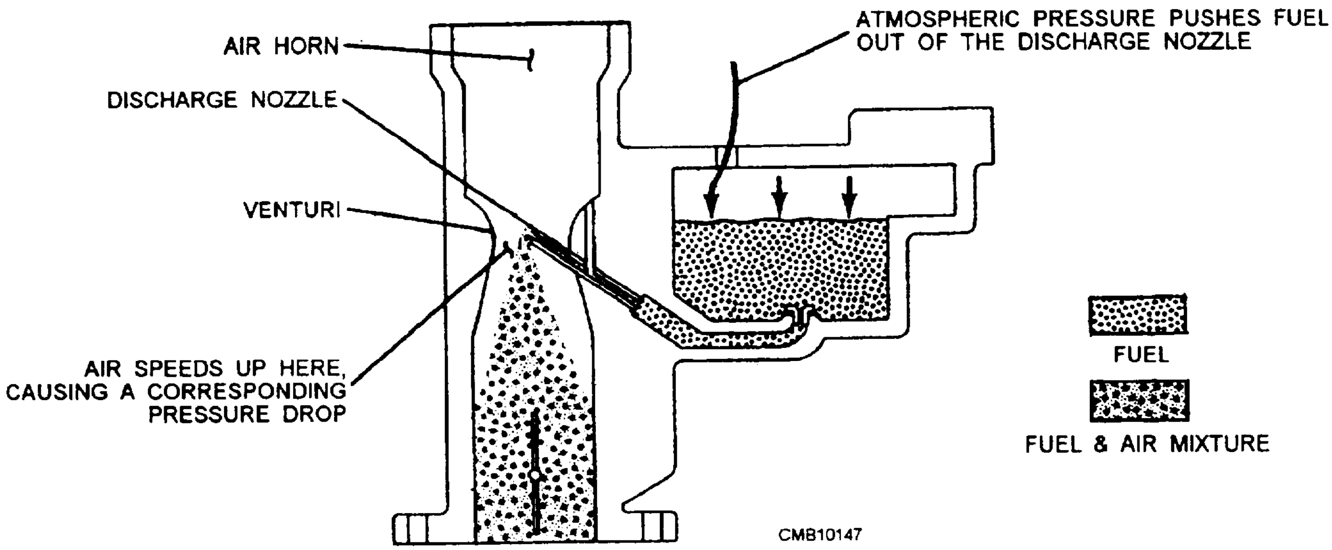


Figure 4-18.—Venturi effect.

CARBURETOR

A carburetor is basically a device for mixing air and fuel in the correct amounts for efficient combustion. The carburetor bolts to the engine intake manifold. The air cleaner fits over the top of the carburetor to trap dust and dirt. The basic carburetor consists of the following parts:

- CARBURETOR BODY. The carburetor body is a cast metal housing for the carburetor components. Usually the main body houses the fuel bowl, main jets, air bleeds, power valve, pump checks, diaphragm type accelerator pump, venturis, circuit passages, and float mechanism. The body is flanged on the bottom to allow the carburetor to be bolted to the intake manifold.

- AIR HORN. The air horn is also called the throat or barrel. It routes outside air into the engine intake manifold. It contains the throttle valve, the venturi, and the outlet end of the main discharge tube. The parts which often fasten to the air horn body are as follows: the choke, the hot idle compensator, the fast idle linkage rod, the choke vacuum break, and sometimes the float and pump mechanisms.

- THROTTLE VALVE (fig. 4-19). This disc-shaped valve controls air flow through the air horn. When closed, it restricts the flow of air and fuel into the engine, and when opened, air flow, fuel flow, andengine power increase.

- VENTURI. The venturi produces sufficient suction to pull fuel out of the main discharge tube.

- MAIN DISCHARGE TUBE. The main discharge tube is also called the main fuel nozzle. It uses venturi vacuum to feed fuel into the air horn and engine. It is a passage that connects the fuel bowl to the center of the venturi.

- FUEL BOWL. The fuel bowl holds a supply of fuel that is NOT under fuel pump pressure.

Carburetor size is stated in CFM (cubic feet of air per minute). This is the amount of air that can flow through the carburetor at wide, open throttle. CPM is an indication of the maximum air flow capacity. Usually, small CPM carburetors are more fuel-efficient than larger carburetors. Air velocity, fuel mixing, and atomization are better with small throttle bores. A larger CPM rating is desirable for high engine power output.

A carburetor system or circuit is a network of passages and related parts that help control the air-fuel ratio under specific engine-operating conditions. The seven basic carburetor systems are the following:

1. FLOAT SYSTEM
2. IDLE SYSTEM
3. OFF IDLE SYSTEM
4. ACCELERATION SYSTEM
5. HIGH-SPEED SYSTEM
6. FULL-POWER SYSTEM
7. CHORE SYSTEM

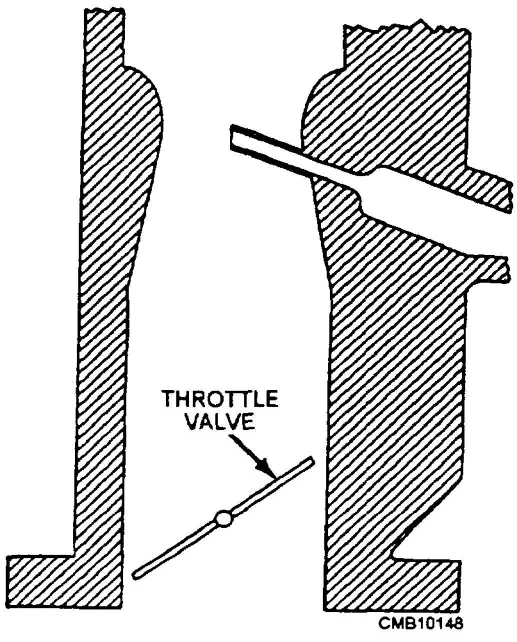


Figure 4-19.—Simple carburetor with throttle valve.

Understanding each of these systems is important. It will help you when diagnosing and repairing carburetor problems.

Float System

The float system (fig. 4-20) maintains a steady working supply of gasoline at a constant level in the carburetor. This action is critical to the proper operation of the carburetor. Since the carburetor uses differences in pressure to force fuel into the air horn, the fuel bowl must be kept at atmospheric pressure. The float system keeps the fuel pump from forcing too much gasoline into the carburetor bowl. An excessively high float level will cause fuel to flow too freely from the discharge tube, causing an overly rich mixture, whereas an excessively low float level will cause an overly lean mixture. The basic parts of the float system are the fuel bowl, the float, the needle valve, the needle seat, the bowl vent, and the hinge assembly. Study the relationship of each part as follows:

- The CARBURETOR FLOAT rides on top of the fuel in the fuel bowl to open and close the needle valve. It is normally made of thin brass or plastic. One end of the float is hinged to the side of the carburetor body and the other end is free to swing up and down.

- The NEEDLE VALVE regulates the amount of fuel passing through the fuel inlet and the needle seat. The needle valve is usually made of brass. Sometimes the end of the valve will have a soft viton (synthetic rubber) tip. The soft tip seals better than a metal tip, especially if dirt gets caught in the needle seat.

- The NEEDLE SEAT works with the needle valve to control fuel flow into the bowl. It is a brass fitting that threads into the carburetor body.

- The BOWL VENT prevents pressure or vacuum buildup in the carburetor fuel bowl. Without venting, pressure could form in the bowl, as the fuel pump fills the carburetor. This could also cause vacuum to form in the bowl, as fuel is drawn out of the carburetor and into the engine. On vehicles equipped with an evaporation control type emission system, the fuel bowl is vented into a hose going to a charcoal canister instead of the outside. The canister stores toxic fuel vapors and prevents them from entering the atmosphere.

Basic float system operation is as follows:

- When engine speed or load increases, fuel is rapidly pulled out of the fuel bowl and into the venturi. This action causes the fuel to drop in the bowl. The needle valve also drops away from its seat. The fuel pump can then force more fuel into the bowl.

- As the fuel level in the bowl rises, the float pushes the needle valve against its seat. When the fuel level is high enough, the float closes the opening between the needle valve and the seat by the rising float, as the fuel reaches the desired level in the fuel bowl.

With the engine running, the needle valve usually lets some fuel leak into the bowl. As a result, the float system maintains a stable quantity of fuel in the bowl. This is very important because the fuel level in the bowl can affect the air-fuel ratio.

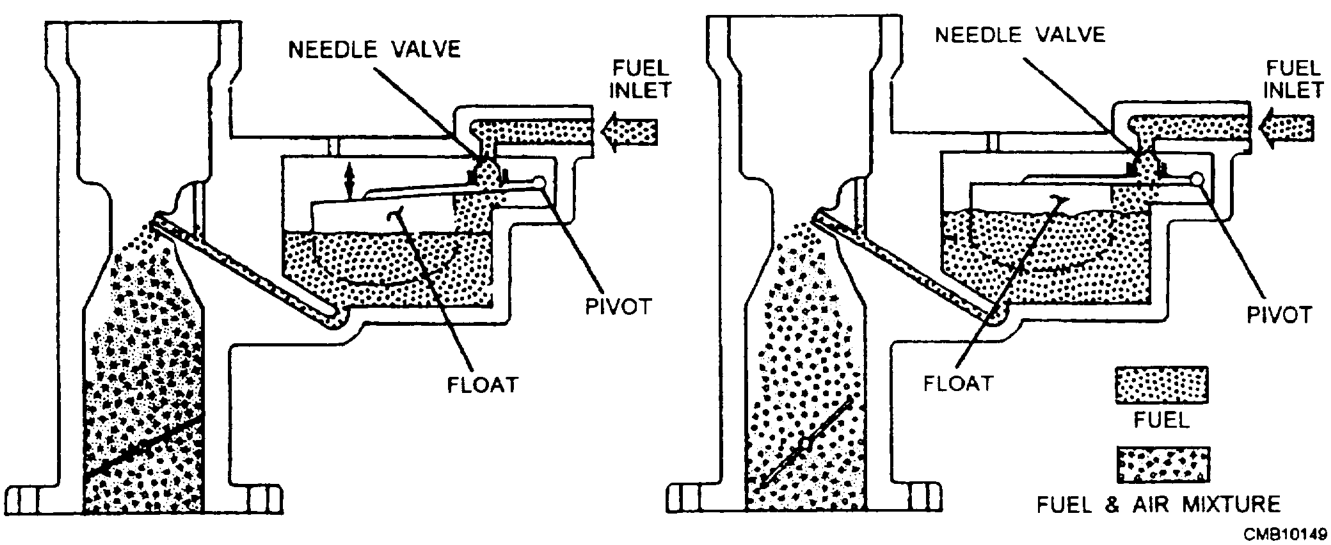


Figure 4-20.—Float system.

Idle System

The carburetor idle system (fig. 4-21) provides the air-fuel mixture at speeds below approximately 800 rpm or 20 mph When the engine is idling, the throttle is almost closed Air flow through the air horn is restricted to produce enough vacuum in the venturi. Since venturi vacuum is too low to pull fuel from the main discharge tube, the high intake manifold vacuum BELOW the throttle plate and the idle circuit are used to feed fuel into the air horn.

The fundamental parts of the carburetor idle system include a section of the main discharge tube, a low-speed jet, an idle air bleed, a bypass, a idle passage, an economizer, an idle screw port, and an idle mixture screw.

- The LOW-SPEED JET is a restriction in the idle passage that limits maximum fuel flow in the idle system. It is placed in the fuel passage before the idle air bleed and economizer.

- The IDLE AIR BLEED works with the economizer and bypass to add air bubbles in the fuel flowing to the idle port. The air bubbles help break up or atomize the fuel. This makes the air-fuel mixture burn more efficiently once it is in the engine.

- The IDLE PASSAGE carries the air-fuel slurry (mixture of liquid and air bubbles) to the idle screw port.

- The IDLE SCREW PORT is an opening into the air horn below the throttle valve.

- The IDLE MIXTURE SCREW allows adjustment of the size of the opening in the idle screw port. Turning the screw IN reduces the size of the idle port and the amount of fuel entering the horn. Turning the screw OUT increases the size of the idle port and enriches the fuel mixture at idle.

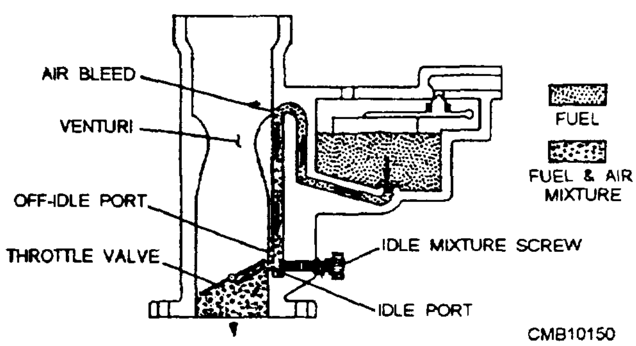


Figure 4-21.—Idle system.

Most modern carburetors have sealed idle mixture screws that are NOT normally adjusted. The seal prevents tampering with the factory settings of the idle mixture. Sometimes a plastic limiter cap is pressed over the idle mixture screws. They restrict how far the screws can be adjusted toward the rich or lean settings. Correcting idle screw adjustment on modern carburetors is critical to proper exhaust emission.

The basic operation of the idle system is as follows:

- At idle, fuel flows out of the fuel bowl, through the main discharge tube, and into the low-speed jet. The low-speed jet restricts maximum fuel flow.

- At the bypass, outside air is pulled into the idle system. This partially atomizes the fuel into slurry. As the air and fuel bubbles pass through the economizer, the air bubbles are reduced in size to further improve mixing.

- The fuel and air slurry then enters the idle screw port. The setting of the idle screw controls how much fuel enters the air horn at idle.

- With the throttle plate closed, high intake manifold pressure pulls fuel out of the idle system.

Off Idle System

The off idle, also known as the part throttle, feeds more fuel into the air horn when the throttle plate is partially open. It is an extension of the idle system. It functions above approximately 800 rpm or 20 mph. Without the off idle system, the fuel mixture would become too lean slightly above idle. The idle system alone is not capable of supplying enough fuel to the air stream passing through the carburetor. The off idle system helps supply fuel during the change from idle to high speed.

Basic off idle system operation is as follows:

- The driver presses down on the accelerator and cracks open the throttle plate. As the throttle plate swings open, the off idle ports are exposed to intake manifold vacuum.

- Vacuum then begins to pull fuel out of the idle screw and the off idle port. This action provides enough extra fuel to mix with the additional air flowing around the throttle plate.

Acceleration System

The carburetor acceleration system, like the off idle system, provides extra fuel when changing from the idle system to the high-speed system. The acceleration system squirts a stream of fuel into the air horn when the fuel pedal is pressed and the throttle plates swing open. Without the acceleration system, too much fuel would rush into the engine, as the throttle quickly opened. The mixture would become too lean for combustion and the engine would STALL or HESITATE. The acceleration system prevents a lean air-fuel mixture from upsetting a smooth increase in engine speed.

The basic parts of the acceleration system are the pump linkage, the accelerator pump, the pump check ball, the pump reservoir, the pump check weight, and the pump nozzle.

- The ACCELERATOR PUMP develops the pressure to force fuel out of the pump nozzle and into the air horn. There are two types of accelerator pumps—piston and diaphragm type (figs. 4-22 and 4-23).

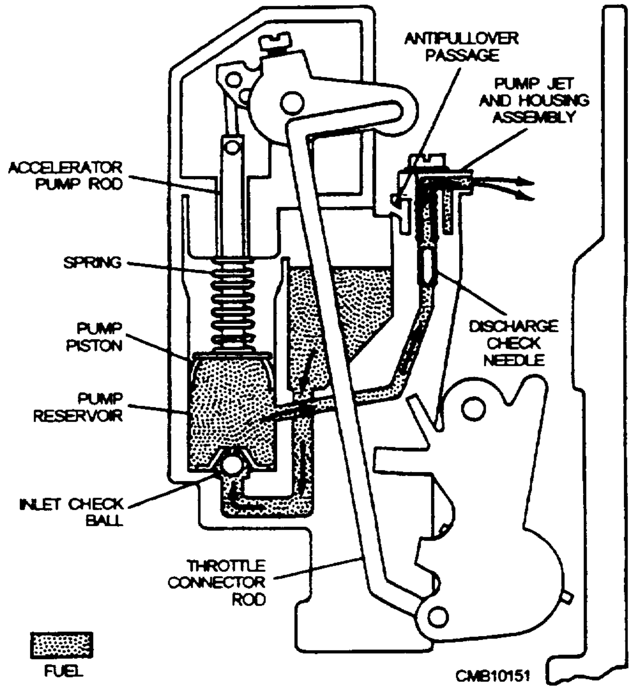


Figure 4-22.—Piston accelerator pump.

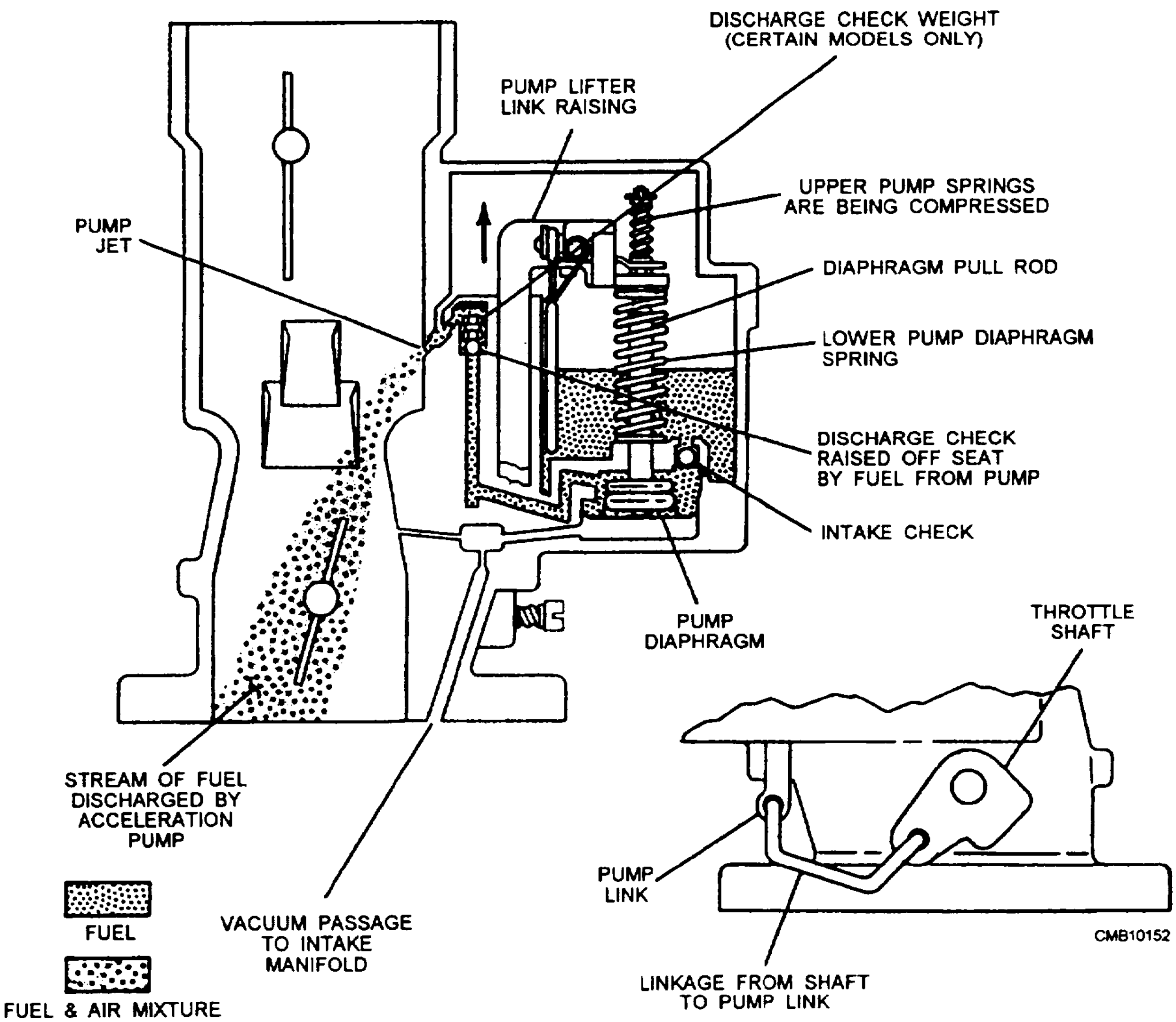


Figure 4-23.—Diaphragm accelerator pump.

• The PUMP CHECK BALL only allows fuel to flow into the pump reservoir. It stops fuel from flowing back into the fuel bowl when the pump is actuated.

• The PUMP CHECK WEIGHT prevents fuel from being pulled into the air horn by venturi vacuum. Its weight seals the passage to the pump nozzle and prevents fuel siphoning.

• The PUMP NOZZLE, also known as the pump jet, has a fixed opening that helps control fuel flow out of the pump. It also guides the fuel stream into the center of the air horn.

The basic operation of the acceleration system is as follows:

• The pump piston or diaphragm is pushed down in the pump chamber, as the throttle plate is opened, forcing fuel through the outlet passage.

• At the same moment, the pump check ball will seat, keeping fuel from being pumped back into the float bowl.

• The pump check weight will be forced off its seat, allowing fuel to pass to the pump discharge nozzle, and then discharged into the carburetor.

• The pump piston or diaphragm is raised in the pumping chamber when the throttle plate is closed, causing the pump check weight to seat blocking the outlet passageway.

• At the same time, the pump check ball is pulled off its seat and fuel is pulled into the pump chamber from the float bowl.

• The pump chamber is filled with fuel and ready for discharge whenever the throttle plate is opened.

The linkage between the accelerator pump and the throttle cannot be solid. If it were, the pump would act as a damper, not allowing the throttle to be opened and closed readily. The linkage activates the pump through a slotted shaft When the throttle is closed, the pump is held by its linkage. When the throttle is open, the pump is activated by being pushed down by a spring that is called a duration spring (fig. 4-24). The tension of the duration spring controls the length of time that the stream of fuel lasts. The spring is calibrated to specific applications. Too much spring pressure will cause fuel to be discharged too quickly, resulting in reduced fuel economy. Too little spring pressure will result in the fuel being discharged too slowly, causing engine hesitation.

High-Speed System

The, high-speed system, also called the main metering system, supplies the engine air-fuel mixture at normal cruising speeds. This system begins to function when the throttle plate is opened wide enough for the venturi action. Air flow through the carburetor must be relatively high for venturi vacuum to draw fuel out of the main discharge tube. The high-speed system

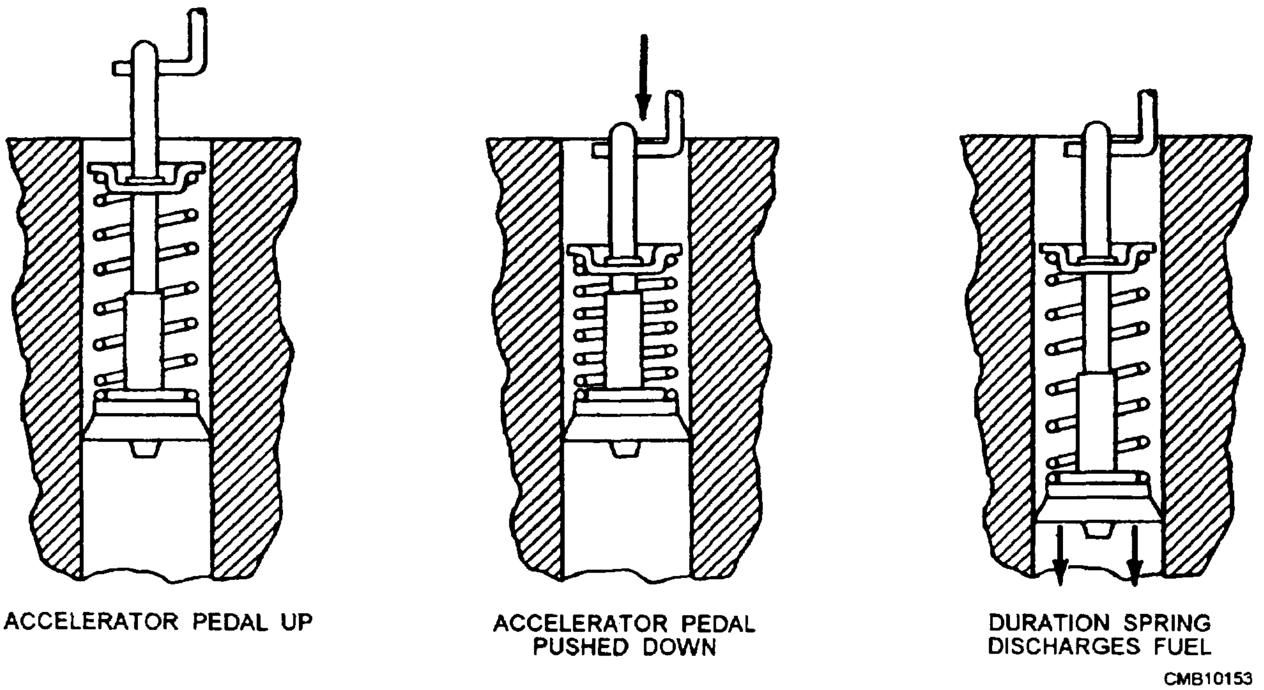


Figure 4-24.—Duration spring.

provides the leanest, most fuel efficient air-fuel ratio. It functions from about 20 to 55 mph or 2,000 to 3,000 rpm.

The high-speed system is the simplest system. It consists of the high-speed jet, the main discharge passage, the emulsion tube, the air bleed, and the venturi.

- The HIGH-SPEED JET is a fitting with a precision hole drilled into the center. This fitting screws into a threaded hole in the fuel bowl. One jet is used for each air horn. The hole size determines how much fuel flows through the system. A number is stamped on the high-speed jet to denote the diameter of the hole. Since jet numbering systems vary, refer to the manufacturer's manual for information on jet size.

- The EMULSION TUBE and AIR BLEED add air to the fuel flowing through the main discharge tube. The premixing of air with fuel helps the fuel atomize, as it is discharged into the air horn.

- The VENTURI is the hourglass shape, formed in the side of the carburetor air horn. One or two booster venturis (fig. 4-25) can be added inside the primary venturi to increase vacuum at lower engine speeds.

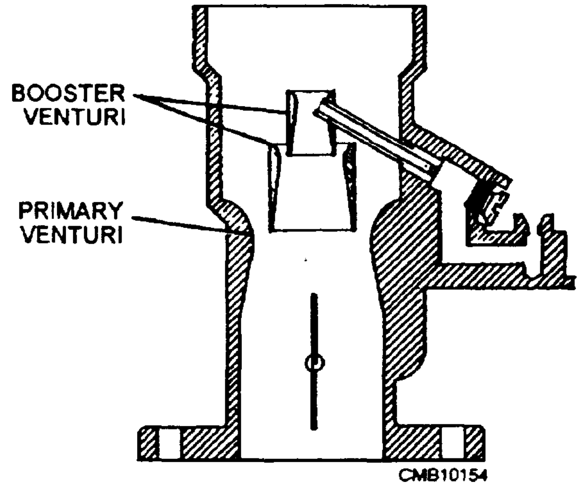


Figure 4-25.—Booster venturi

The basic operation of the high-speed system is as follows:

- When the engine speed is high enough, air flow through the carburetor forms a high vacuum in the venturi. The vacuum pulls fuel through the main metering system.

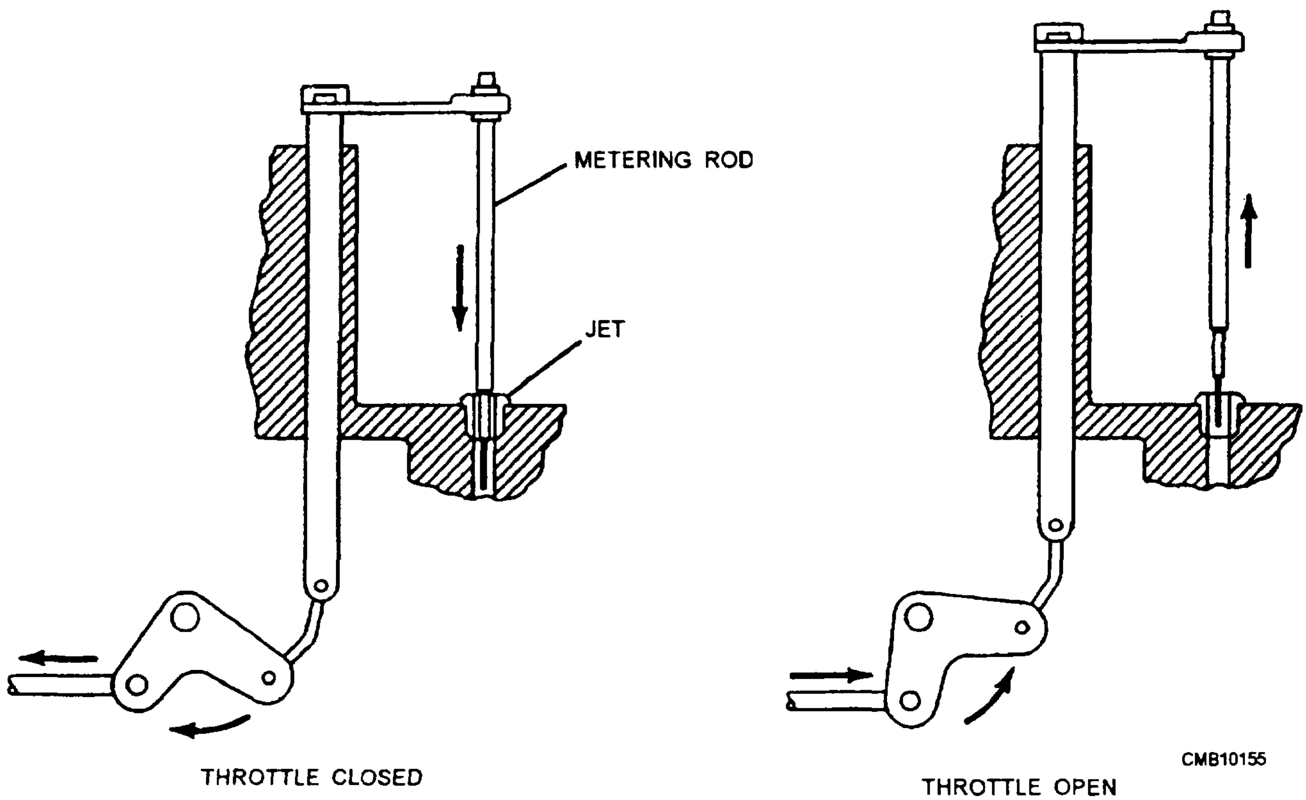


Figure 4-26.—Mechanically operated metering rod.

- The fuel flows through the main jet that meters the amount of fuel entering the system. The fuel then flows into the main discharge tube and emulsion tube.

- The emulsion tube causes air from the air bleed to mix with the fuel. The fuel, mixed with air, is finally pulled out the main nozzle and into the engine.

Full-Power System

The full-power system provides a means of enriching the fuel mixture for high-speed, high-power conditions. This system operates, for example, when the driver presses the fuel pedal to pass another vehicle or to climb a steep hill. The full-power system is an addition to the high-speed system. Either a metering rod or a power valve (jet) can be used to provide variable, high-speed air-fuel ratio.

A metering rod is a stepped rod that moves in and out of the main jet to alter fuel flow. When the rod is down inside the jet, flow is restricted and a leaner fuel mixture results. When the rod is pulled out of the jet, flow is increased and a richer fuel mixture results for more power output. The metering rod is either mechanical-linkage or engine-vacuum operated.

- The MECHANICAL LINKAGE metering rod (fig. 4-26) is linked to the throttle lever. Whenever the throttle is opened wide, the linkage lifts the metering rod out of the jet. When the throttle is closed, the linkage lowers the metering rod into the jet.

- 'The VACUUM OPERATED metering rod (fig. 4-27) that is controlled by engine vacuum is connected to a diaphragm. At steady speeds, power demands are low and engine vacuum is high, and the piston pushes the metering rod into the jet against spring pressure, restricting the flow to the discharge tube. When the load increases, vacuum decreases, causing the piston spring to lift the metering rod out of the jet, progressively increasing the flow of fuel to the discharge tube.

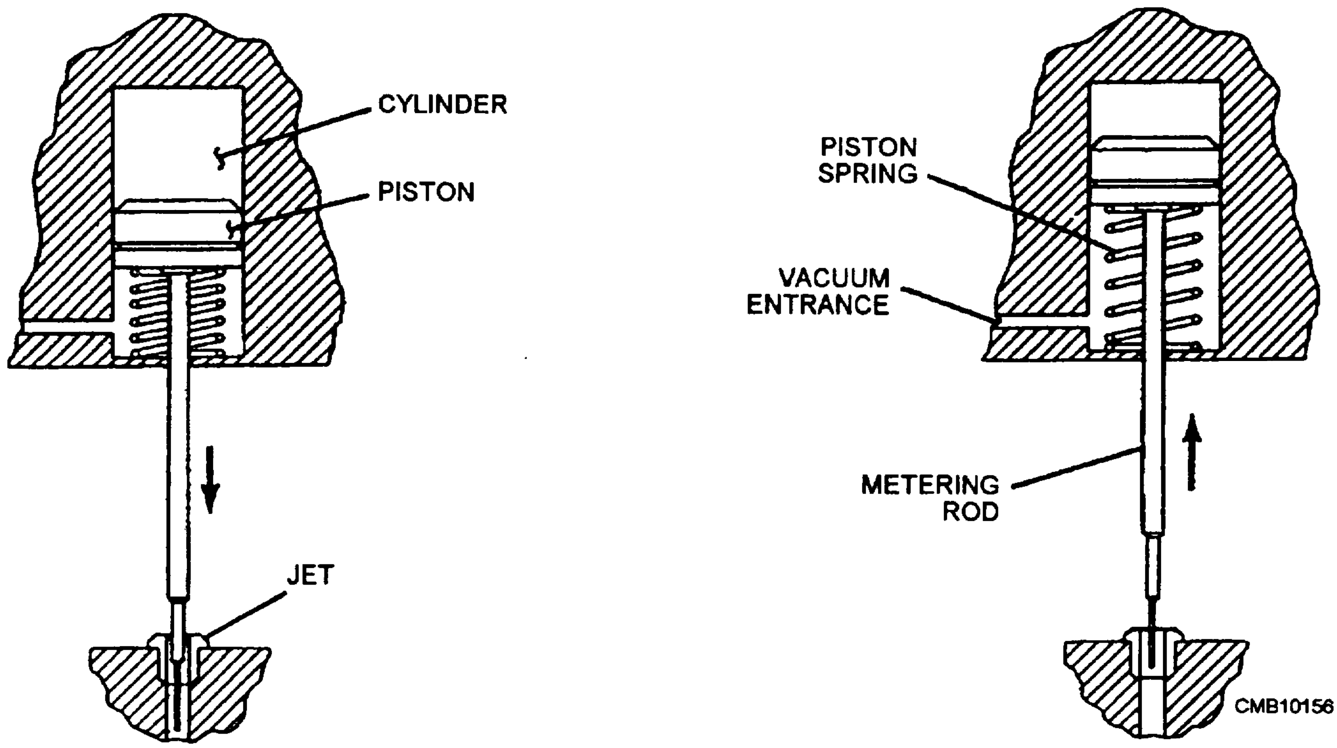


Figure 4-27.—Vacuum operated metering rod.

A vacuum power jet valve (fig. 4-28), also known as an economizer, performs the same function as a metering rod; it provides a variable high-speed fuel mixture. A power jet valve consists of a fuel valve, a vacuum diaphragm, and a spring. The spring holds the power valve in the normally OPEN position. A vacuum passage runs to the power valve diaphragm. When the power valve is open, it serves as an extra jet that feeds fuel into the high-speed system.

When the engine is cruising at normal highway speeds, engine intake manifold vacuum is high. This vacuum acts on the power valve diaphragm and pulls the fuel valve closed. No additional fuel is added to the metering system under normal conditions; however, when the throttle plate is swung open for passing or climbing a hill, engine vacuum drops. The spring in the power valve can push the fuel valve open. Fuel flows through the power valve and into the main metering system, adding more fuel for more engine power.

Choke System

When the engine is cold, the fuel tends to condense into large drops in the manifold, rather than vaporizing. By supplying a richer mixture (8:1 to 9:1), there will be enough vapor to assure complete combustion. The carburetor is fitted with a choke system to provide this richer mixture. The choke system provides a very rich mixture to start the engine and to make the mixture less rich gradually, as the engine reaches operating temperature. The two types of choke systems are the manual and automatic:

- The manual choke system (fig. 4-29) was once the most popular way of controlling the choke plate; however, because of emissions regulations the possible danger when used with catalytic converters and technological advances in automatic choke systems, manual chokes are not often used today. In the manual choke system, the choke plate is operated by a flexible cable that extends into the operator's compartment. As the control is pulled out, the choke plate will be closed, so the engine can be started. As the control is pushed back in, the position of the choke plate is adjusted to provide the proper mixture. The following are two features that are incorporated into the manual choke to reduce the possibility of the engine flooding by automatically admitting air into the engine.

- A spring-loaded poppet valve (fig. 4-30) that is automatically pulled open by the force of the engine intake strokes.

- An off-center choke valve (fig. 4-31) that creates a pressure differential between the two sides of the choke plate when it is subjected to engine intake, causing it to be pulled open against the force of spring loaded linkage.

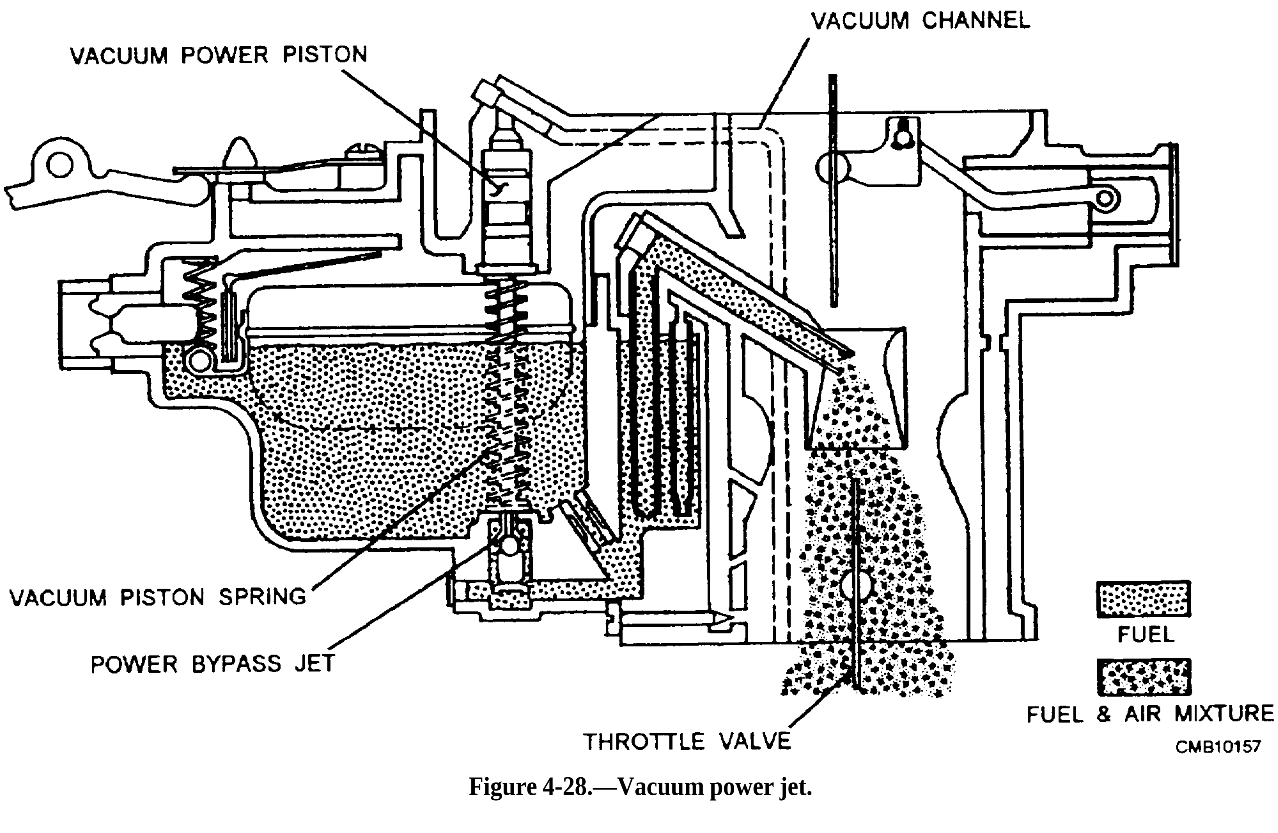


Figure 4-28.—Vacuum power jet.

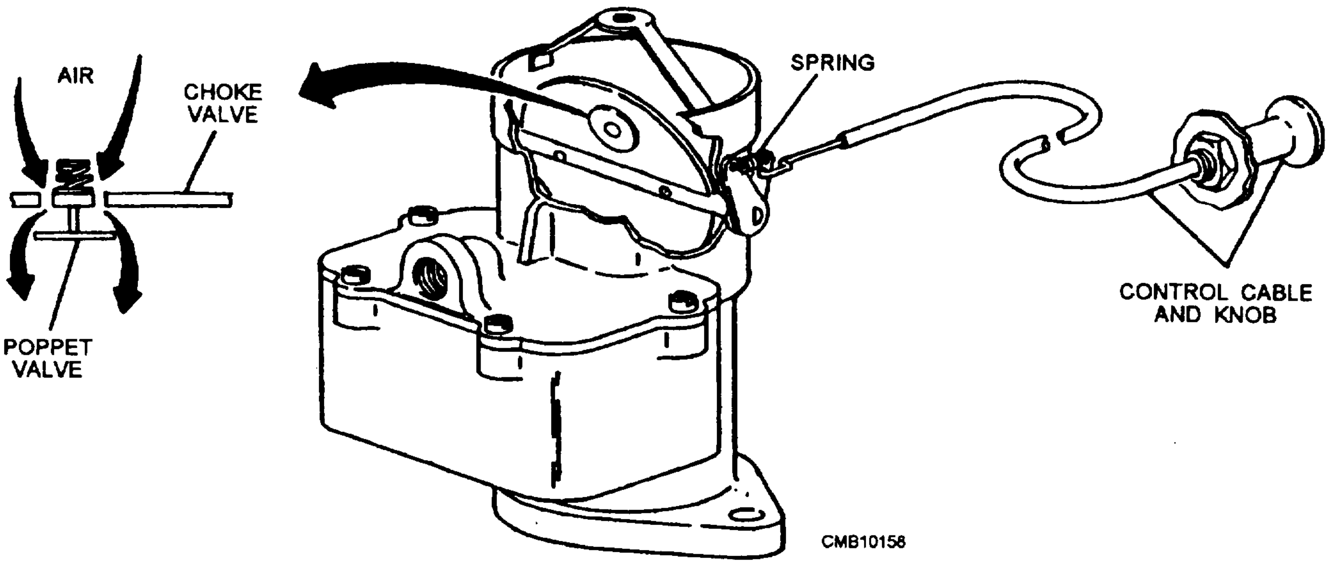


Figure 4-29.—Manual choke system.

● Automatic chokes (fig. 4-32) have replaced the conventional manual choke. They control the air-fuel ratio for quick starting at low temperature and also provide for the proper amount of choking to enrich the air-fuel mixture for all conditions of engine operation

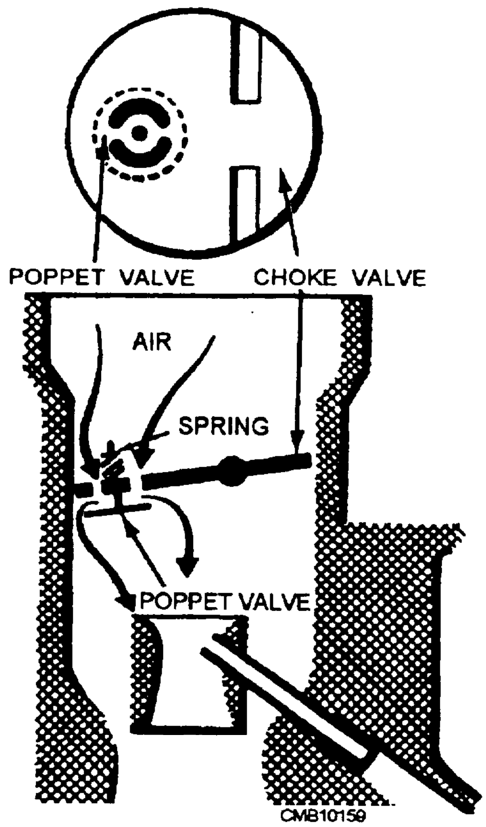


Figure 4-30.—Spring-loaded poppet valve in the choke valve.

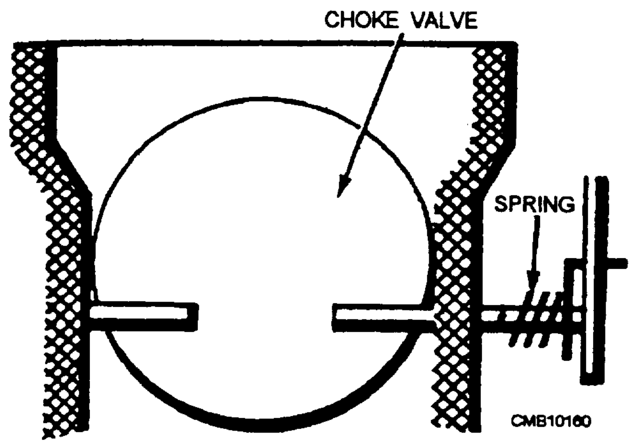


Figure 4-31.—Off center choke valve.

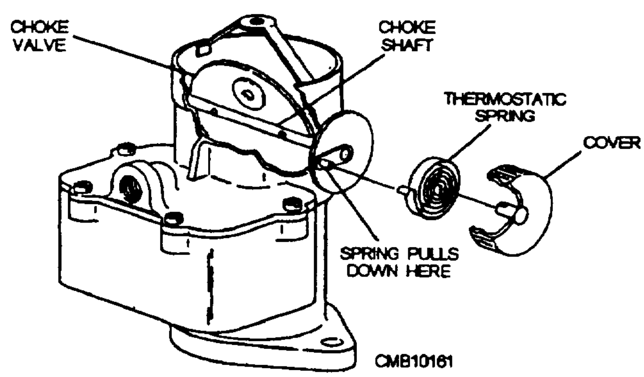


Figure 4-32.—Automatic choke.

during the warm-up period. An automatic choke system has a choke plate (valve), a thermostatic spring, and other parts depending upon choke design.

- The choke plate is a butterfly (disc) valve near the top of the carburetor air horn. When the choke plate is closed, it blocks normal air flow through the carburetor.

- The thermostatic spring is a bimetal spring (spring made of two dissimilar metals) which may be used to open and close the choke. The two metals have a different rate of expansion that make the spring coil tighter when cold and uncoils when heated. This coiling-uncoiling action is used to operate the choke.

The basic operation of the automatic choke system is as follows:

- With the engine cold, the thermostatic spring holds the choke closed. When the engine is started, the closed choke causes high vacuum in the carburetor air horn. This pulls a large amount of fuel out of the main discharge tube.

- As the engine and thermostatic spring warm, the spring uncoils and opens the choke plate. ‘This action produces a leaner mixture. A warm engine will not run properly if the choke were to remain closed.

Various methods are used to control the warming of the choke thermostatic spring. The four methods of providing controlled heat to the thermostatic spring are as follows: electricity, engine coolant, well-type heated, and exhaust manifold.

- ELECTRICITY (fig. 4-33) uses an electric coil to heat the thermostatic spring. The heating coil is switched on with the ignition switch. Some systems use a control unit that prevents power from reaching the electric coil until the engine compartment reaches a desired temperature.

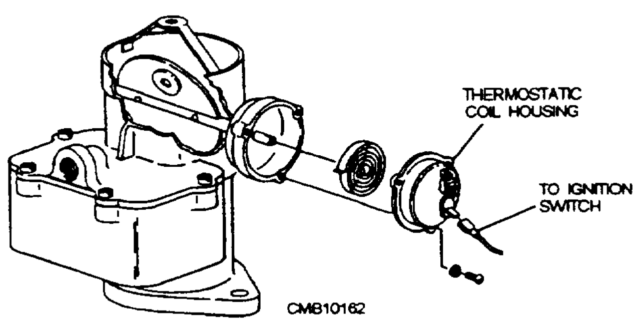


Figure 4-33.—Electric choke.

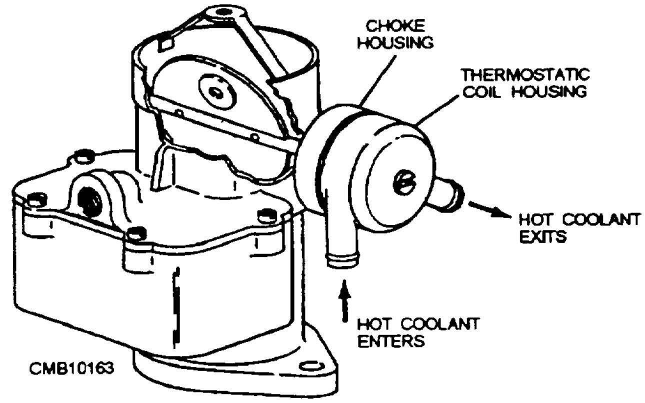


Figure 4-34.—Engine coolant heated choke.

- ENGINE COOLANT (fig. 4-34) uses a passage in the thermostat housing to circulate engine coolant for heating the thermostatic spring.

- WELL-TYPE HEATED (fig. 4-35) mounts the thermostatic spring in the top of the exhaust manifold. As the engine and manifold warms, the thermostatic spring uncoils to open the choke.

- The EXHAUST MANIFOLD (fig. 4-36) uses heat from the exhaust manifold to heat the thermostatic spring. The exhaust heat is brought to the choke through the means of a heat tube. The heat tube passes through the exhaust manifold, so as it takes in fresh air via the choke stove, it picks up heat from the exhaust without sending any actual exhaust fumes to the choke mechanism.

When the choke system is operating during warm-up, the engine must run at a faster idle speed to improve drivability and prevent flooding. To accomplish this, fit

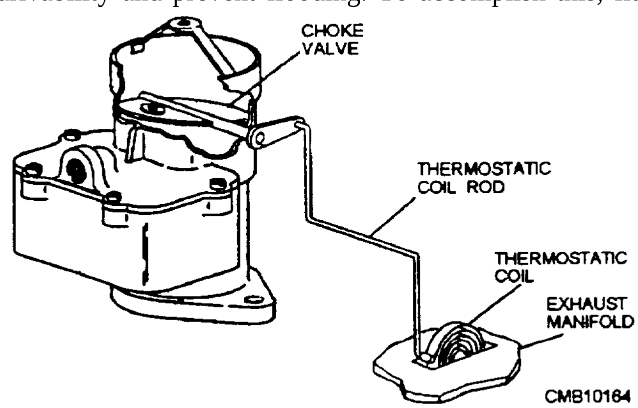


Figure 4-35.—Well-type exhaust-heated choke.

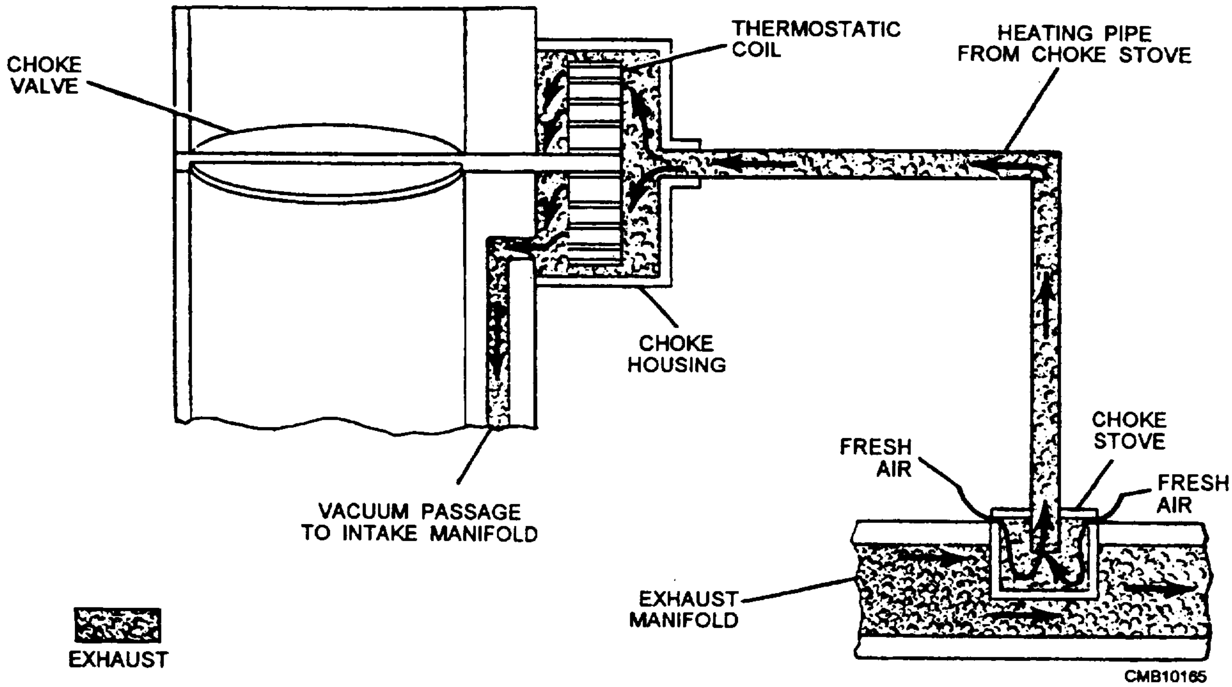


Figure 4-36.—Exhaust-manifold heat-tube choke.

the carburetor with a fast idle cam (fig. 4-37) that is operated by linkage from the choke.

When the choke closes, the fast idle cam swings around in front of the fast idle screw. As a result, the fast idle cam and fast idle screw prevent the throttle plate from closing. Engine idle speed is increased to smooth cold engine operation and prevents stalling. As soon as the engine warms, the choke opens and the fast idle cam is deactivated. When the throttle is opened, the choke linkage swings away from the fast idle screw and the engine returns to curb idle (normal, hot idle speed).

If for some reason the engine should flood when it is cold, a device is needed to open the choke, so air may be admitted to correct the condition. This is accomplished

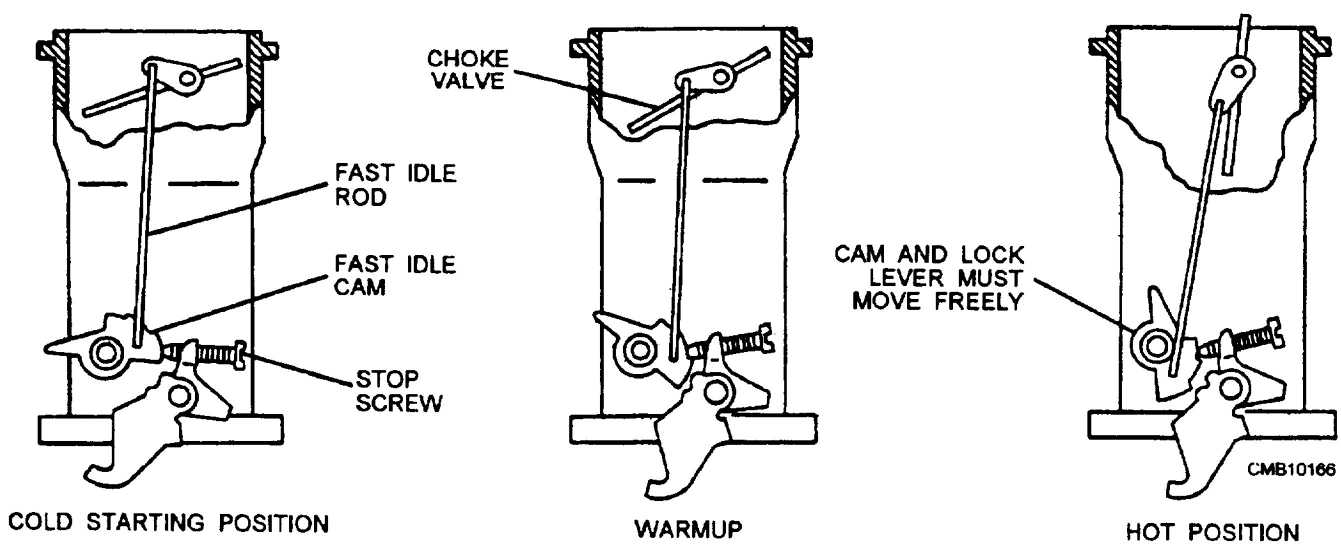


Figure 4-37.—Fast idle cam operation.

by the choke unloader (fig. 4-38). The choke unloader can be either mechanical- or vacuum-operated.

A mechanical choke unloader physically opens the choke plate any time the throttle swings fully open. It uses a metal lug on the throttle lever. When the throttle lever moves to the fully opened position, the lug pushes on the choke linkage (fast idle linkage). This provides the operator a means of opening the choke. Air can then enter the air horn to help clear a flooded engine (engine with too much liquid fuel in the cylinders and intake manifold).

A vacuum choke unloader (fig. 4-39). also called a choke brake, uses engine vacuum to crack open the choke plate as soon as the engine starts. It automatically prevents the engine from flooding.

Before the engine starts, the choke spring holds the choke plate almost completely closed. This action primes the engine with enough fuel for starting. Then as the engine starts, the intake manifold vacuum acts on the choke brake diaphragm. The diaphragm pulls the choke linkage and lever to swing the choke plate open slightly. This action helps avoid an overly rich mixture and improves cold engine drivability.

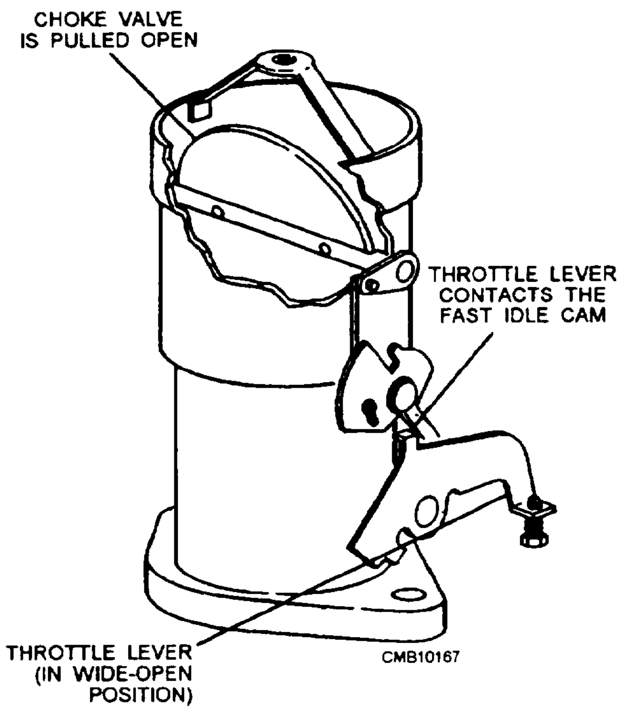


Figure 4-38.—Choke unloader.

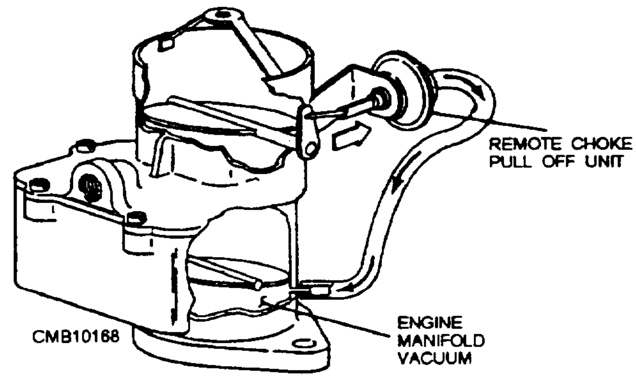


Figure 4-39.—Vacuum choke unloader.

CARBURETOR ACCESSORIES

There are several devices used on carburetors to improve drivability and economy. These devices are as follows: the fast idle solenoid, the throttle return dashpot, the hot idle compensator, and the altitude compensator. Their applications vary from vehicle to vehicle.

Fast Idle Solenoid

A fast idle solenoid, also known as an antidieseling solenoid (fig. 4-40), opens the carburetor throttle plates during engine operation but allows the throttle plates to close as soon as the engine is turned off. In this way, a faster idle speed can be used while still avoiding dieseling (engine keeps running even though the ignition key is turned off). This is a particular problem with newer emission controlled vehicles due to higher operating temperatures, higher idle speeds, leaner fuel mixtures, and lower octane fuel.

When the engine is running, current flows to the fast idle solenoid, causing the plunger to move outward. The throttle plates are held open to increase engine speed. The plunger is adjustable, so the idle speed can be adjusted. When the engine is turned off, current flow to the solenoid stops. The solenoid plunger retracts and the throttle plates are free to swing almost closed.

Throttle Return Dashpot

The throttle return dashpot, also known as an antistall dashpot (fig. 4-41), acts as a damper to keep the throttle from closing too quickly when the accelerator pedal is suddenly released. It is commonly used on carburetors for automatic transmission equipped vehicles.

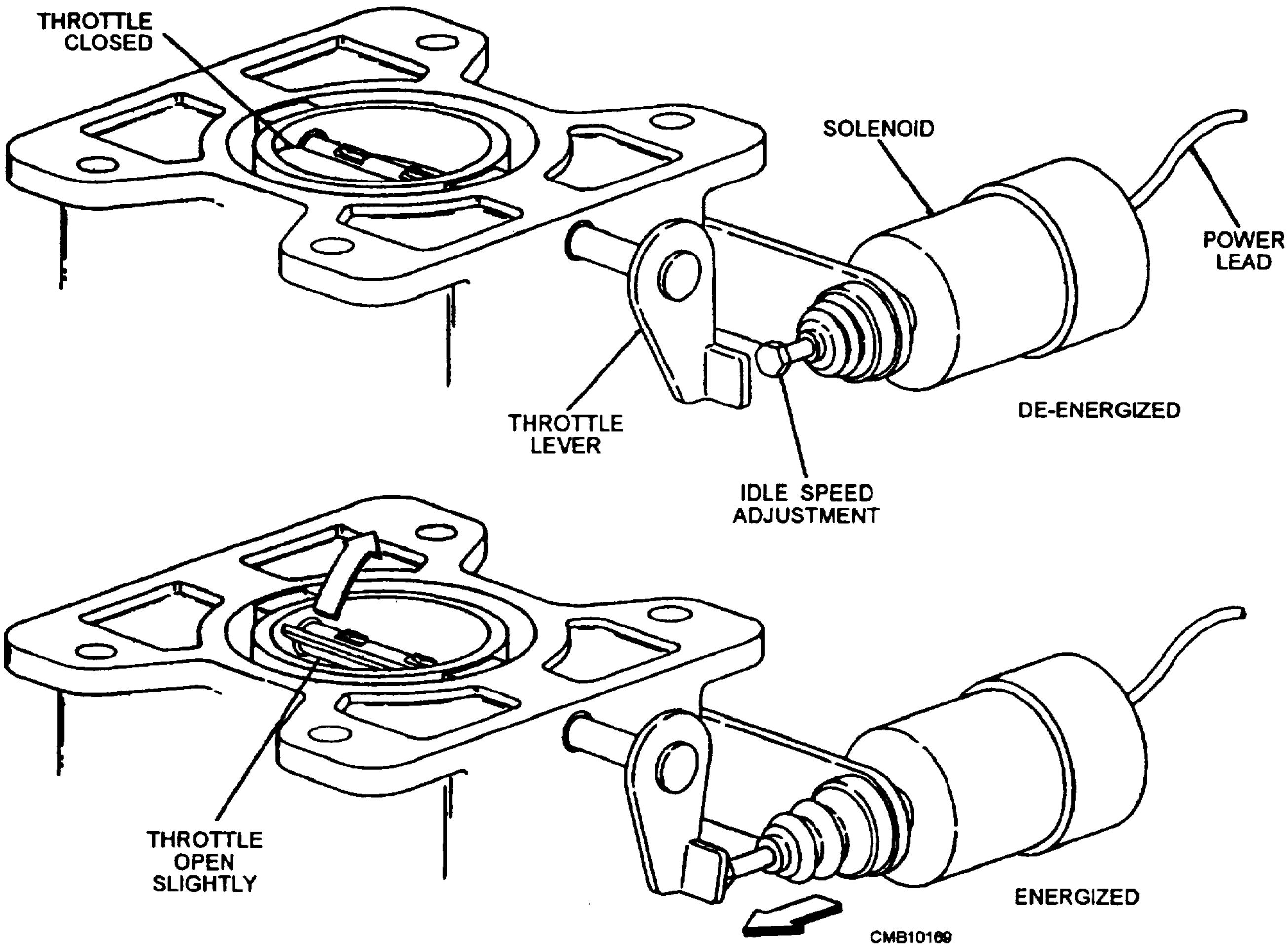


Figure 4-40.—Antidieseling solenoid operation.

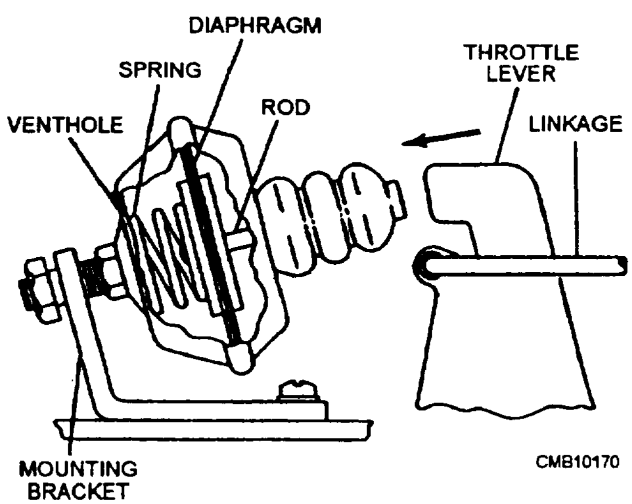


Figure 4-41.—Throttle return dashpot

Without the throttle return dashpot, the engine could stall when the engine quickly returned to idle. The drag of the automatic transmission could kill the engine.

The throttle return dashpot works something like a shock absorber. It uses a spring-loaded diaphragm mounted in a sealed housing. A small hole is drilledinto the diaphragm housing to prevent rapid movement of the dashpot plunger and diaphragm. Air must bleed out of the hole slowly.

When the vehicle is traveling down the road (throttle plates open), the spring pushes the dashpot plunger forward. When the engine returns to idle, the throttle lever strikes the extended dashpot plunger, and air leaks out of the throttle return dashpot, returning the engine slowly to curb idle. This action gives the automatic transmission enough time to disconnect (torque converter releases) from the engine without the engine stalling.

Hot Idle Compensator

A hot idle compensator (fig. 4-42) is a thermostatically controlled device that prevents engine stalling or a rough idle under high engine temperatures. The temperature sensitive valve admits extra air into the engine to increase idle speed and smoothness.

At normal engine temperatures, the hot-idle compensator valve remains closed, and the engine idles normally. When temperatures are high (prolonged idling periods, for example), fuel vapors can enter the air horn and enrich the air-fuel mixture. The hot idle compensator opens to allow extra air to enter the intake manifold. This action compensates for the extra fuel vapors and corrects the air-fuel mixture.

Altitude Compensator

An altitude compensator is used to change the air-fuel mixture in the carburetor with changes in the vehicle height above sea level. Normally the compensator is an aneroid device (bellows device that expands and contracts with changes in atmospheric pressure).

As a vehicle is driven up a mountain, the density of the air decreases. This condition tends to make the air-fuel mixture richer. The reduced air pressure causes the aneroid to expand, opening an air valve. Extra air flows into the air horn and the air-fuel mixture becomes leaner. The opposite occurs when the vehicle descends from the mountain. The greater air density and pressure tends to make the carburetor mixture too lean. The increased air pressure collapses the aneroid and the air valve closes. This action enriches the mixture enough to compensate for the low altitude.

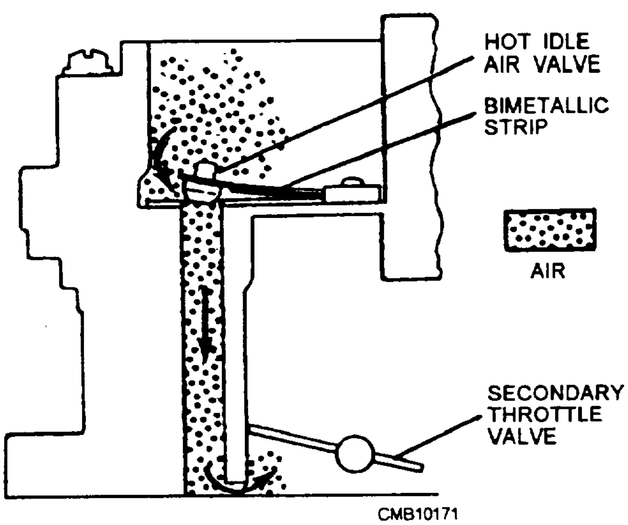


Figure 4-42.—Hot idle compensator.

COMPUTER-CONTROLLED CARBURETORS

A computer-controlled carburetor uses a solenoid-operated valve to respond to commands from the microcomputer (electronic control unit). The system uses various sensors to send information to the computer that calculates how rich or lean to set the carburetor air-fuel mixture. The system is also known as a computer controlled emission system which consists of the following: oxygen sensor, temperature sensor, pressure sensor, electromechanical carburetor, mixture control solenoid, computer, and idle speed actuator. The function of each is as follows:

- The OXYGEN SENSOR, or exhaust gas sensor, monitors the oxygen content in the engine exhaust. The amount of oxygen in the exhaust indicates the richness (low oxygen content) or leanness (high oxygen content) of the air- fuel mixture. The sensor voltage output changes with any change in oxygen content in the exhaust gases.

- The TEMPERATURE SENSOR detects the operating temperature of the engine. Its resistance changes with the temperature of the engine. The change in resistance allows the computer to enrich the fuel mixture during cold engine operations.

- The MANIFOLD PRESSURE SENSOR (MAP) measures intake manifold vacuum and engine load. High engine load or power output causes intake manifold vacuum to drop. The pressure sensor then signals the computer with a change in resistance and current flow. As manifold pressure drops, the computer increases the air-fuel mixture for added power. As the manifold pressure increases, the computer makes the carburetor setting leaner for improved economy.

- The ELECTROMECHANICAL CARBURETOR has both electrical and mechanical control devices. It is commonly used with a computer control system.

- The MIXTURE CONTROL SOLENOID alters the air-fuel mixture in the electromechanical carburetor. Electrical signals from the computer activate the solenoid to open and close air and fuel passages in the carburetor.

- The COMPUTER, also called the electronic control unit (ECU), uses sensor information to operate the mixture control solenoid of the carburetor.

- The IDLE SPEED ACTUATOR is a tiny electric motor and gear mechanism that allows the computer to change engine idle speed by holding the throttle lever in the desired position.

Many of the components and sensors are also used in gasoline fuel injection systems, which we will discuss later in this chapter.

In a computer-controlled carburetor, the air-fuel ratio is maintained by cycling the mixture solenoid ON and OFF several times a second. Control signals from the computer are used to meter different amounts of fuel out of the carburetor. When the computer sends a rich command to the solenoid, the signal voltage to the mixture solenoid is in the OFF position more than it is ON, causing the solenoid to stay open more. During a lean signal the mixture solenoid has more ON time, causing less fuel to pass through the solenoid valve and the mixture becomes leaner.

NOTE

Computerized carburetor systems vary. For exact detail on a particular system, refer to the manufacturer's service manual, which will explain how the specific system functions.

CARBURETOR TROUBLES

Some of the engine troubles that can usually (but not ALWAYS) be traced to some fault in the carburetor system are as follows:

- EXCESSIVE FUEL CONSUMPTION can result from a high float level, a leaky float, a sticking metering rod or full power piston, a sticking accelerator pump, and/or too rich of an idling mixture.

- A SLUGGISH ENGINE may be the result of a poorly operating accelerator pump, a low float level, dirty or gummy fuel passages, or a clogged air cleaner.

- POOR IDLING, often characterized by a stalling of the engine, is usually due to a too rich idle mixture, a defective choke, or an incorrectly adjusted idle speed screw at the throttle plate.

- FAILURE OF THE ENGINE TO START may be caused by an incorrectly adjusted choke, clogged fuel lines, or air leak into the intake manifold.

- HARD STARTING OF A WARM ENGINE could be due to a defective or improperly adjusted throttle link.

- SLOW ENGINE WARM-UP may indicate a defective choke or defective radiator thermostat.

- SMOKY BLACK EXHAUST indicates a very rich air-fuel mixture.

- STALLING OF THE ENGINE AS IT WARMS could be caused by a defective choke or closed choke valve.

- A BACKFIRING ENGINE may be due to an incorrect, often lean, air-fuel mixture reaching the engine. In turn, this condition could be caused by a clogged fuel line or a fluctuating fuel level.

- An ENGINE RUNS BUT MISSES, the most likely cause is a vacuum leak at a vacuum hose or the intake manifold. In addition, it could be an improper air-fuel mixture reaching the engine due to clogged or worn carburetor jets or an incorrect fuel level in the float bowl.

Several quick checks can be made to see how well the carburetor is working. More accurate analysis requires test instruments, such as an exhaust gas analyzer and an intake manifold vacuum gauge. The quick checks are as follows:

1. FLOAT LEVEL ADJUSTMENT. With the engine warmed up and running at idle speed, remove the air cleaner. Carefully note the condition of the high-speed nozzle. If the nozzle tip is wet or is dripping fuel, the float level is probably too high. This could cause a continuous discharge of fuel from the nozzle, even at idle.

2. IDLE SYSTEM. If the engine does not idle smoothly after it is warmed up, the idle system could be at fault. Slowly open the throttle until the engine is running at about 3,000 rpm. If the speed does not increase evenly and the engine runs roughly through this speed range, the idle or main metering system is probably defective.

3. ACCELERATOR PUMP SYSTEM. With the air cleaner off and the engine not running, open the throttle suddenly. See if the accelerator pump system discharges a squirt of fuel into the air horn. The flow should continue for a few seconds after the throttle plate reaches the wide, open position.

4. MAIN METERING SYSTEM. With the engine warmed up and running at 2,000 rpm, slowly cover part of the air horn with a piece of stiff cardboard The engine should speed up slightly, since this action causes a normal operating main metering system to discharge more fuel.

WARNING

Do NOT use your hand to cover the air horn when performing this test.

Q5. *Name the seven basic carburetor systems?*

Q6. *What system maintains a steady working supply of fuel to a constant level in the carburetor?*

Q7. *What device acts as a damper to keep the throttle from closing too quickly when the accelerator pedal is suddenly released?*

Q8. *What sensor in a computerized carburetor system measures intake vacuum and engine load?*

GASOLINE FUEL INJECTION SYSTEMS

LEARNING OBJECTIVE: *Identify and describe the different gasoline fuel injection systems.*

A modern gasoline injection system uses pressure from an electric fuel pump to spray fuel into the engine intake manifold. Like a carburetor, it must provide the engine with the correct air-fuel mixture for specific operating conditions. Unlike a carburetor, however, PRESSURE, not engine vacuum, is used to feed fuel into the engine. This makes the gasoline injection system very efficient.

A gasoline injection system has several possible advantages over a carburetor type of fuel system. Some advantages are as follows:

- Improved atomization. Fuel is forced into the intake manifold under pressure that helps break fuel droplets into a fine mist.

- Better fuel distribution. Equal flow of fuel vapors into each cylinder.

- Smoother idle. Lean fuel mixture can be used without rough idle because of better fuel distribution and low-speed atomization.

- Lower emissions. Lean efficient air-fuel mixture reduces exhaust pollution.

- Better cold weather drivability. Injection provides better control of mixture enrichment than a carburetor.

- Increased engine power. Precise metering of fuel to each cylinder and increased air flow can result in more horsepower output.

- Fewer parts. Simpler, late model, electronic fuel injection system have fewer parts than modern computer-controlled carburetors.

There are many types of gasoline injection systems. Before studying the most common ones, you should have a basic knowledge of the different classifications. Systems are classified either single- or multi-point injection and indirect or direct injection.

The point or location of fuel injection is one way to classify a gasoline injection system. A single-point injection system, also call throttle body injection (TBI), has the injector nozzles in a throttle body assembly on top of the engine. Fuel is sprayed into the top center of the intake manifold

A multi-point injection system, also called port injection, has an injector in the port (air-fuel passage) going to each cylinder. Gasoline is sprayed into each intake port and toward each intake valve. Thereby, the term multi-point (more than one location) fuel injection is used.

An indirect injection system sprays fuel into the engine intake manifold. Most gasoline injection systems are of this type. Direct injection forces fuel into the engine combustion chambers. Diesel injection systems are direct type.

There are three basic configurations of gasoline fuel injection—timed, continuous, and throttle body.

TIMED FUEL INJECTION SYSTEM

Timed fuel injection systems for gasoline engines inject a measured amount of fuel in timed bursts that are synchronized to the intake strokes of the engine. ‘limed injection is the most precise form of fuel injection but is also the most complex. There are two basic forms of timed fuel injection-mechanical and electronic.

The basic operation of a mechanical-timed injection system (fig. 4-43) is as follows:

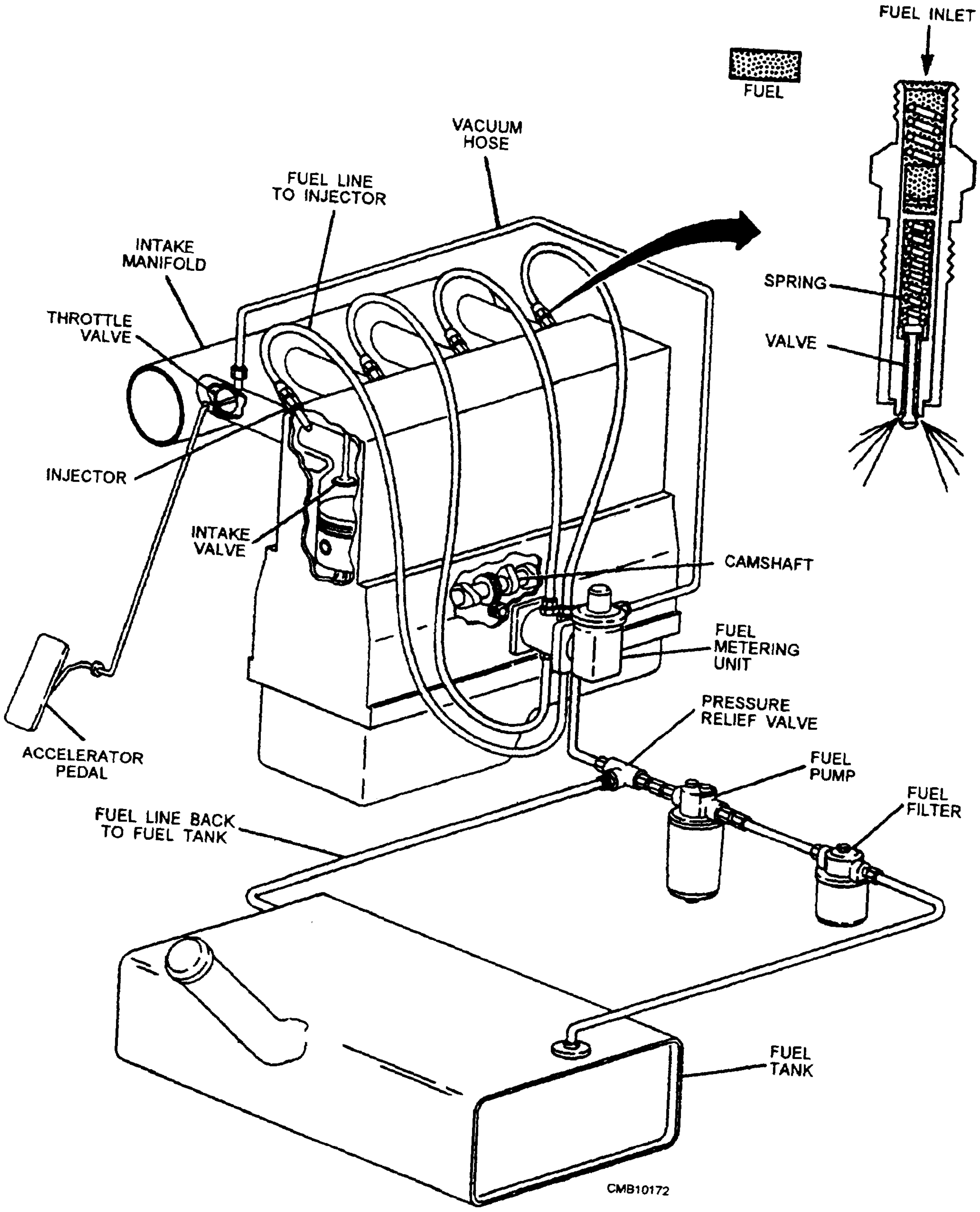


Figure 4-43.—Mechanical-timed injection.

● A high-pressure electric pump draws fuel from the fuel tank and delivers it to the metering unit. A pressure relief valve is installed between the fuel pump and the metering unit to regulate fuel line pressure by bleeding off excess fuel back to the tank.

● The metering unit is a pump that is driven by the engine camshaft. It is always in the same rotational relationship with the camshaft, so it can be timed to feed the fuel to the injectors just at the right moment.

● Each injector contains a spring-loaded valve that is opened by fuel pressure, injecting fuel into the intake at a point just before the intake valve.

● The throttle valve regulates engine speed and power output by regulating manifold vacuum, which, in turn, regulates the amount of fuel supplied to the injectors by the metering pump.

The more common type of timed fuel injection is the electronic-timed fuel injection, also known as electronic fuel injection (EFI) (fig. 4-44). Anelectronic fuel injection system can be divided into four subsystems:

1. Fuel delivery system
2. Air induction system
3. Sensor system
4. Computer control system

The fuel delivery system of an EFI system includes an electric fuel pump, a fuel filter, a pressure regulator, the injector valves, and the connecting lines and hoses.

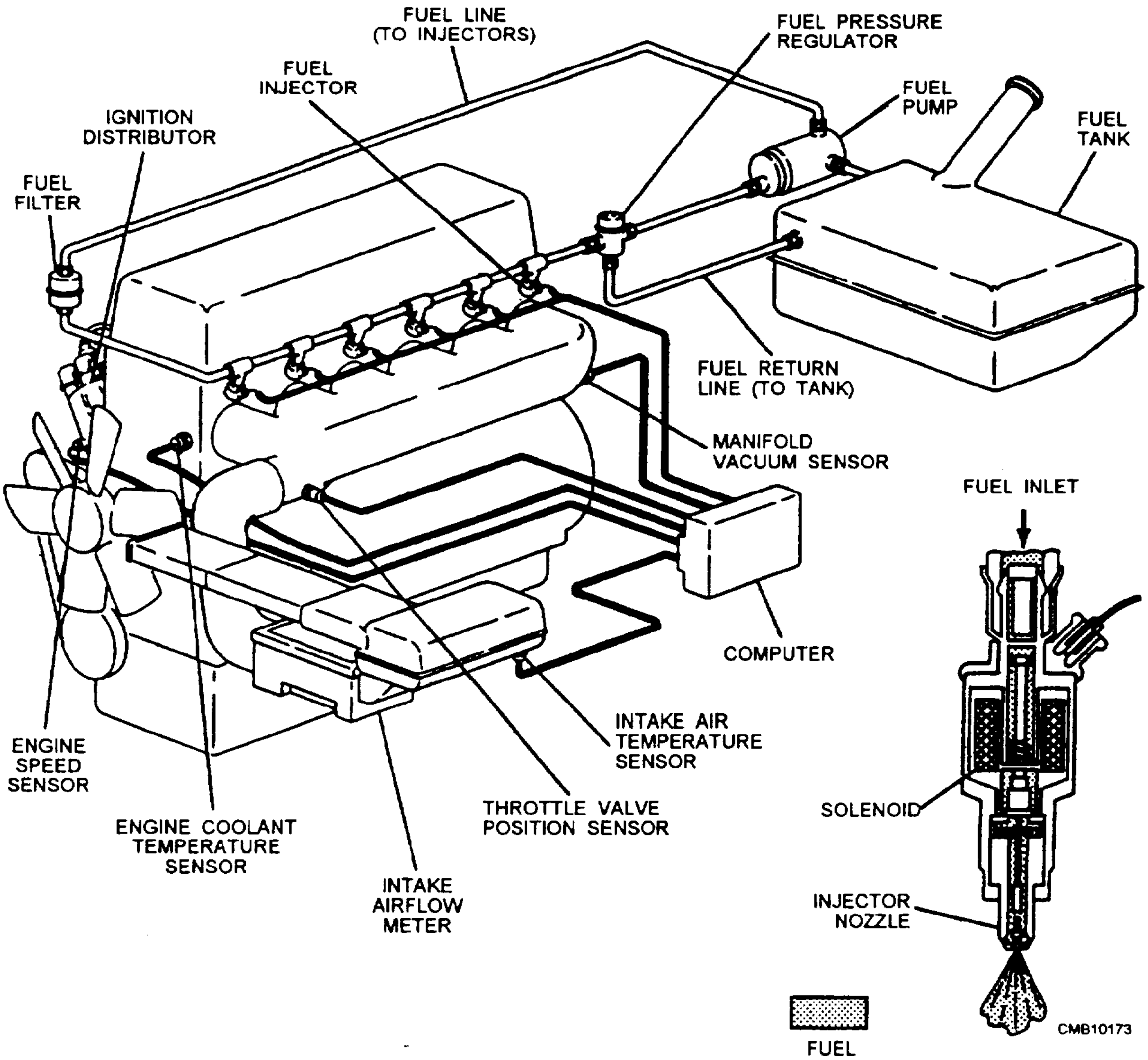


Figure 4-44.—Electronic-timed injection.

- The ELECTRIC FUEL PUMP draws fuel out of the tank and forces it into the pressure regulator.

- The FUEL PRESSURE REGULATOR controls the amount of pressure entering the injector valves. When sufficient pressure is attained, the regulator returns excess fuel to the tank. This maintains a preset amount of fuel pressure for injector valve operation.

- The FUEL INJECTOR for an EFI system is a coil or solenoid-operated fuel valve. When not energized, spring pressure keeps the injector closed, keeping fuel from entering the engine. When current flows through the injector coil or solenoid, the magnetic field attracts the injector armature. The injector opens, squirting fuel into the intake manifold under pressure.

The air induction system for the EFI typically consists of a throttle valve, sensors, an air filter, and connecting ducts.

The throttle valve regulates how much air flows into the engine. In turn, it controls engine power output. Like the carburetor throttle valve, it is connected to the gas pedal. When the pedal is depressed, the throttle valve swings open to allow more air to rush into the engine.

The EFI sensor system monitors engine operating conditions and reports this information to the computer. A sensor is an electrical device that changes circuit resistance or voltage with a change in a condition (temperature, pressure, position of parts, etc.). For example, the resistance of a temperature sensor may decrease as temperature increases. The computer can use the icreased current flow through the sensor to calculate any needed change in the injector valve opening. Typical sensors for an EFI system include the following:

1. Exhaust gas or oxygen sensor
2. Manifold pressure sensor
3. Throttle position sensor
4. Engine temperature sensor
5. Air flow sensor
6. Inlet air temperature sensor
7. Crankshaft position sensor

Since some of these sensors were discussed in the section on computerized carburetor systems, we will only concentrate on the sensors that are particular to the EFI system. These sensors are as follows:

- The THROTTLE POSITION SENSOR is a variable resistor connected to the throttle plate shaft. When the throttle swings open for more power or closes for less power, the sensor changes resistance and signals the computer. The computer can then enrich or lean the mixture as needed

- The AIR FLOW SENSOR is used in many EFI systems to measure the amount of outside air entering the engine. It is usually an air flap or door that operates a variable resistor. Increased air flow opens the air flap more to change the position of the resistor. Information is sent to the computer indicating air inlet volume.

- The INLET AIR TEMPERATURE SENSOR measures the temperature of the air entering the engine. Cold air is more dense, requiring a little more fuel. Warm air is NOT as dense as cold, requiring a little less fuel. The sensor helps the computer compensate for changes in outside air temperature and maintain an almost perfect air-fuel mixture ratio.

- The CRANKSHAFT POSITION SENSOR is used to detect engine speed It allows the computer to change injector openings with changes in engine rpm.

The signal from the engine sensors can be either a digital or an analog type output. Digital signals are on-off signals. An example is the crankshaft position sensor that shows engine rpm. Voltage output or resistance goes from maximum to minimum, like a switch. An analog signal changes in strength to let the computer know about a change in condition. Sensor internal resistance may smoothly increase or decrease with temperature, pressure, or part position. The sensor acts as a variable resistor.

Basic operation of an electronic-timed injection system is as follows:

- Fuel is fed by a high-pressure electric fuel pump to the injectors that are connected in parallel to a common fuel line.

- The fuel pressure regulator is installed in-line with the injectors to keep fuel pressure constant by diverting excess fuel back to the tank.

- Each injector contains a solenoid valve and is normally in a closed position. With a pressurized supply of fuel behind it, each injector will operate individually whenever electric current is applied to the solenoid valve.

● The electronic computer sends the electric impulses and provides the proper amount of fuel. The computer receives a signal for the ignition distributor to establish the timing sequence.

● By sending electric current impulses to the injectors in a sequence timed to coincide with the needs of the engine, the system will supply fuel to the engine as it should.

CONTINUOUS FUEL INJECTION SYSTEM

Continuous fuel injection systems (fig. 4-45) provide a continuous spray of fuel from each injector at a point in the intake port located just before the intake valve. Because the entrance of the fuel into the cylinder is controlled by the intake valve, the continuous system fulfills the requirements of a gasoline engine.

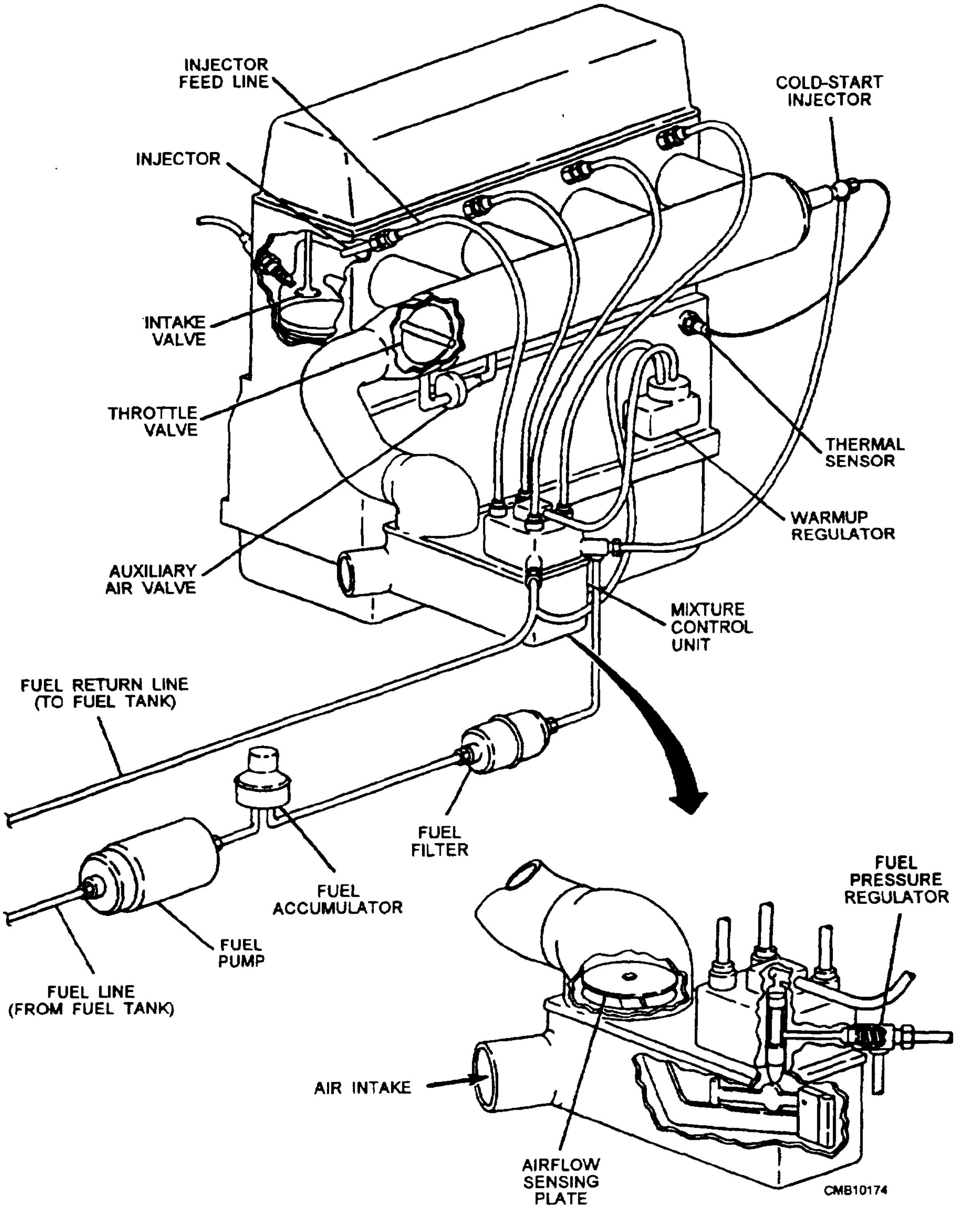


Figure 4-45.—Continuous fuel injection system.

Basic operation of a continuous fuel injection is as follows:

- Fuel is fed to the system by an electric fuel pump that delivers fuel to the mixture control unit. A fuel pressure regulator maintains fuel line pressure and sends excess fuel back to the tank.

- The mixture control unit regulates the amount of fuel that is sent to the injectors based on the amount of air flow through the intake and the engine temperature. The unit is operated by the air flow sensing plate and warm-up regulator.

- The accelerator pedal regulates the rate of air flow through the intake by opening and closing the throttle valve.

- A cold-start injector is installed in the intake to provide a richer mixture during engine start-up and warm-up. It is actuated by electric current from the thermal sensor any time the temperature of the coolant is below a certain level.

The injector for a continuous fuel injection system is a simple spring-loaded valve. It injects fuel all the time the engine is running. A spring holds the valve in a normally closed position with the engine OFF. This action keeps fuel from dripping into the engine. When the engine STARTS, fuel pressure builds and pushes the injector valve open. A steady stream of gasoline then sprays toward each intake valve. The fuel is pulled into the engine when the intake valves open

THROTTLE BODY INJECTION SYSTEM

The throttle body injection (TBI) system (fig. 4-46) uses one or two injector valves mounted in a throttle body assembly. The injectors spray fuel into the top of the throttle body air horn The TBI fuel spray mixes with the air flowing through the air horn. The mixture is then pulled into the engine by intake manifold vacuum. The throttle body injection assembly typically consists of the following: throttle body housing, fuel injectors, fuel pressure regulator, throttle positioner, throttle position sensor, and throttle plates.

- The THROTTLE BODY housing, like a carburetor body, bolts to the pad on the intake manifold. It houses the metal castings that hold the injectors, the fuel pressure regulator, and the throttle plates. The throttle plates are located in the lower section of the body. A linkage or cable connects the throttle plates with the accelerator pedal. An inlet fuel line and outlet return line connects to the fittings on the body.

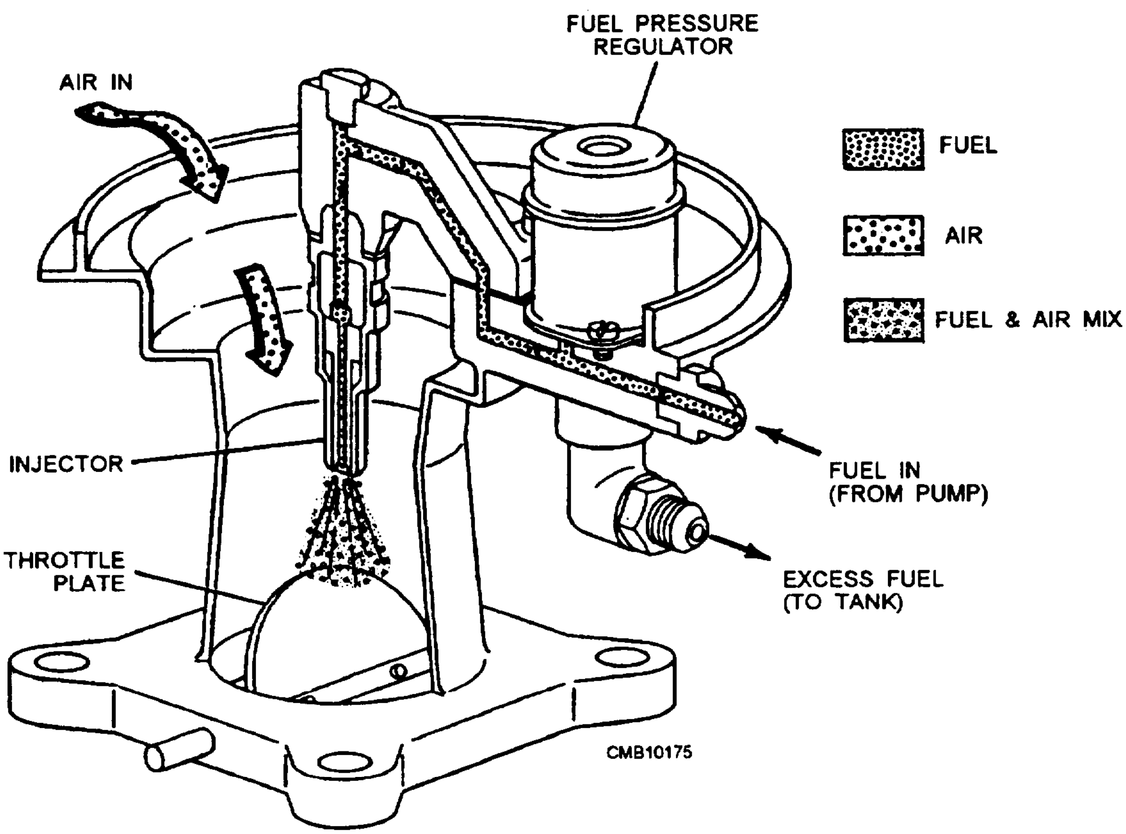


Figure 4-46.—Throttle body injection.

- The THROTTLE BODY INJECTOR consists of an electric solenoid coil, armature or plunger, ball or needle valve and seat, and injector spring. Wires from the computer connect to terminals on the injectors. When the computer energizes the injectors, a magnetic field is produced in the injector coil. The magnetic field pulls the plunger and valve up to open the injector. Fuel can then squirt through the injector nozzle and into the engine.

- The THROTTLE BODY PRESSURE REGULATOR consists of a fuel valve, a diaphragm, and a spring. When fuel pressure is low, the spring holds the fuel valve closed, causing pressure to build as fuel flows into the regulator from the fuel pump. When a preset pressure is reached, pressure acts on the diaphragm. The diaphragm compresses the spring and opens the fuel valve. Fuel can then flow back to the fuel tank, limiting the maximum fuel pressure at the injectors.

- ʹThe THROTTLE POSITIONER is used on throttle body assemblies to control engine idle speed. The computer actuates the positioner to open or close the throttle plates. In this way, the computer can maintain a precise idle speed with changes in engine temperature, load, and other conditions.

Although throttle body injection does not provide the precise fuel distribution of the direct port injection, it is much cheaper to produce and provide a much higher degree of precision fuel metering than a carburetor.

Q9. What type of fuel injection system is the most precise but is also the most complex?

Q10. In an electronic fuel injection system, what sensor is used to detect engine speed?

Q11. On a throttle body injection system, what device is used to control engine idle speed?

EXHAUST AND EMISSION CONTROL SYSTEMS

LEARNING OBJECTIVE: *Identify components of the exhaust and emission control systems. Describe the operation of the exhaust and emission control systems.*

Over the past several years, exhaust and emission control has greatly increased because of stringent antipollution laws and EPA guidelines. This has made the exhaust and emission control systems of vehicles invaluable and a vital part of today’s vehicles.

The waste products of combustion are carried away from the engine to the rear of the vehicle by the exhaust system where they are expelled to the atmosphere. The exhaust system also serves to dampen engine noise. The parts of a typical exhaust system include the following: exhaust manifold, header pipe, catalytic converter, intermediate pipe, muffler, tailpipe, hangers, heat shields, and muffler clamps.

The control of exhaust emissions is a difficult job. The ideal situation would be to have the fuel combine completely with the oxygen from the intake air. The carbon would then combine with the oxygen to form carbon dioxide (CO_2); the hydrogen would combine to form water (H_2O); and the nitrogen present in the intake would stand alone. The only other product present in the exhaust would be oxygen from the intake air that was not used in the burning of the fuel. In a real life situation, however, this is not what happens. The fuel never combines completely with the oxygen, and undesirable exhaust emissions are created as a result.

The most dangerous of the emissions is CARBON MONOXIDE (CO) which is a poisonous gas that is colorless and odorless. CO is formed as a result of insufficient oxygen in the combustion mixture and combustion chamber temperatures that are too low. Other exhaust emissions that are considered major pollutants are as follows:

- HYDROCARBONS (HC) are unburned fuel. They are particulate (solid) in form, and, like carbon monoxide, they are manufactured by insufficient oxygen in the combustion mixture and combustion chamber temperatures that are too low. Hydrocarbons are harmful to all living things. In any urban area where vehicular traffic is heavy, hydrocarbons in heavy concentrations react with the sunlight to produce a brown fog, known as photochemical smog.

- OXIDES OF NITROGEN (NO_X) are formed when nitrogen and oxygen in the intake air combine when subjected to high temperatures of combustion. Oxides of nitrogen are harmful to all living things.

The temperatures of the combustion chamber would have to be raised to a point that would melt pistons and valves to eliminate carbon monoxide and carbon dioxide emissions. This is compounded with the fact that oxides of nitrogen emissions go up with any increase in the combustion chamber temperature. Knowing these facts, it can be seen that emission control devices are necessary.

EXHAUST MANIFOLD

The exhaust manifold (fig. 4-47) connects all the engine cylinders to the exhaust system. It is usually made of cast iron. If the exhaust manifold is properly formed, it can create a scavenging action that will cause all of the cylinders to help each other get rid of exhaust gases. Back pressure (the force that the pistons must exert to push out the exhaust gases) can be reduced by making the manifold with smooth walls and without any sharp bends. All these factors are taken into consideration when the exhaust manifold is designed, and the best possible manifold is manufactured to fit into the confines of the engine compartment.

MANIFOLD HEAT CONTROL VALVE

On some gasoline engines, a valve is placed in the exhaust manifold to deflect exhaust gases toward a hot spot in the intake manifold until the engine reaches operating temperature (fig. 4-48). This valve is a flat metal plate that is the same shape as the opening that controls it. It pivots on a shaft and is operated by a thermostatic coil spring. The spring pulls the valve closed against a counterweight before warm-up. The spring expands as the engine warms up, and the counterweight pulls the valve open.

MUFFLER

The muffler (fig. 4-49) reduces the acoustic pressure of exhaust gases and discharges them to the atmosphere with a minimum of noise. The muffler usually is located at a point about halfway in the vehicle with the exhaust pipe between it and the exhaust manifold and the tailpipe leading from the muffler to the rear of the vehicle.

The inlet and outlet of the muffler usually is slightly larger than their connecting pipes, so that it may hook up by slipping over them. The muffler is then secured to the exhaust pipe and tailpipe by clamps.

A typical muffler has several concentric chambers with openings between them. The gas enters the inner chamber and expands, as it works its way through a series of holes in the other chambers and finally to the atmosphere. They must be designed also to quiet exhaust noise while creating minimum back pressure. High back pressure could cause loss of engine power and economy and also cause overheating.

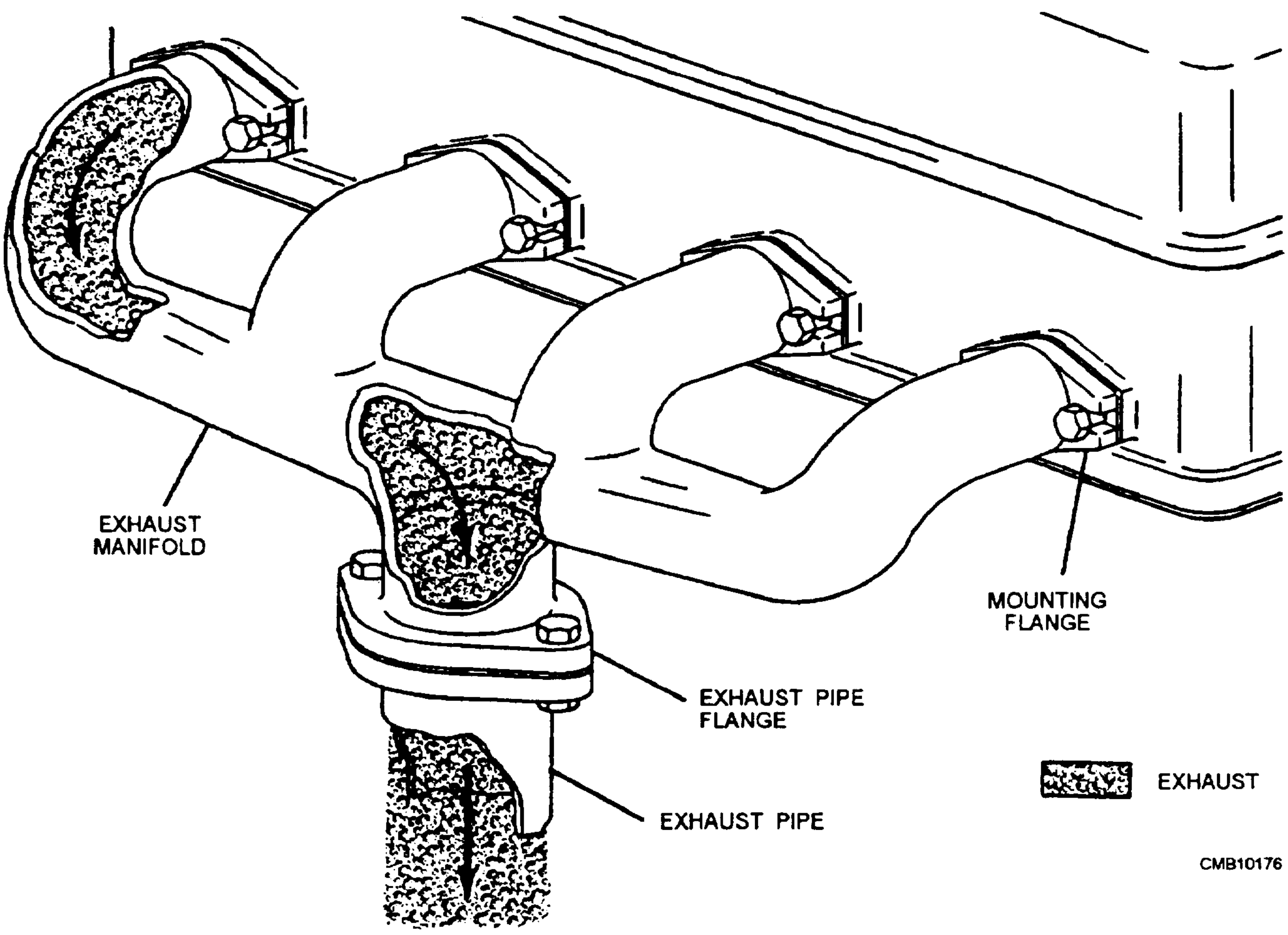


Figure 4-47.—Exhaust manifold.

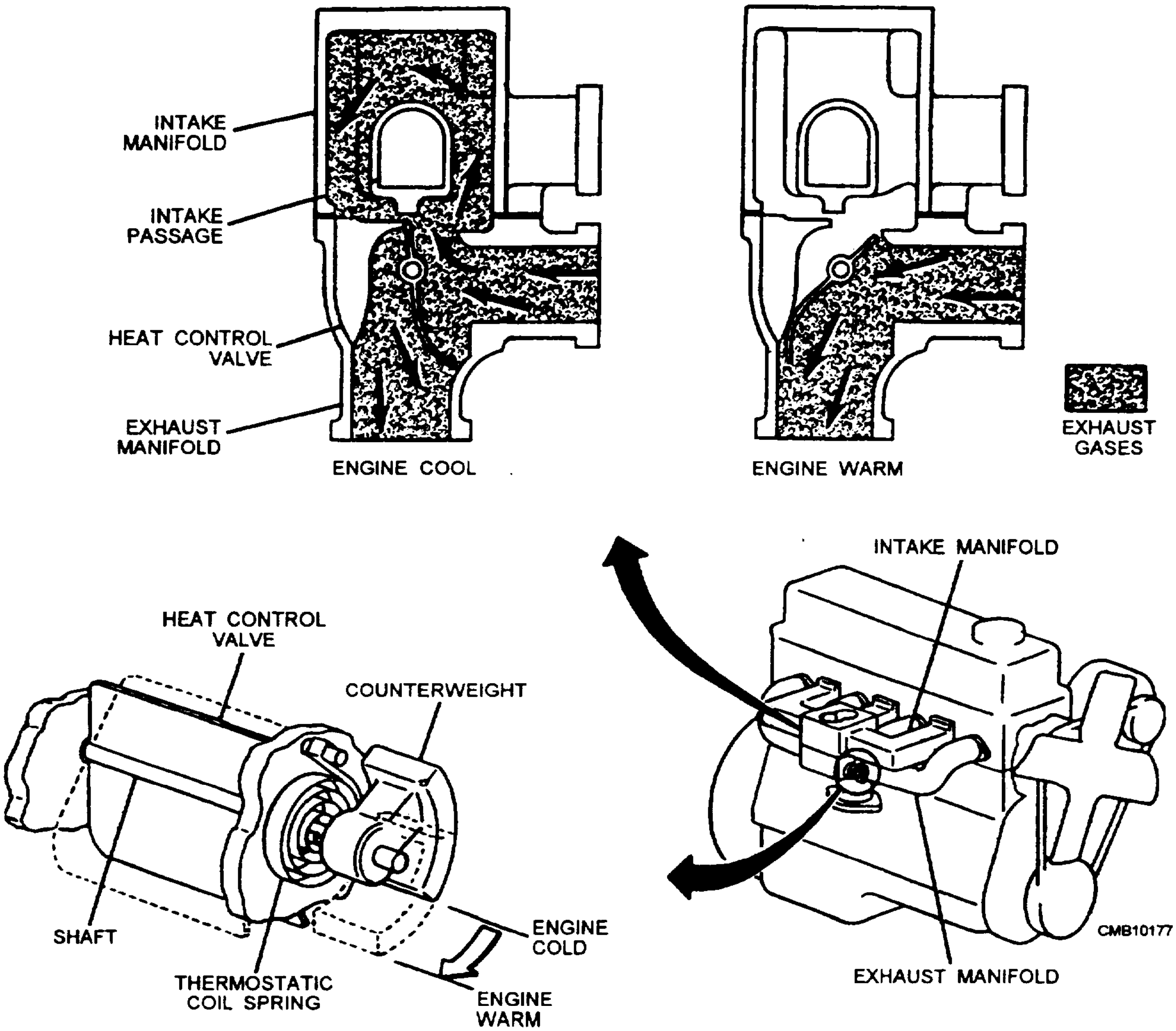


Figure 4-48.—Manifold heat control valve.

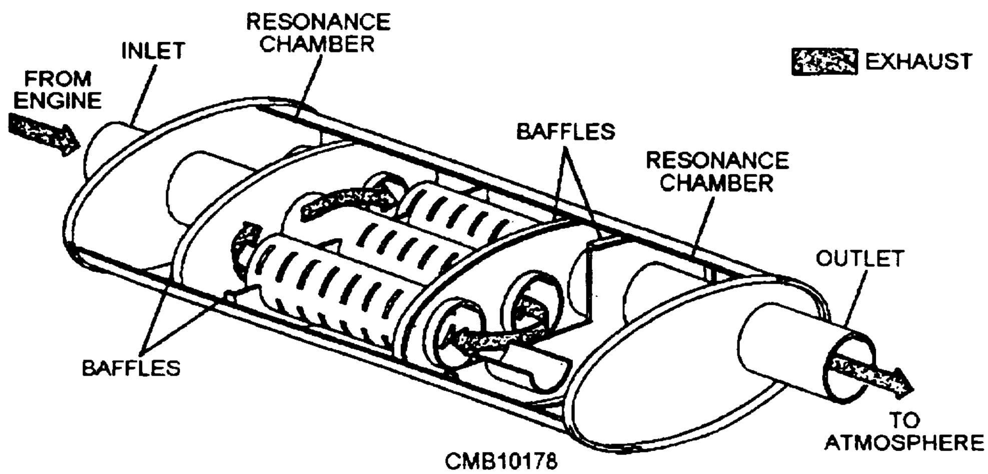


Figure 4-49.—Muffler.

Exhaust system components usually are made of steel. They are coated with aluminum or zinc to retard corrosion. Stainless steel also is used in exhaust systems in limited quantities due to its high cost. A stainless steel exhaust system will last indefinitely.

CATALYTIC CONVERTERS

It is impossible to keep carbon monoxide and hydrocarbon emissions at acceptable levels by controlling them in the cylinder without shortening engine life considerably. The most practical method of controlling these emissions is outside the engine using a catalytic converter. The catalytic converter is similar in appearance to the muffler and is positioned in the exhaust system between the engine and muffler. As the engine exhaust passes through the converter, carbon monoxide and hydrocarbons are oxided (combined with oxygen), changing them into carbon dioxide and water.

The catalytic converter contains a material (usually platinum or palladium) that acts as a catalyst. The catalyst is something that causes a reaction between two substances without actually getting involved. In the case of the catalytic converter, oxygen is joined chemically with carbon monoxide and hydrocarbons in the presence of its catalyst. Because platinum and palladium are both very precious metals and the catalyst must have a tremendous amount of surface area in order to work properly, it has been found that the following internal structures work best for catalytic converters:

- PELLET TYPE (fig. 4-50) is filled with aluminum oxide pellets that have a very thin coating of catalytic material. Aluminum oxide has a rough outer surface, giving each pellet a tremendous amount of surface area. The converter contains baffles to ensure maximum exposure of the exhaust to the pellets.

- MONOLITHIC TYPE (fig. 4-50) uses a one-piece ceramic structure in a honeycomb style form. The structure is coated thinly with a catalytic material. The honeycomb shape has a tremendous surface area to ensure maximum exposure of exhaust gases to the catalyst.

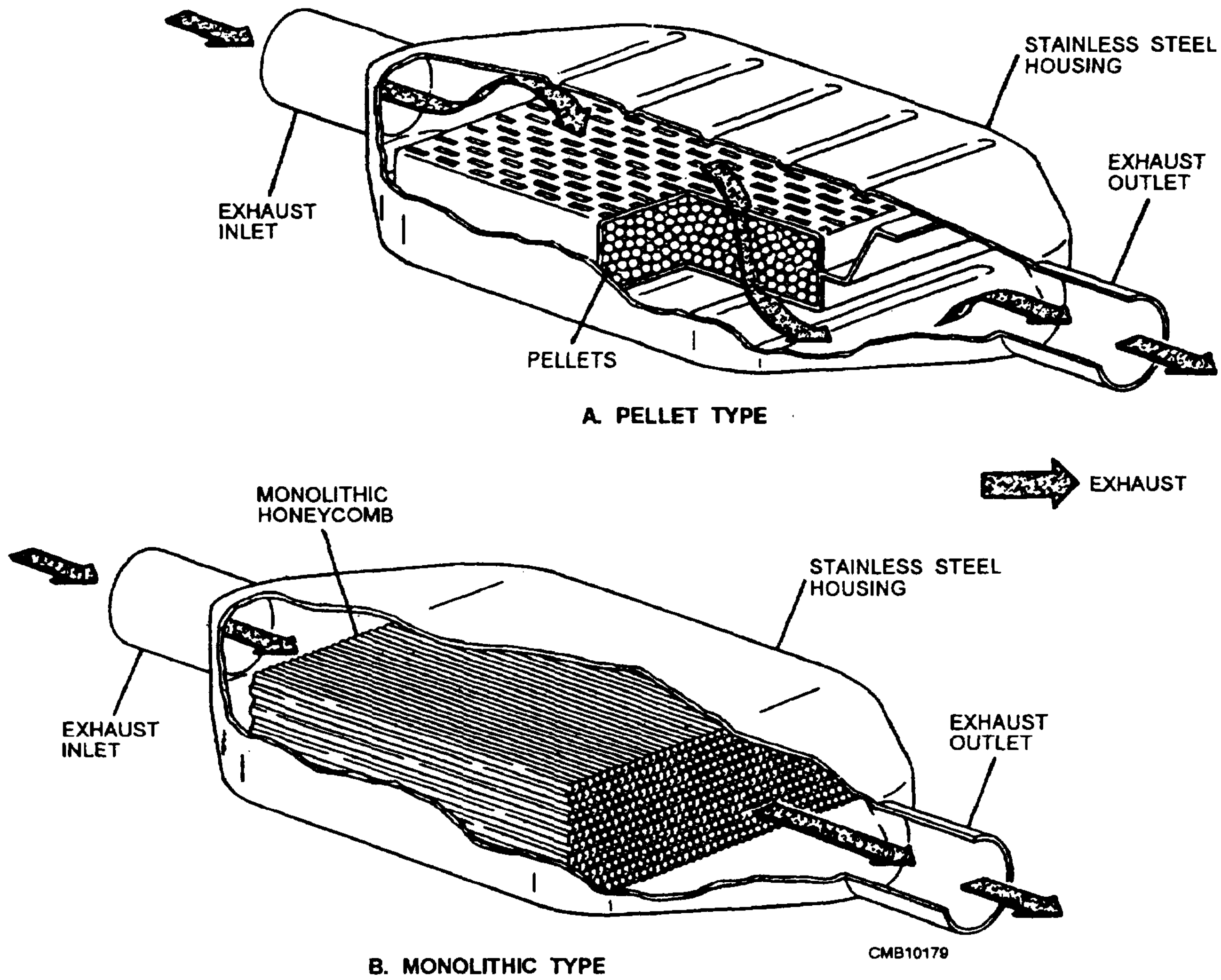


Figure 4-50.—Catalytic converter.

An adequate amount of oxygen must be present in the exhaust system for the catalytic converter to operate; therefore, a supporting system, such as an air injection system, usually is placed on catalytic converter equipped engines to dilute the exhaust stream with fresh air.

AIR INJECTION SYSTEM

An air injection system (fig. 4-51) forces fresh air into the exhaust ports of the engine to reduce HC and CO emissions. The exhaust gases leaving an engine can contain unburned and partially burned fuel. Oxygen from the air injection system causes this fuel to continue to burn. The major parts of the system are the air pump, the diverter valve, the air distribution manifold, and the air check valve.

- The AIR PUMP is belt-driven and forces air at low pressure into the system. A hose is connected to the output of the diverter valve.

- The DIVERTER VALVE keeps air from entering the exhaust system during deceleration. This prevents backfiring in the exhaust system. Also, the diverter valve limits maximum system air pressure when needed, releasing excessive pressure through a silencer or a muffler.

- AIR DISTRIBUTION MANIFOLD directs a stream of fresh air toward each engine exhaust valve. Fittings on the air distribution manifold screw into a threaded hole in the exhaust manifold or cylinder head.

- AIR CHECK VALVE is usually located in the line between the diverter valve and the air distribution manifold. It keeps exhaust gases from entering the air injection system.

Basic operation of the air injection system is as follows:

- When the engine is running, the spinning vanes of the air pump force air into the diverter valve. If not decelerating, the air is forced through the diverter valve, the check valve, the air injection manifold, and into the engine. The fresh air blows on the exhaust valves.

- During periods of deceleration, the diverter valve blocks air flow into the engine exhaust manifold. This prevents a possible backfire that could damage the exhaust system of the vehicle. When needed, the diverter valve will release excess pressure in the system.

POSITIVE CRANKCASE VENTILATION (PCV) SYSTEM

The positive crankcase ventilation system uses manifold vacuum to purge the crankcase blow-by fumes. The fumes are then aspirated back into the engine where they are reburned.

A hose is tapped into the crankcase at a point that is well above the engine oil level. The other end of the hose is tapped into the intake manifold or the base of the carburetor.

NOTE

> If the hose is tapped into the carburetor base, it will be in a location that is between the throttle valves and the intake manifold so that it will receive manifold vacuum.

An inlet breather is installed on the crankcase in a location that is well above the level of the engine oil. The inlet breather also is located strategically to ensure complete purging of the crankcase fresh air. The areas of the crankcase where the vacuum hose and inlet breather are tapped have baffles to keep motor oil from leaving the crankcase.

A flow control valve is installed in the line that connects the crankcase to the manifold. It is called a positive crankcase ventilation (PCV) valve (fig. 4-52) and serves to avoid the air-fuel mixture by doing the following:

- Any periods of large throttle opening will be accompanied by heavy engine loads. Crankcase blow-by will be at its maximum during heavy engine loads. The PCV valve will react to the small amount of manifold vacuum that also is present during heavy engine loading by opening fully through the force of its control valve spring. In this way, the system provides maximum effectiveness during maximum blow-by periods.

- Any period of small throttle opening will be accompanied by small engine loads, high manifold vacuum, and a minimum amount of crankcase blow-by. During these periods, the high manifold vacuum will pull the PCV valve to its position of minimum opening. This is important to prevent an excessively lean air-fuel mixture.

- In the event of engine backfire (flame traveling back through the intake manifold), the reverse pressure will push the rear shoulder of the control valve against

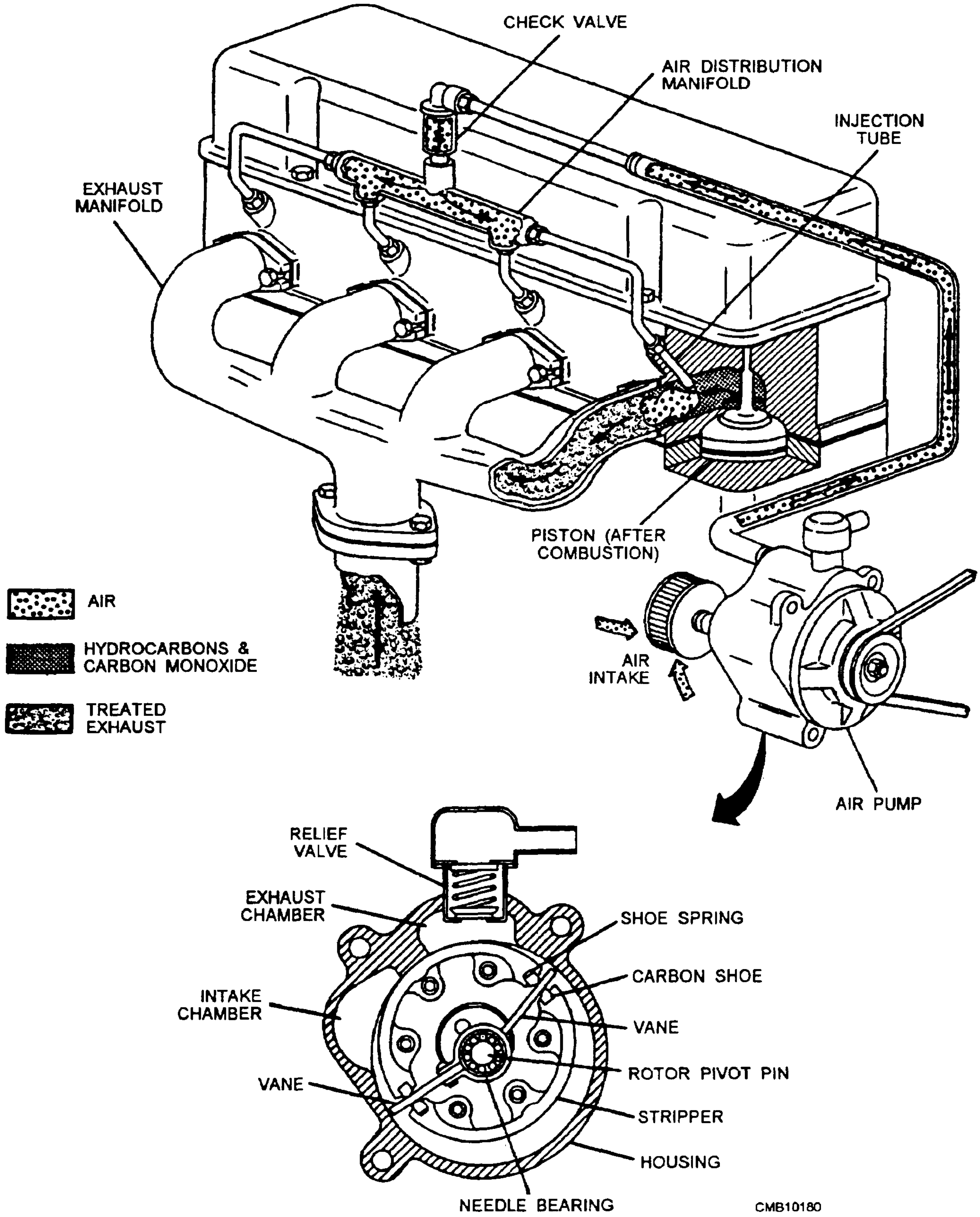


Figure 4-51.—Air injection system.

the valve body. This will seal the crankcase from the backfire which could otherwise cause an explosion.

The positive crankcase ventilation system can be either the open or closed type (fig. 4-52).

- The open type has an inlet breather that is open to the atmosphere. When this system is used, it is possible for a portion of the crankcase blow-by to escape through the breather whenever the engine is under a sustained heavy load.

- The closed type has a sealed breather that is connected to the air filter by a hose. Any blow-by gases that escape from the breather when this system is used will be aspirated into the carburetor and reburned.

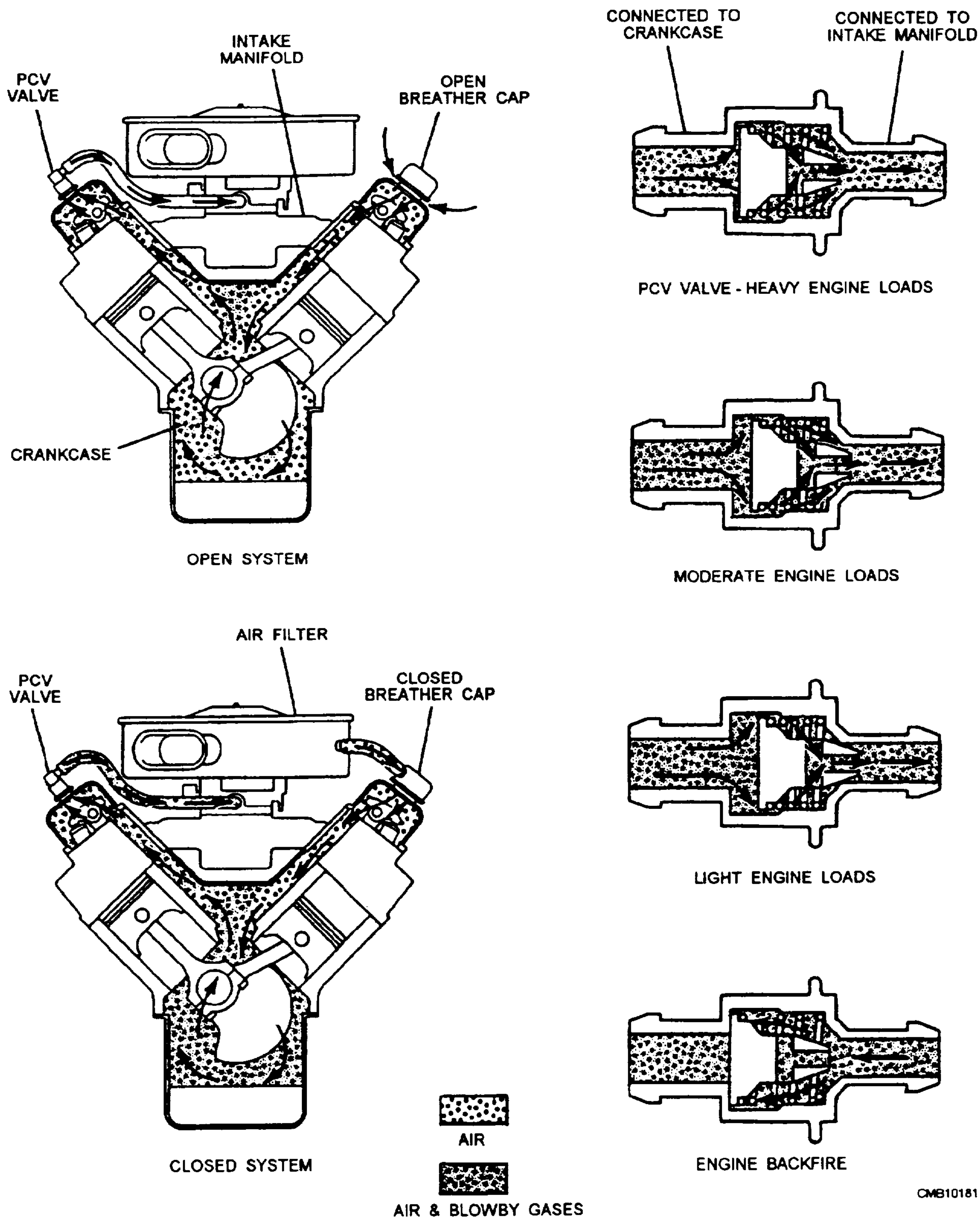


Figure 4-52.—PCV system.

EXHAUST GAS RECIRCULATION (EGR) SYSTEM

When the temperature of the combustion flame exceeds approximately 2,500°F, the nitrogen that is present in the intake air begins to combine with oxygen to produce oxides of nitrogen (NO_x). The exhaust gas recirculation (EGR) system (fig. 4-53) helps to control the formation of oxides of nitrogen by recirculating a portion of the exhaust gases back through the intake manifold, resulting in cooler combustion chamber temperatures.

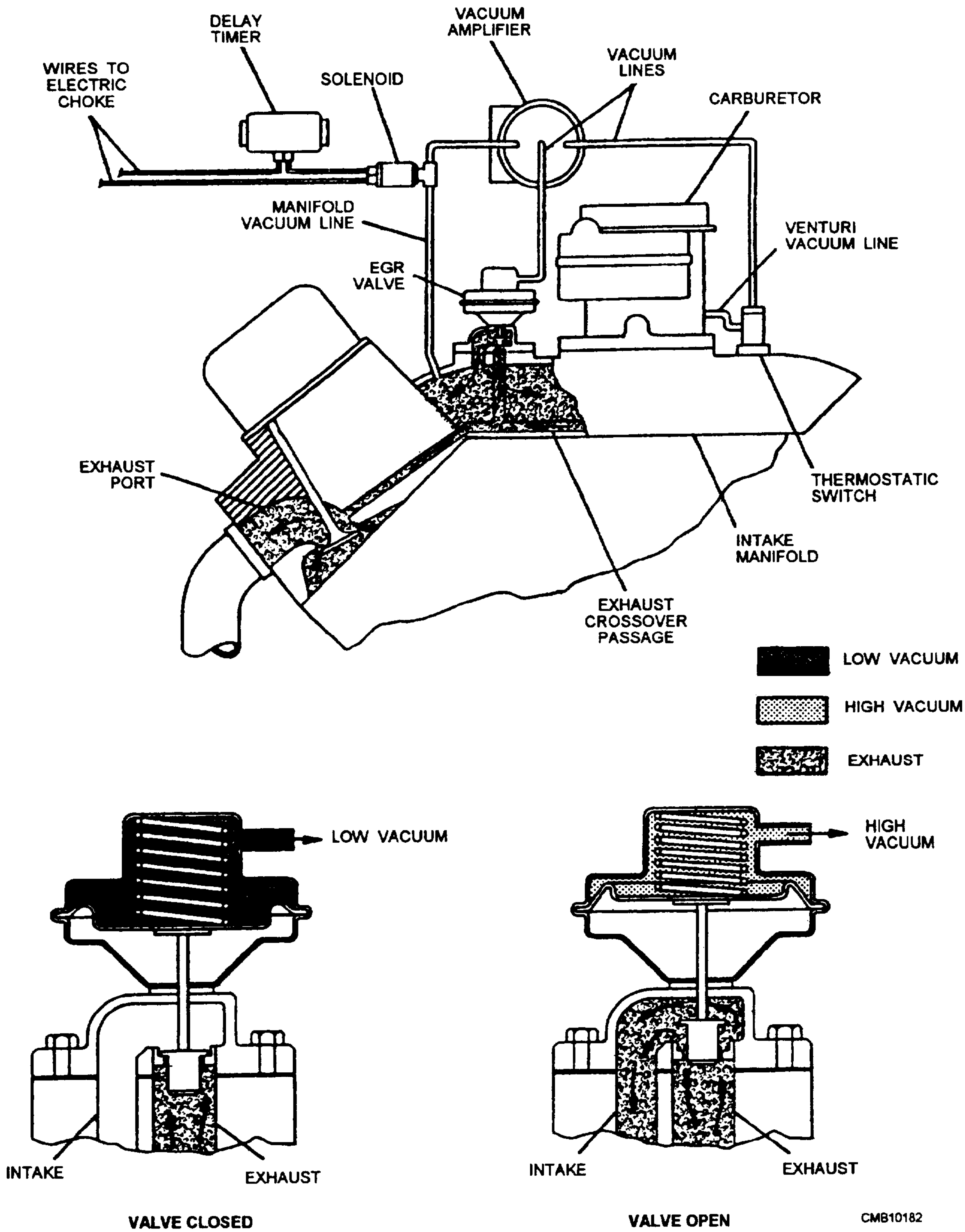


Figure 4-53.—EGR system.

A basic EGR system is simple, consisting of a vacuum operated EGR valve and a vacuum line from the carburetor. The EGR valve usually bolts to the engine intake manifold or a carburetor plate. Exhaust gases are routed through the cylinder head and intake manifold to the EGR valve.

The EGR valve consists of a vacuum diaphragm, a spring, an exhaust gas valve, and a diaphragm housing. It is designed to control exhaust flow into the intake manifold.

Though there are minor differences between systems, the basic operation of an exhaust gas recirculation system is as follows:

- At idle, the throttle plate in the carburetor or fuel injection throttle body is closed. This blocks off engine vacuum, so it cannot act on the EGR valve. The EGR spring holds the valve shut, and the exhaust gases do NOT enter the intake manifold. If the EGR valve were to open at idle, it could upset the air-fuel mixture and the engine would stall.

- When the throttle plate is swung open to increase speed, engine vacuum is applied to the EGR hose. Vacuum pulls the EGR diaphragm up. In turn, the diaphragm pulls the valve open. Engine exhaust can enter the intake manifold and combustion chambers. At higher engine speeds, there is enough air flowing into the engine that the air-fuel mixture is not upset by the open EGR valve.

There are two different methods of supply vacuum to the EGR valve as follows:

- The first method uses a vacuum port into the carburetor throat located just above the throttle plate. As the throttle begins to open, vacuum will begin to be applied to the port and operates the EGR valve. The valve will continue to operate fully until approximately half throttle is reached. As the throttle is open past the halfway point, exhaust gas recirculation gradually will diminish to zero, as the throttle approaches the fully opened position.

- The second method uses a vacuum port that is directly in the carburetor venturi (fig. 4-53). The carburetor venturi provides vacuum for the EGR valve any time the engine is running at high speed. The problem with using venturi vacuum is that it is not strong enough to open the EGR valve. So to make it work, manifold vacuum is used to operate the EGR valve through a vacuum amplifier. The vacuum amplifier switches the manifold vacuum supply to the EGR valve whenever venturi vacuum is applied to its signal port. At times of large engine loading (wide, open throttle), manifold vacuum will be weak, producing the desired condition of no exhaust gas recirculation.

An engine coolant temperature switch may be used to prevent exhaust gas recirculation when the engine is cold. A cold engine does not have extremely high combustion temperatures and does not produce very much NO_x. By blocking vacuum to the EGR valve below 100°F, you can improve the drivability and performance of the cold engine.

FUEL EVAPORIZATION CONTROL SYSTEM

The fuel evaporization control system prevents vapors from the fuel tank and carburetor from entering the atmosphere (fig. 4-54). Older, pre-emission vehicles used vented fuel tank caps. Carburetor bowls were also vented to the atmosphere. This caused a considerable amount of emissions. Modern vehicles commonly use fuel evaporization control systems to prevent this source of pollution. The major components of the fuel evapotization control systems are the sealed fuel tank cap, fuel air dome, liquid-vapor separator, roll-over valve, fuel tank vent line, charcoal canister, carburetor vent line, and the purge line.

- SEALED FUEL TANK CAP is used to keep fuel vapors from entering the atmosphere through the tank filler neck. It may contain pressure and vacuum valves that open in extreme cases of pressure or vacuum. When the fuel expands (from warming), tank pressure forces fuel vapors out a vent line or line at the top of the fuel tank, not out of the cap.

- FUEL AIR DOME is a hump designed into the top of the fuel tank to allow for fuel expansion. The dome normally provides about 10 percent air space to allow for fuel heating and volume increase.

- LIQUID-VAPOR SEPARATOR is frequently used to keep liquid fuel from entering the evaporation control system. It is simply a metal tank located above the main fuel tank. Liquid fuel condenses on the walls of the separator and then flows back into the fuel tank.

- ROLL-OVER VALVE is sometimes used in the vent line from the fuel tank. It keeps liquid fuel from entering the vent line after an accident where the vehicle rolled upside down. The valve contains a metal ball or plunger valve that blocks the vent line when the valve is turned over.

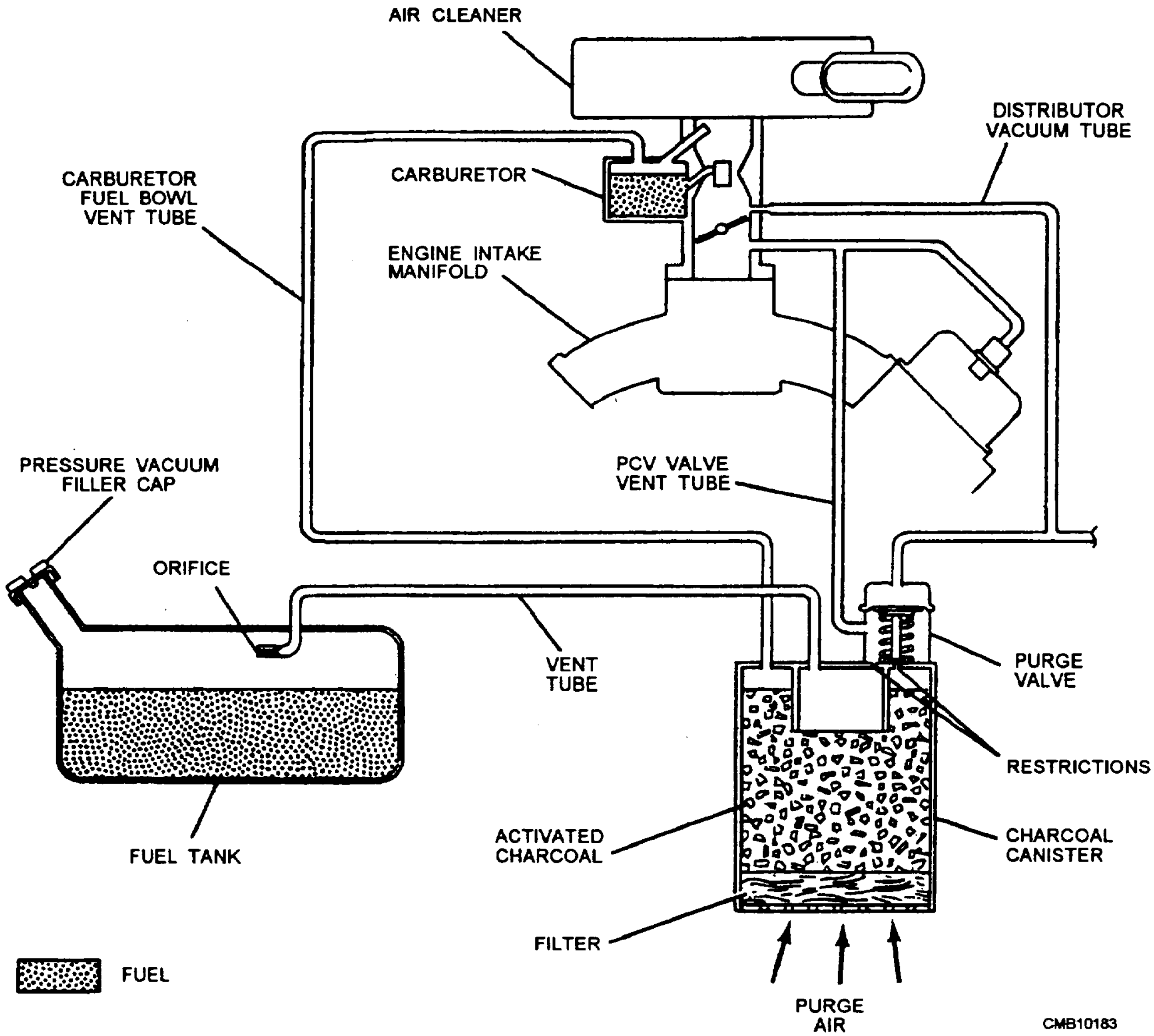


Figure 4-54.—Fuel evaporization system.

- FUELTANK VENTLINE carries fuel vapors up to a charcoal canister in the engine compartment.

- CHARCOAL CANISTER stores fuel vapors when the engine is NOT running. The metal or plastic canister is filled with activated charcoal granules capable of absorbing fuel vapors.

- CARBURETOR VENT LINE connects the carburetor fuel bowl with the charcoal canister. Bowl vapors flow through this line and into the canister.

- PURGE LINE is used for removing or cleaning the stored vapors out of the charcoal canister. It connects the canister and the engine intake manifold.

Basic operation of a fuel evaporization control system is as follows:

- When the engine is running, intake manifold vacuum acts on the purge line, causing fresh air to flow through the filter at the bottom of the canister. The incoming fresh air picks up the stored fuel vapors and carries them through the purge line. The vapors enter the intake manifold and are pulled into the combustion chambers for burning.

- When the engine is shut off, engine heat produces excess vapors. These vapors flow through the carburetor vent line and into the charcoal canister for storage. The vapors that form in the tank flow through the liquid vapor separator into the tank vent line to the charcoal canister. ‘The charcoal canister absorbs these fuel vapors and holds them until the engine is started again.

Q12. A gasoline engine produces what three major pollutants?

Q13. What material(s) is used in a catalytic converter to act(s) as a catalyst?

Q14. What type of catalytic converter is of a honeycomb design?

Q15. What device is used to prevent exhaust gas recirculation when the engine is cold?

CHAPTER 5

DIESEL FUEL SYSTEMS

LEARNING OBJECTIVE: Describe *the different type of diesel fuel systems, how the components function to provide fuel to the engine in proper quantities, and servicing of the diesel fuel systems.*

Maintenance personnel form part of an important network of dedicated people who ensure that medium- and heavy-duty trucks and construction equipment are kept in a state of safe and acceptable performance standards. The diesel fuel injection system is a major component of a properly operating engine. An engine out of adjustment can cause excessive exhaust smoke, poor fuel economy, heavy carbon buildup within the combustion chambers, and short engine life.

DIESEL FUEL SYSTEMS

LEARNING OBJECTIVE: *Identify the properties of diesel fuel. Describe the function and operation of governors and fuel system components.*

Like the gasoline engine, the diesel engine is an internal combustion engine using either a two- or four-stroke cycle. Burning or combustion of fuel within the engine cylinders obtains power. The diesel engine does not use a carburetor because the diesel fuel is mixed in the cylinder with compressed air.

Compression ratios in the diesel engine range between 14:1 and 19:1. This high ratio causes increased compression pressures of 400 to 600 psi and cylinder temperature reach 800°F to 1200°F. At the proper time, the diesel fuel is injected into the cylinder by a fuel injection system, which usually consists of a pump, fuel line, and injector or nozzle. When the fuel oil enters the cylinder, it will ignite because of the high temperatures. The diesel engine is known as a COMPRESSION-IGNITION engine, while the gasoline engine is a SPARK-IGNITION engine.

Figure 5-1 shows the comparison of the four strokes of a four-cycle diesel engine and a four-cycle gasoline engine.

The speed of a diesel engine is controlled by the amount of fuel injected into the cylinders. In a gasoline engine, the speed of the engine is controlled by the amount of air admitted into the carburetor or gasoline fuel injection systems.

Mechanically, the diesel engine is similar to the gasoline engine. The intake, compression, power, and exhaust strokes occur in the same order. The arrangement of the pistons, connecting rods, crankshaft, and engine valves is about the same. The diesel engine is also classified as IN-LINE or V-TYPE.

In comparison to the gasoline engine, the diesel engine produces more power per pound of fuel, is more reliable, has lower fuel consumption per horsepower per hour, and presents less of a fire hazard.

These advantages are partially offset by higher initial cost, heavier construction needed for its high compression pressures, and the difficulty in starting which results from these pressures.

DIESEL FUEL

Diesel fuel is heavier than gasoline because it is obtained from the residue of the crude oil after the more volatile fuels have been removed. As with gasoline, the efficiency of diesel fuel varies with the type of engine in which it is used. By distillation, cracking, and blending of several oils, a suitable diesel fuel can be obtained for all engine operating conditions. Using a poor or improper grade of fuel can cause hard starting, incomplete combustion, a smoky exhaust, and engine knocks.

The high injection pressures needed in the diesel fuel system result from close tolerances in the pumps and injectors. These tolerances make it necessary for the diesel fuel to have sufficient lubrication qualities to prevent rapid wear or damage. It must also be clean,

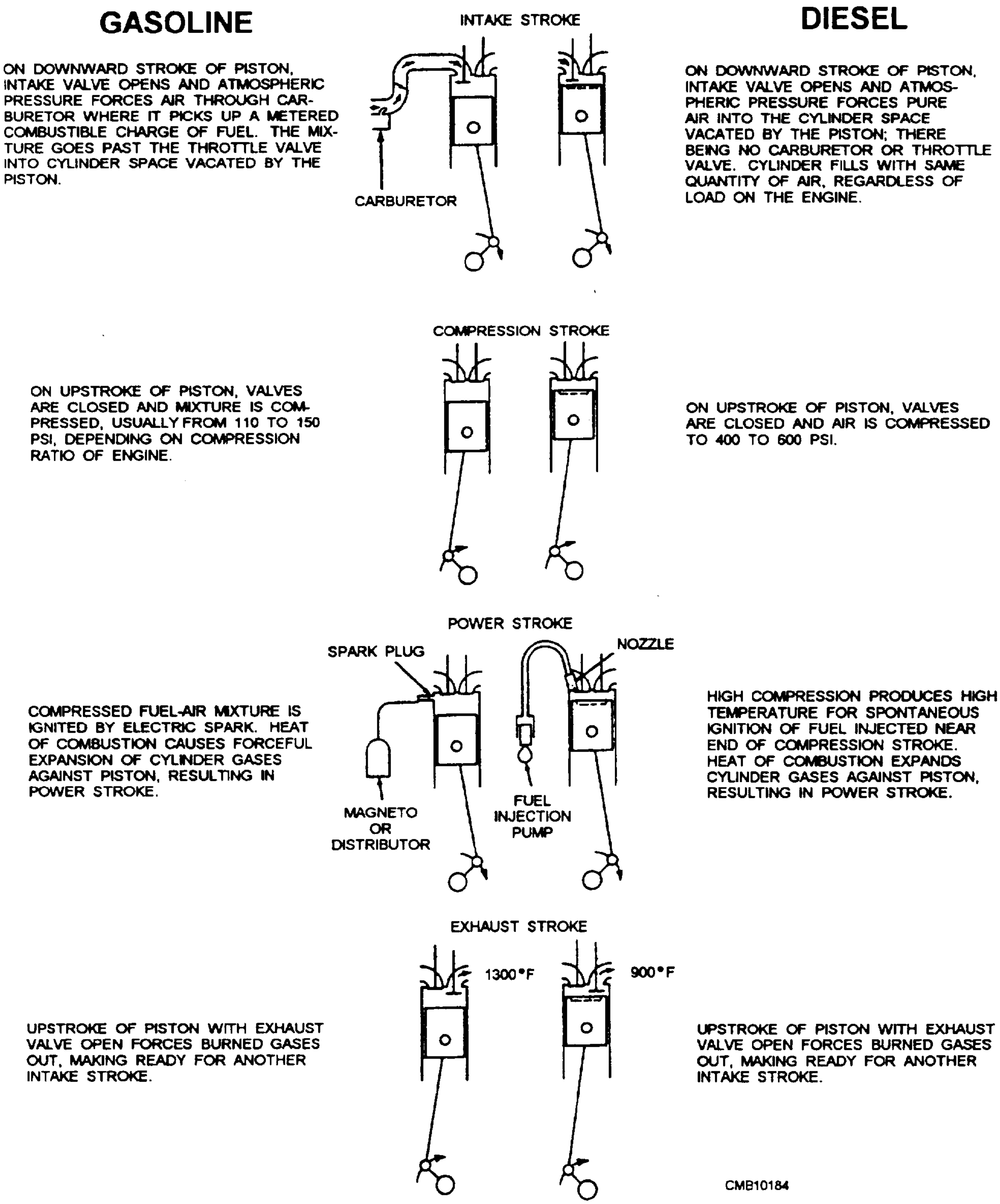


Figure 5-1.—Comparison of sequence of events in diesel and gasoline four-cycle engines.

mix rapidly with the air, and burn smoothly to produce an even thrust on the piston during combustion.

Diesel Fuel Oil Grades

Diesel fuel is graded and designated by the American Society for Testing and Materials (ASTM), while its specific gravity and high and low heat values are listed by the American Petroleum Institute (API). Each individual oil refiner and supplier attempts to produce diesel fuels that comply as closely as possible with ASTM and API specifications. Because of different crude oil supplies, the diesel fuel may be on either the high or low end of the prescribed heat scale in Btu per pound or per gallon. Because of deterioration of diesel fuel, there are only two recommended grades of fuel that is considered acceptable for use in high-speed heavy-duty vehicles. These are the No. 1D or No. 2D fuel oil classification

Grade No. 1D comprises the class of volatile fuel oils from kerosene to the intermediate distillates. Fuels within this classification are applicable for use in high-speed engines in service involving frequent and relatively wide variations in loads and speeds. In cold weather conditions, No. 1D fuel allows the engine to start easily. In summary, for heavy-duty high-speed diesel vehicles operating in continued cold-weather conditions, No. 1D fuel provides better operation than the heavier No. 2D.

Grade No. 2D includes the class of distillate oils of lower volatility. They are applicable for use in high-speed engines in service involving relatively high loads and speeds. This fuel is used more by truck fleets, due to its greater heat value per gallon, particularly in warm to moderate climates. Even though No. 1D fuel has better properties for cold weather operations, many still use No. 2D in the winter, using fuel heater/water separators to provide suitable starting, as well as fuel additive conditioners, which are added directly into the fuel tank.

Selecting the correct diesel fuel is a must if the engine is to perform to its rated specifications. Generally, the seven factors that must be considered in the selection of a fuel oil are as follows:

1. Starting characteristics
2. Fuel handling
3. Wear on injection equipment
4. Wear on pistons
5. Wear on rings, valves, and cylinder liners
6. Engine maintenance
7. Fuel cost and availability

Other considerations in the selection of a fuel oil are as follows:

- Engine size and design
- Speed and load range
- Frequency of load and speed changes
- Atmospheric conditions

Cetane Number

Cetane number is a measure of the fuel oils volatility; the higher the rating, the easier the engine will start and the combustion process will be smoother within the ratings specified by the engine manufacturer. Current 1D and 2D diesel fuels have a cetane rating between 40 and 45.

Cetane rating differs from octane rating that is used in gasoline in that the higher the number of gasoline on the octane scale, the greater the fuel resistance to self-ignition, which is a desirable property in gasoline engines with a high compression ratio. Using a low octane fuel will cause pm-ignition in high compression engines. However, the higher the cetane rating, the easier the fuel will ignite once injected into the diesel combustion chamber. If the cetane number is too low, you will have difficulty in starting. This can be accompanied by engine knock and puffs of white smoke during warm-up in cold weather.

High altitudes and low temperatures require the use of diesel fuel with an increased cetane number. Low temperature starting is enhanced by high cetane fuel oil in the proportion of 1.5°F—lower starting temperature for each cetane number increase in the fuel.

Volatility

Fuel volatility requirements depend on the same factors as cetane number. The more volatile fuels are best for engines where rapidly changing loads and speeds are encountered. Low volatile fuels tend to give better fuel economy where their characteristics are needed for complete combustion and will produce less smoke, odor, deposits, crankcase dilution, and engine wear.

The volatility of a fuel is established by a distillation test where a given volume of fuel is placed into a container that is heated gradually. The readiness with which a liquid changes to a vapor is known as the volatility of the liquid The 90 percent distillation temperature measures volatility of diesel fuel. This is the temperature at which 90 percent of a sample of the fuel has been distilled off. The lower the distillation temperature, the higher the volatility of the fuel. In small diesel engines higher fuel volatility is needed than in larger engines in order to obtain low fuel consumption, low exhaust temperature, and minimum exhaust smoke.

Viscosity

The viscosity is a measure of the resistance to flow of the fuel, and it will decrease as the fuel oil temperature increases. What this means is that a fluid with a high viscosity is heavier than a fluid with low viscosity. A high viscosity fuel may cause extreme pressures in the injection systems and will cause reduced atomization and vaporization of the fuel spray.

The viscosity of diesel fuel must be low enough to flow freely at its lowest operational temperature, yet high enough to provide lubrication to the moving parts of the finely machined injectors. The fuel must also be sufficiently viscous so that leakage at the pump plungers and dribbling at the injectors will not occur. Viscosity also will determine the size of the fuel droplets, which, in turn, govern the atomization and penetration qualities of the fuel injector spray.

Recommended fuel oil viscosity for high-speed diesel engines is generally in the region of 39 SSU (Seconds Saybolt Universal) which is derived from using a Saybolt Viscosimeter to measure the time it takes for a quantity of fuel to flow through a restricted hole in a tube. A viscosity rating of 39 SSU provides good penetration into the combustion chamber, atomization of fuel, and suitable lubrication.

Sulfur Content

Sulfur has a definite effect on the wear of the internal components of the engine, such as piston ring, pistons, valves, and cylinder liners. In addition a high sulfur content fuel requires that the engine oil and filter be changed more often. This is because the corrosive effects of hydrogen sulfide in the fuel and the sulfur dioxide or sulfur triioxide that is formed during the combustion process combines with water vapor to form acids. High additive lubricating oils are desired when high sulfur fuels are used. Refer to the engine manufacturer's specifications for the correct lube oil when using high sulfur fuel.

Sulfur content can only be established by chemical analysis of the fuel. Fuel sulfur content above 0.4% is considered as medium or high and anything below 0.4% is low. No. 2D contains between 0.2 and 0.5% sulfur, whereas No. 1D contains less than 0.1%.

Sulfur content has a direct bearing on the life expectancy of the engine and its components. Active sulfur in diesel fuel will attack and corrode injection system components in addition to contributing to combustion chamber and injection system deposits.

Cloud and Pour Point

Cloud point is the temperature at which wax crystals in the fuel (paraffin base) begin to settle out with the result that the fuel filter becomes clogged. This condition exists when cold temperatures are encountered and is the reason that a thermostatically controlled fuel heater is required on vehicles operating in cold weather environments. Failure to use a fuel heater will prevent fuel from flowing through the filter and the engine will not run. Cloud point generally occurs 9-14°F above the pour point.

Pour point of a fuel determines the lowest temperature at which the fuel can be pumped through the fuel system. The pour point is 5°F above the level at which oil becomes a solid or refuses to flow.

Cleanliness and Stability

Cleanliness is an important characteristic of diesel fuel. Fuel should not contain more than a trace of foreign substances; otherwise, fuel pump and injectors difficulties will develop leading to poor performance or seizure. Because it is heavier and more viscous, diesel fuel will hold dirt particles in suspension for a longer period than gasoline. Moisture in the fuel can also damage or cause seizure of injector parts when corrosion occurs.

Fuel stability is its capacity to resist chemical change caused by oxidation and heat. Good oxidation stability means that the fuel can be stored for extended periods of time without the formation of gum or sludge. Good thermal stability prevents the formation or carbon in hot parts, such as fuel injectors or turbine nozzles. Carbon deposits disrupt the spray patterns and cause inefficient combustion.

COMBUSTION CHAMBER DESIGN

The fuel injected into the combustion chamber must be mixed thoroughly with the compressed air and

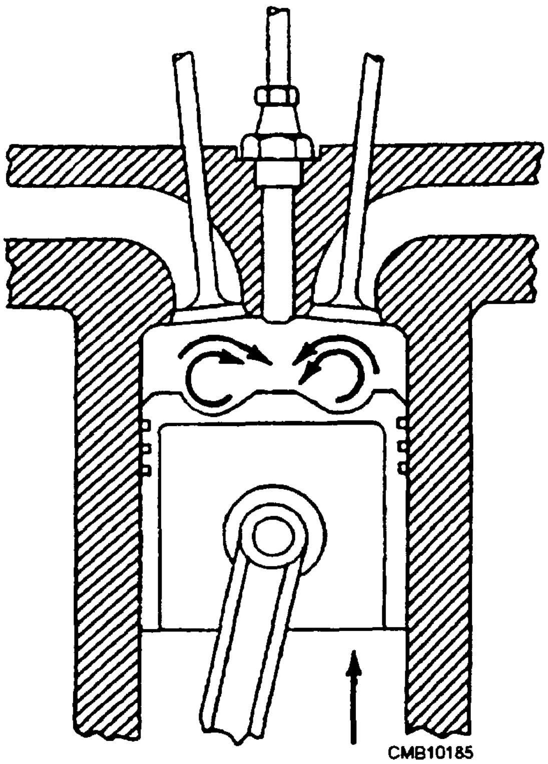


Figure 5-2.—Open combustion chamber.

distributed as evenly as possible throughout the chamber if the engine is to function at maximum efficiency and exhibit maximum drivabilty. A well-designed engine uses a combustion chamber that is designed for the intended usage of the engine. The injects used should compliment the combustion chamber. The combustion chambers described on the following pages are the most common and cover virtually all of the designs that are currently in use. These are the open chamber, precombustion chamber, turbulence chamber, and spherical (hypercycle) chamber.

Open Combustion Chamber

The open combustion chamber (fig. 5-2) is the simplest form of chamber. It is suitable for only slow-speed, four-stroke cycle engines, but is widely used in two-stroke cycle diesel engines. In the open chamber, the fuel is injected directly into the space on top of the cylinder. The combustion space, formed by the top of the piston and the cylinder head, usually is shaped to provide s swirling action of the air, as the piston comes up on the compression stroke. There are no special pockets, cells, or passages to aid the mixing of the fuel and air. This type of chamber requires a higher injection pressure and a greater degree of fuel atomization than is required by other combustion chambers to obtain an acceptable level of fuel mixing. To equalize combustion in the combustion chamber, use a multiple orifice-type injector tip for effective penetration. This chamber design is very susceptible to ignition lag.

Precombustion Chamber

The precombustion chamber (fig. 5-3) is an auxiliary chamber at the top of the cylinder. It is connected to the main combustion chamber by a restricted throat or passage. The precombustion chamber conditions the fuel for final combustion in the cylinder. A hollowed-out portion of the piston top

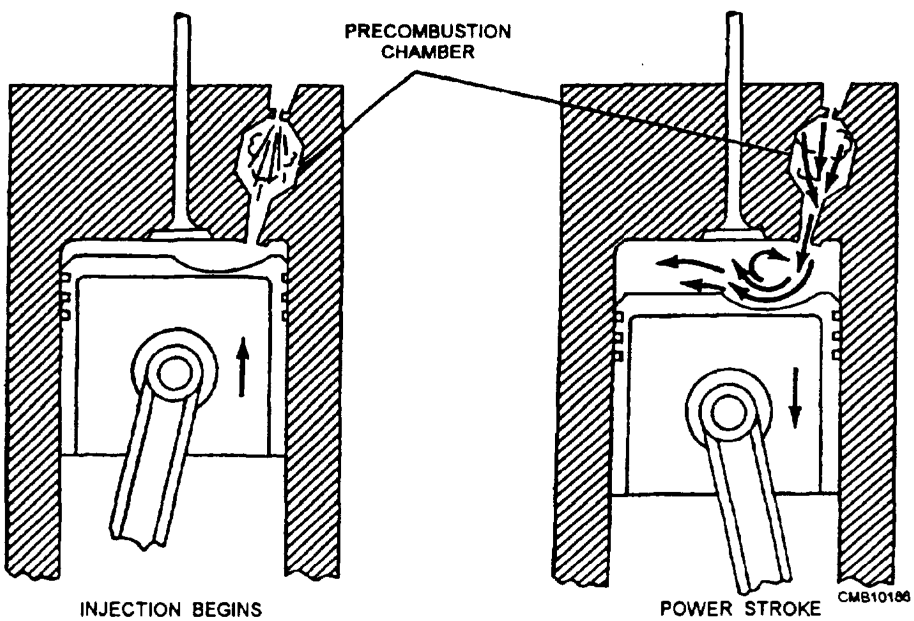


Figure 5-3.—Precombustion chamber.

causes turbulence in the main combustion chamber, as the fuel enters from the precombustion chamber to aid in mixing with air. The following steps occur during the precombustion process:

- During the compression stroke of the engine, air is forced into the precombustion chamber and, because the air is compressed, it is hot. At the beginning of injection, the precombustion chamber contains a definite volume of air.
- As the injection begins, combustion begins in the precombustion chamber. The burning of the fuel, combined with the restricted passage to the main combustion chamber, creates a tremendous amount of pressure in the combustion chamber. The pressure and the initial combustion cause a super-heated fuel charge to enter the main combustion chamber at a high velocity.
- The entering mixture hits the hollowed-out piston top, creating turbulence in the chamber to ensure complete mixing of the fuel charge with the air. This mixing ensures even and complete combustion. This chamber design provides satisfactory performance with low fuel injection pressures and coarse spray patterns because a large amount of vaporization occurs in the precombustion chamber. This chamber also is not very susceptible to ignition lag, making it suitable for high-speed operations.

Turbulence Chamber

The turbulence chamber (fig. 54) is similar in appearance to the precombustion chamber, but its function is different. There is very little clearance between the top of the piston and the head, so a high percentage of the air between the piston and cylinder head is forced into the turbulence chamber during the compression stroke. The chamber is usually spherical, and the small opening through which the air must pass causes an increase in air velocity, as it enters the chamber. This turbulence speed is about 50 times crankshaft speed. The fuel injection is timed to occur when the turbulence in the chamber is greatest. This ensures a thorough mixing of the fuel and air, causing the greater part of combustion to take place in the turbulence chamber. The pressure, created by the expansion of the burning gases, is the force that drives the piston downward on the power stroke.

Spherical (Hypercycle) Chamber

The spherical (hypercycle) combustion chamber (fig. 5-5) is designed principally for use in the multifuel diesel engine. The chamber consists of a basic open type chamber with a spherical shaped relief in the top of the piston head. The chamber works in conjunction with a strategically positioned injector and an intake port that produces a swirling effect, as it enters the chamber. Operation of the chamber is as follows:

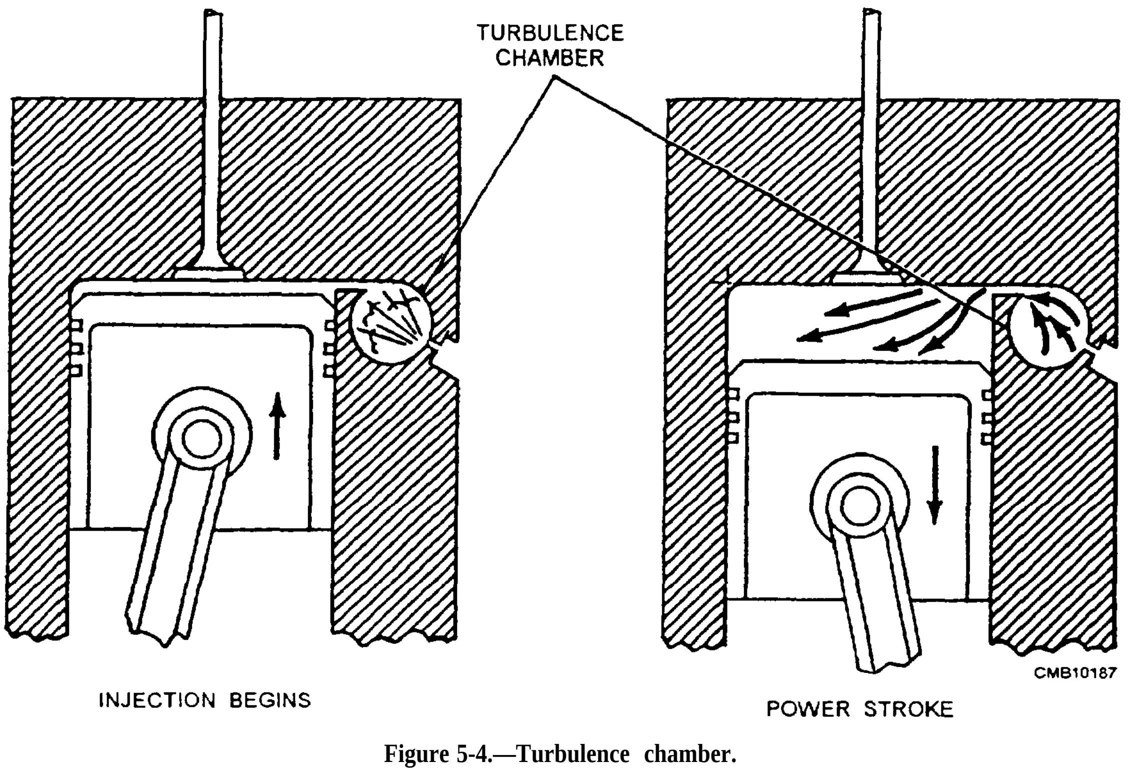


Figure 5-4.—Turbulence chamber.

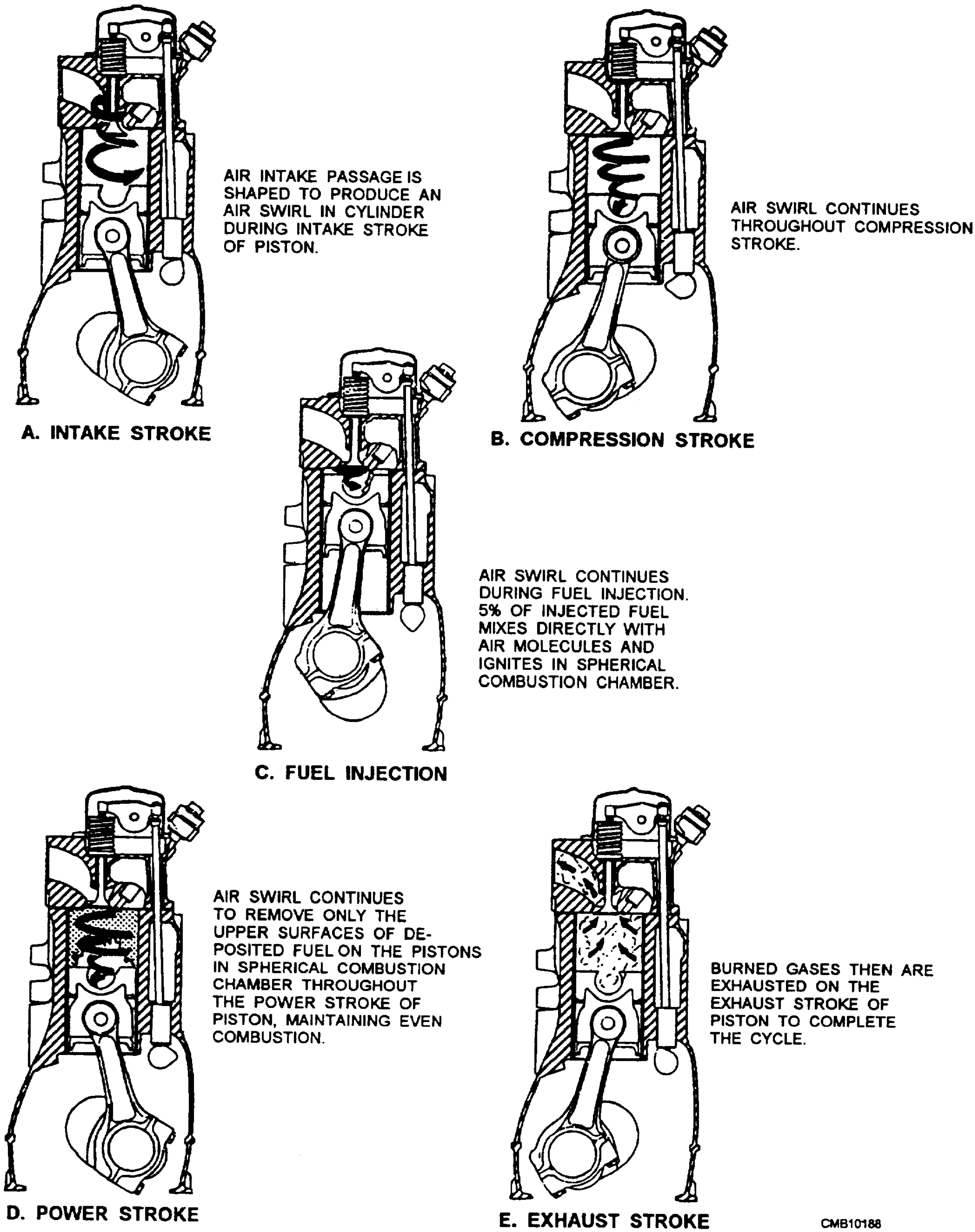


Figure 5-5.—Spherical chamber.

1. As the air enters the combustion chamber, the shape of the intake port (fig. 5-5) introduces a swirling effect to it.
2. During the compression stroke, the swirling motion of the air continues as the temperature in the chamber increases (fig. 5-5).
3. As the fuel is injected, approximately 95 percent of it is deposited on the head of the piston and the remainder mixes with the air in the spherical combustion chamber (fig. 5-5).
4. As combustion begins, the main portion of the fuel is swept off the piston head by the high-velocity swirl that was created by the intake and the compression strokes. As the fuel is swept off of the head, it burns through the power stroke, maintaining even combustion and eliminating detonation (fig. 5-5).

GOVERNORS

A governor is required on a diesel engine to control the idling and maximum speeds of the engine, with some governors being designed to control the speed within the overall operating range of the engine. It is possible for the operator to control the engine speed between idle and maximum through the operation of the throttle. Idle and maximum speeds must be controlled to prevent the engine from stalling during low-speed idle and to keep the speed from exceeding the maximum desired limits desired by the manufacturer. The main reason that a diesel requires a governor is that a diesel engine operates with excess air under all loads and speeds.

Even though it is not part of the fuel system, a governor is directly related to this system since it functions to regulate speed by the control of fuel or of the air-fuel mixture, depending on the type of engine. In diesel engines governors are connected in the linkage between the throttle and the fuel injectors. The governor acts through the fuel injection equipment to regulate the amount of fuel delivered to the cylinders. As a result the governor holds engine speed reasonably constant during fluctuations in load.

Before discussing governor types and operations, governor terms should be addressed and understood since they are commonly used when discussing engine speed regulation.

Terms

To understand why different types of governors are needed for different kinds of job, you will need to know the meaning of several terms that are used in describing the characteristics of action of the governor.

- **Maximum no-load speed** or high idle is used to describe the highest engine rpm obtainable when the throttle linkage is moved to its maximum position with no load applied to the engine.
- **Maximum full-load speed** or rated speed is used to indicate the engine rpm at which a particular engine will produce its maximum designed horsepower setting as stated by the manufacturer.
- **Idle** or low-idle speed is used to indicate the normal speed at which the engine will rotate with the throttle linkage in the released or closed position,
- **Work capacity** is used to describe the amount of available work energy that can be produced to the output shaft of the governor.
- **Stability** refers to the ability of the governor to maintain speed with either constant or varying loads without hunting.
- **Speed droop** is used to express the difference in the change in the governor rotating speed which causes the output shaft of the governor to move from its full-open throttle position to its full-closed position or vice versa.
- **Hunting** is a repeated and sometimes rhythmic variation of speed due to overcontrol by the governor. Also called speed drift.
- **Sensitivity** is an expression of how quickly the governor responds to a speed change.
- **Response time** is normally the time taken in seconds for the fuel linkage to be moved from a no-load to a full-load position.
- **Isochronous** is used to indicate zero-droop capability. In others words, the full-load and no-load speeds are the same.
- **Overrun** is used to express the action of the governor when the engine exceeds its maximum governed speed.

- **Underrun** is a simple term to describe the ability of the governor to prevent engine speed from dropping below a set idle, particularly when the throttle has been moved rapidly to a decreased fuel setting from maximum full-load position.

- **Deadband** is the change in speed required before the governor will make a corrective movement of the throttle.

- **State of balance** is used to describe the speed at which the centrifugal force of the rotating flyweights of the governor matches and balances the spring force of the governor.

Types of Governors

The type of governor used on diesel engines is dependent upon the application required. The six basic types of governors are as follows:

1. Mechanical centrifugal flyweight style that relies on a set of rotating flyweights and a control spring; used since the inception of the diesel engine to control its speed.

2. Power-assisted servomechanical style that operates similar to the mechanical centrifugal flyweight but uses engine oil under pressure to move the operating linkage.

3. Hydraulic governor that relies on the movement of a pilot valve plunger to control pressurized oil flow to a power piston, which, in turn, moves the fuel control mechanism.

4. Pneumatic governor that is responsive to the air flow (vacuum) in the intake manifold of an engine. A diaphragm within the governor housing is connected to the fuel control linkage that changes its setting with increases or decreases in the vacuum.

5. Electromechanical governor uses a magnetic speed pickup sensor on an engine-driven component to monitor the rpm of the engine. The sensor sends a voltage signal to an electronic control unit that controls the current flow to a mechanical actuator connected to the fuel linkage.

6. Electronic governor uses magnetic speed sensor to monitor the rpm of the engine. The sensor continuously feeds information back to the ECM (electronic control module). The ECM then computes all the information sent from all other engine sensors, such as the throttle position sensor, turbocharger-boost sensor, engine oil pressure and temperature sensor, engine coolant sensor, and fuel temperature to limit engine speed.

The governors, used on heavy-duty truck applications and construction equipment, fall into one of two basic categories:

1. Limiting-speed governors, sometimes referred to as minimum/maximum models since they are intended to control the idle and maximum speed settings of the engine. Normally there is no governor control in the intermediate range, being regulated by the position of the throttle linkage.

2. Variable-speed or all range governors that are designed to control the speed of the engine regardless of the throttle setting.

Other types of governors used on diesel engines are as follows:

1. Constant-speed, intended to maintain the engine at a single speed from no load to full load.

2. Load limiting, to limit the load applied to the engine at any given speed. Prevents overloading the engine at whatever speed it may be running.

3. Load-control, used for adjusting to the amount of load applied at the engine to suit the speed at which it is set to run.

4. Pressure regulating, used on an engine driving a pump to maintain a constant inlet or outlet pressure on the pump.

At this time on heavy-duty truck and construction equipment applications, straight mechanically designed units dominate the governor used on nonelectronic fuel injection systems.

Mechanical Governors

In most governors installed on diesel engines used by the Navy, the centrifugal force of rotating weights (flyballs) and the tensions of a helical coil spring (or springs) are used in governor operation. On this basis, most of the governors used on diesel engines are generally called mechanical centrifugal flyweight governors.

In mechanical centrifugal flyweight governors (fig. 5-6), two forces oppose each other. One of these forces is tension spring (or springs) which may be varied either by an adjusting device or by movement of the manual throttle. The engine produces the other force. Weights, attached to the governor drive shaft, are rotated, and a centrifugal force is created when the engine drives the shaft. The centrifugal force varies with the speed of the engine.

Transmitted to the fuel system through a connecting linkage, the tension of the spring (or springs) tends to increase the amount of fuel delivered to the cylinders. On the other hand, the centrifugal force of the rotating weights, through connecting linkage, tends to reduce the quantity of fuel injected. When the two opposing forces are equal, or balanced, the speed of the engine remains constant

To show how the governor works when the load increases and decreases, let us assume you are driving a truck in hilly terrain. When a truck approaches a hill at a steady engine speed, the vehicle is moving from a set state of balance in the governor assembly (weights and springs are equal) with a fixed throttle setting to an unstable condition. As the vehicle starts to move up the hill at a fixed speed, the increased load demands result in a reduction in engine speed. This upsets the state of balance that had existed in the governor. The reduced rotational speed at the engine results in a reduction in speed, and, therefore, the centrifugal force of the governor weights. When the state of balance is upset, the high-speed governor spring is allowed to expand,

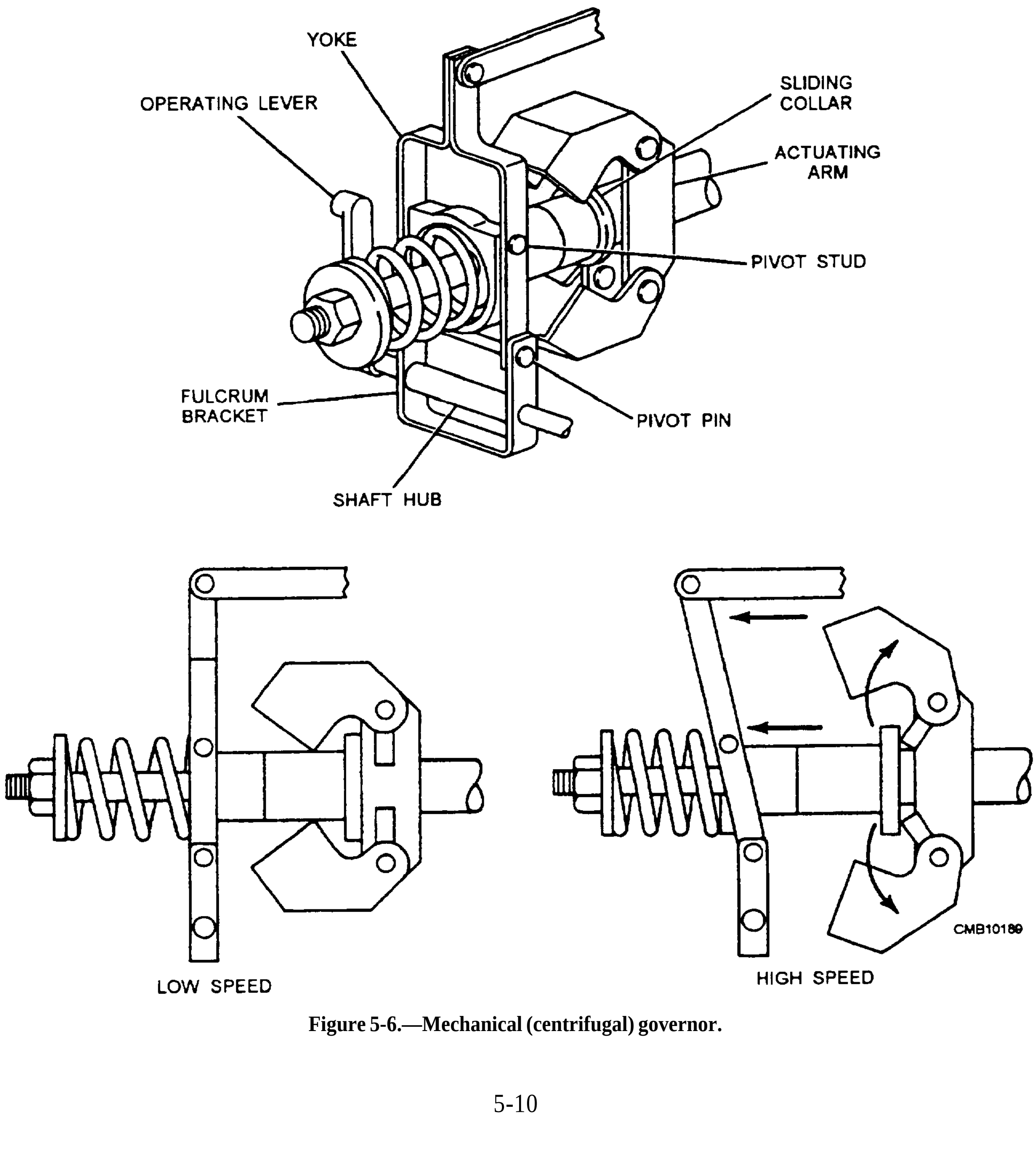


Figure 5-6.—Mechanical (centrifugal) governor.

giving up some of its stored energy, which moves the connecting fuel linkage to an increased delivery position. This additional fuel delivered to the combustion chambers would result in an increase in horsepower, but not necessarily an increase in engine speed.

When the truck moves into a downhill situation, the operator is forced to back off the throttle to reduce the speed of the vehicle; otherwise, the brakes or engine/transmission retarder has to be applied. The operator can also downshift the transmission to obtain additional braking power. However, when the operator does not reduce the throttle position or brake the vehicle mass in some way, an increase in road speed results. This is due to the reduction in engine load because of the additional reduction in vehicle resistance achieved through the mass weight of the vehicle and its load pushing the truck downhill. This action causes the governor weights to increase in speed, and they attempt to compress the high-speed spring, thereby reducing the fuel delivery to the engine. Engine overspeed can result if the road wheels of the vehicle are allowed to rotate fast enough that they, in effect, become the driving member.

The governor assembly would continue to reduce fuel supply to the engine due to increased speed of the engine. If overspeed does occur, the valves can end up floating (valve springs are unable to pull and keep the valves closed) and striking the piston crown. Therefore, it is necessary in a downhill run for the operator to ensure that the engine speed does not exceed maximum governed rpm by application of the vehicle, engine, or transmission forces.

Favorable, as well as unfavorable, characteristics are to be found in mechanical governors. Advantages are as follows:

- They are inexpensive.
- They are satisfactory when it is not necessary to maintain exactly the same speed, regardless of load.
- They are extremely simple with few parts.

Disadvantages are as follows:

- They have large deadbands, since the speed-measuring device must also furnish the force to move the engine fuel control.
- Their power is relatively small unless they are excessively large.
- They have an unavoidable speed droop, and therefore cannot truly provide constant speed when this is needed.

Hydraulic Governors

Although hydraulic governors have more moving parts and are generally more expensive than mechanical governors, they are used in many applications because they are more sensitive, have greater power to move the fuel control mechanism of the engine, and can be timed for identical speed for all loads.

In hydraulic governors (fig. 5-7), the power which moves the engine throttle does NOT come from the speed-measuring device, but instead comes from a hydraulic power piston, or servomotor. This is a piston that is acted upon by fluid pressure, generally oil under the pressure of a pump. By using appropriate piston size and oil pressure, the power of the governor at its output shaft (work capacity) can be made sufficient to operate the fuel-changing mechanism of the largest engines.

The speed-measuring device, through its speeder rod, is attached to a small cylindrical valve, called a pilot valve. The pilot valve slides up and down in a bushing, which contains ports that control the oil, flow to and from the servomotor. The force needed to slide the pilot valve is very little; a small ball head is able to control a large amount of power at the servomotor.

The basic principle of a hydraulic governor (fig. 5-7) is very simple. When the governor is operating at control speed or state of balance, the pilot valve closes the port and there is no oil flow.

When the governor speed falls due to an increase in engine load, the flyweights move in and the pilot valve

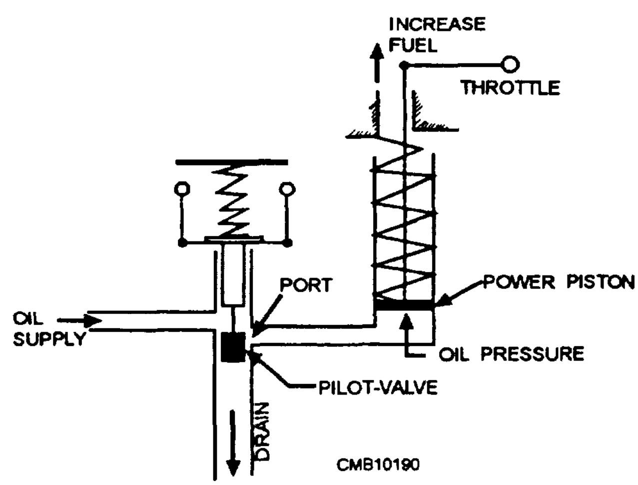


Figure 5-7.—Hydraulic governor.

moves down. This opens the port to the power piston and connects the oil supply of oil under pressure. This oil pressure acts on the power piston, forcing it upward to increase the fuel.

When the governor speed rises due to a decrease of engine load, the flyweights move out and the pilot valve moves up. This opens the port from the power piston to the drain into the sump. The spring above the power piston forces the power piston down, thus decreasing the speed.

Unfortunately, the simple hydraulic governor has a serious defect, which prevents its practical use. It is inherently unstable; that is, it keeps moving continually, making unnecessary corrective actions. In other words it hunts. The cause of this hunting is the unavoidable time lag between the moment the governor acts and the moment the engine responds. The engine cannot come back to the speed called for by the governor.

Most hydraulic governors use a speed droop to obtain stability. Speed droop gives stability because the engine throttle can take only one position for any speed. Therefore, when a load change causes a speed change, the resulting governor action ceases at a particular point that gives the amount of fuel needed for a new load. In this way speed droop prevents unnecessary governor movement and overcorrection (hunting).

Electronic Governors

The recent introduction of electronically controlled diesel fuel injection system on several heavy-duty high-speed truck engines has allowed the speed of the diesel engine to be controlled electronically, rather than mechanically. The same type of balance condition in a mechanical governor occurs in an electronic governor. The major difference is that in the electronic governor, electric currents (amperes) and voltages (pressure) are used together instead of mechanical weight and spring forces. This is possible through the use of magnetic pickup sensor (MPS), which is, in effect, a permanent-magnet single-pole device. This magnetic pickup concept is being used on all existing electronic systems and its operation can be considered common to all of them. MPS's are a vital communications link between the engine crankshaft speed and the onboard computer (ECM). The MPS is installed next to a drive shaft gear made of a material that reacts to a magnetic field. As each gear tooth passes the MPS, the gear interrupts the MPS's magnetic field. This, in turn, produces an ac current signal, which corresponds to the rpm of the engine. This signal is sent to the ECM to establish the amount of fuel that should be injected into the combustion chambers of the engine. Electronic speed governing systems are set up to provide six basic governing modes:

1. Idle speed control
2. Maximum speed control
3. Power takeoff speed control
4. Vehicle speed cruise control
5. Engine speed cruise control
6. Road speed limiting

Each of the control modes above is described in more detail below.

1. The idle speed control provides fixed speed control over the entire torque capability of the engine. Also, the idle speed set point is calculated as a function of the engine temperature to provide an optional cold idle speed, which is usually several hundred rpm higher than normal operating temperature.
2. The engine maximum rpm setting can be programmed for different settings. This can improve fuel economy by eliminating engine overspeed in all gear ranges.
3. The power takeoff speed control setting can operate at any speed between idle and maximum. The operator uses rotary control or a toggle switch in the cab to vary electronically the engine power to the PTO from idle to the preset rpm.
4. Vehicle and engine cruise control includes set, resume, and coast features similar to that of a passenger car, as well as an accelerate (ACCEL) mode to provide a fixed speed increase each time the control switch is activated.
5. The road speed limiting function allows the organization assigned to determine what maximum vehicle road speed they desire independent of the maximum governed speed setting of the engine. Road speed governing provides the best method for ensuring ideal fuel economy.

The major advantage of the electronic governor over the mechanical governor lies in its ability to modify speed reference easily by various means to control such things as acceleration and deceleration, as well as load.

DIESEL FUEL SYSTEM COMPONENTS

Before discussing the various types of fuel injection systems, let's spend some time looking at the basic components that are necessary to hold, supply, and filter the fuel before it passes to the actual injection system. The basic function of the fuel system is to provide a reservoir of diesel fuel, to provide sufficient circulation of clean filtered fuel for lubrication, cooling and combustion purposes, and to allow warm fuel from the engine to recirculate back to the tank(s). The specific layout and arrangement of the diesel fuel system will vary slightly between makes and models.

The basic fuel system consists of the fuel tank(s) and a fuel transfer pump (supply) that can be a separate engine-driven pump or can be mounted on or inside the injection pump. In addition, the system uses two fuel filters—a primary and secondary filter—to remove impurities from the fuel. In some system you will have a fuel filter/water separator that contains an internal filter and water trap.

Tank and Cap

Fuel tanks used today can be constructed from black sheet steel, or for lighter weight, aluminum alloy is used. Baffles are welded into the tanks during construction. The baffle plates are designed with holes in them to prevent the fuel from sloshing during the movement of the vehicle. The fuel lines (inlet and return) should be separated by a baffle in the tank to prevent warm return fuel from being sucked right back up by the fuel inlet line. Both the inlet and return lines should be kept 2 inches above the bottom of the tank, so sediment or water is not drawn into the inlet.

A well-designed tank will contain a drain plug in the base to allow for fuel tank drainage. This allows the fuel to be drained from the tank before removal for any service. Many tanks are equipped with a small low-mounted catchment basin so that any water in the tank can be quickly drained through a drain cock, which is surrounded by a protective cage to prevent damage.

The fuel tank filler cap is constructed with both a pressure relief valve and a vent valve. The vent valve is designed to seal when fuel enters it due to overfilling, vehicle operating angle, or sudden jolt that would cause fuel slosh within the tank. Although some fuel will tend to seep from the vent cap, this leakage should not exceed 1 ounce per minute.

The diesel fuel tank is mounted directly on the chassis of construction equipment because of its weight (when filled) and to prevent movement of the tank when the equipment is operated over rough terrain. Its location depends on the type of equipment and the use of the equipment. On equipment used for ground clearing and earthwork, the tank is mounted where it has less chance of being damaged by foreign objects or striking the ground.

Gauges

The electric gauges used in the diesel fuel system are the same types as used in the gasoline fuel system. Some manufacturers use a bayonet type gauge permanently attached to the filler cap of the fuel tank or installed under the fuel cap. These are graduated and the fuel level is checked by the same method as oil in an engine.

Fuel Filters

The purpose of any diesel fuel filter is mainly to remove foreign particles as well as water. The use of a suitable filtration system on diesel engines is a must to avoid damage to closely fitted injection pump and injector components. The components are manufactured to tolerances as little as 0.0025 mm; therefore, insufficient fuel filtration can cause serious problems. Six principal filter elements have been used for many years:

1. Pleated paper
2. Packed cotton thread
3. Wood fibers
4. Mixtures of packed cotton and wood fibers
5. Wound cotton or synthetic yarn
6. Fiber glass

Filter ability will vary between the type and manufacturer. On diesel engines a primary and secondary filter are used. The primary filter is capable of removing dirt particles down to 30 microns and the secondary filter between 10 to 12 microns. Secondary filters are available between 3 and 5 microns, which are used in severe service operations. The primary is usually located between the tank and the supply pump and the secondary filter between the supply pump and the injection pump. Diesel fuel filters are referred to as full-flow filters, because all the fuel must pass through them before reaching the injection pumps.

Some filters use an internal replaceable element inside a bowl or shell; these are commonly referred to as a shell and element design (fig. 5-8). However, most filters used today are of the spin-on type, which allows for faster change out since the complete filter is a throwaway. Fuel filter elements or cartridges should be replaced at the recommended interval designated by the manufacturer's service manual.

NOTE

Should the engine run rough after a fuel filter change, it is likely that air is trapped in the system. Bleed all air from the filter by loosening the bleed screw. In the absence of a bleed screw, individually loosen the fuel lines until all air has been vented.

Water Separators

The purpose of a fuel filter is mainly to remove foreign particles as well as water. However, too much water in a fuel filter will render it incapable of protecting the system. So to ensure this does not happen, most diesel engine fuel systems are now equipped with fuel filter/water separators for the main purpose of trapping and holding water that may be mixed in with the fuel. Generally, when a fuel filter/water separator is used on a diesel engine, it also serves as the primary filter. There are a number of manufacturers who produce fuel filter/water separators with their concept of operation being common and only design variations being the major difference. Basic operation is as follows:

- The first stage of the fuel filter/water separator uses a pleated paper element to change water particles into large enough droplets that will fall by gravity to a water sump at the bottom of the filter.
- The second stage is made of silicone-treated nylon that acts as a safety device to prevent small particles of water that avoid the first stage from passing into the engine.

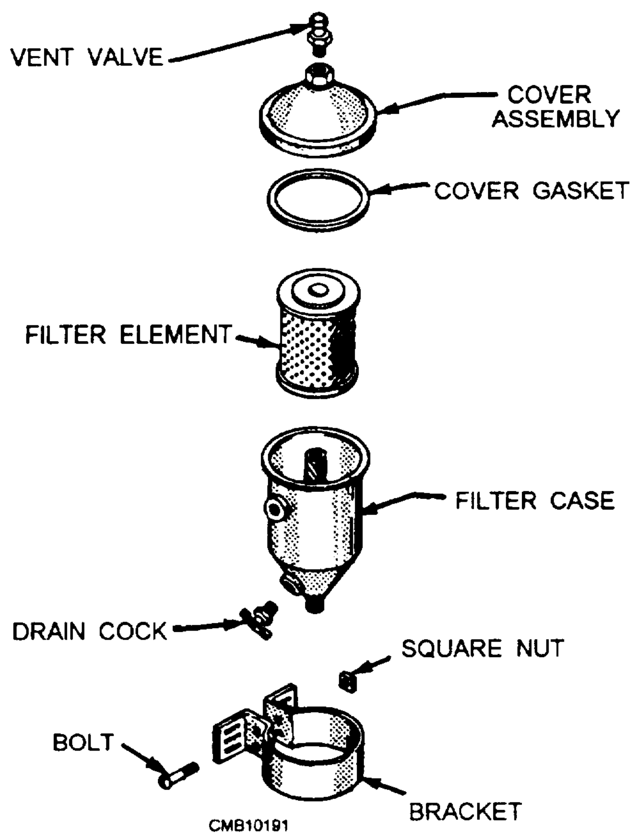


Figure 5-8.—Fuel filter assembly with replaceable element.

Supply Pump

Fuel injection pumps must be supplied with fuel under pressure because they have insufficient suction ability. All diesel injection systems require a supply pump to transfer fuel from the supply tank through the filters and lines to the injection pump. Supply pumps can be either external or internal to the injection pump. The two types of supply pumps used on diesel engines today are the gear type and the vane type.

The remaining task to be accomplished by the fuel system is to provide the proper quantity of fuel to the cylinders of the engine. This is done differently by each manufacturer and is referred to as FUEL INJECTION.

Q1. What grade of diesel fuel is used in warm and moderate climates?

Q2. What determines the lowest temperature at which diesel fuel can be pumped through the system?

Q3. What is the most important characteristic of diesel fuel?

Q4. What combustion chamber is designed principally for the use in the multifuel engine?

Q5. What term is used to indicate the zero-droop capability of a governor?

Q6. What type of governor uses a magnetic speed pickup to monitor the rpm of the engine?

Q7. What component in a hydraulic governor provides power to move the throttle of the engine?

Q8. How many governing modes does the electronic speed governing system provide?

Q9. How far should the inlet and outlet lines be from the bottom of a fuel tank?

METHODS OF INJECTION

LEARNING OBJECTIVE: *Describe the principles and operation of the different diesel fuel systems.*

You have probably heard the statement that "the fuel injection system is the actual heart of the diesel engine." When you consider that indeed a diesel could not be developed until an adequate fuel injection system was designed and produced, this statement takes on a much broader and stronger meaning.

In this section, various methods of mechanical injections and metering control are described. There have been many important developments in pumps, nozzles, and unit injectors for diesel engines over the years with the latest injection system today relying on electronic controls and sensors.

FUEL INJECTION SYSTEMS

Diesel fuel injection systems must accomplish five particular functions-meter, inject, time, atomize, and create pressure. A description of these functions follows:

1. **METER—**Accurately measure the amount of fuel to be injected.
2. **INJECT—**Force and distribute the fuel into the combustion chamber.
3. **TIME—**Injection of the fuel must start and stop at the proper time.
4. **ATOMIZE—**Break the fuel up into a fine mist.
5. **CREATE PRESSURE—**Create the necessary high pressure for injection.

You can remember these functions by the initials, **MITAC.** All five of these functions are necessary for complete and efficient combustion

Metering

Accurate metering or measuring of the fuel means that, for the same fuel control setting, the same quantity of fuel must be delivered to each cylinder for each power stroke of the engine. Only in this way can the engine operate at uniform speed with uniform power output. Smooth engine operation and an even distribution of the load between the cylinders depend upon the same volume of fuel being admitted to a particular cylinder each time it fires and upon equal volumes of fuel being delivered to all cylinders of the engine.

Injection Control

A fuel system must also control the rate of injection. The rate at which fuel is injected determines the rate of combustion. The rate of injection at the start should be low enough that excessive fuel does not accumulate in the cylinder during the initial ignition delay (before combustion begins). Injection should proceed at such a rate that the rise in combustion pressure is not to great, yet the rate of injection must be such that fuel is introduced as rapidly as possible to obtain complete combustion. An incorrect rate of injection affects engine operation in the same way as improper timing. When the rate of injection is too high, the results are similar to those caused by an injection that is too early; when the rate is too low, the results are similar to those caused by an injection that is too late.

Timing

In addition to measuring the amount of fuel injected, the system must properly time injection to ensure efficient combustion so that maximum energy can be obtained from the fuel. When the fuel is injected too early in the cycle, ignition may be delayed because the temperature of the air, at this point, is not high enough. An excessive delay, on the other hand, gives rough and noisy operation of the engine. It also permits some fuel to be lost due to the wetting of the cylinder walls and piston head. This, in turn, results in poor fuel economy, high exhaust gas temperature, and smoke in the exhaust. When fuel is injected too late in the cycle, all the fuel will not be burned until the piston has traveled well past top center. When this happens, the engine does not develop enough power, the exhaust is smoky, and fuel consumption is high.

Atomization of Fuel

As used in connection with fuel injection, atomization means the breaking up of the fuel, as it enters the cylinder into small particles, which form a mistlike spray. Atomization of the fuel must meet the requirements of the type of combustion chamber in use. Some chambers require very fine atomization; while others function with coarser atomization. Properly atomization makes it easier to start the burning process and ensures that each minute particle of fuel is surrounded by particles of oxygen with which it can combine.

Atomization is generally obtained when liquid fuel, under high pressure, passes through the small opening (or openings) in the injector or nozzle. As the fuel enters the combustion space, high velocity is developed because the pressure in the cylinder is lower than the fuel pressure. The created friction, resulting from the fuel passing through the air at high velocity, causes the fuel to break up into small particles.

Creating Pressure

A fuel injection system must increase the pressure of the fuel to overcome compression pressure and to ensure proper dispersion of the fuel injected into the combustion space. Proper dispersion is essential if the fuel is to mix thoroughly with the air and burn efficiently. While pressure is a chief contributing factor, the dispersion of the fuel is influenced, in part, by atomization and penetration of the fuel. (Penetration is the distance through which the fuel particles are carried by the motion given them, as they leave the injector or nozzle .)

If the atomization process reduces the size of the fuel particles too much, they will lack penetration. Too little penetration results in the small particles of fuel igniting before they have been properly distributed or dispersed in the combustion space. Since penetration and atomization tend to oppose each other, a compromise in the degree of each is necessary in the design of the fuel injection equipment, particularly if uniform distribution of fuel within the combustion chamber is to be obtained.

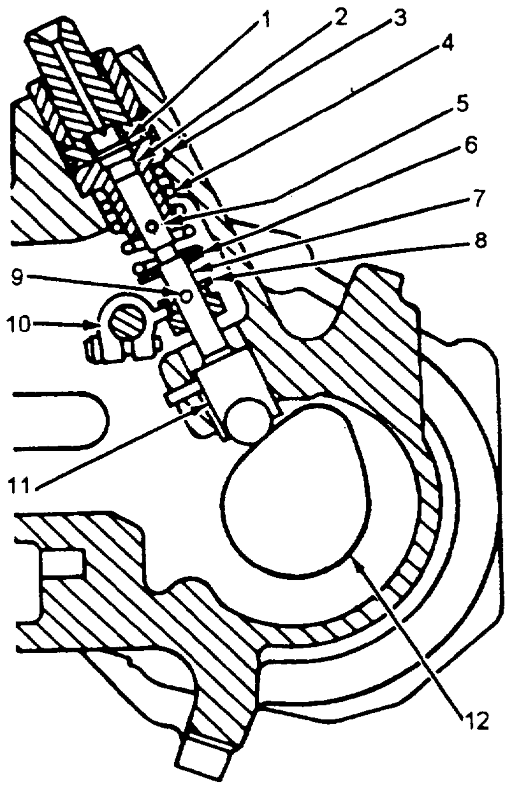
CATERPILLAR FUEL SYSTEMS

The Caterpillar diesel engine uses the pump and nozzle injection system. Each pump measures the amount of fuel to be injected into a particular cylinder, produces the pressure for injection of the fuel, and times the exact point of injection. The injection pump plunger is lifted by cam action and returned by spring action. The turning of the plungers in the barrels varies the metering of fuel. These plungers are turned by governor action through a rack that meshes with the gear segments on the bottom of the pump plungers. Each pump is interchangeable with other injection pumps mounted on the pump housing.

The sleeve metering and scroll-type pumps that are used by Caterpillar operate on the same fundamentals—a jerk pump system (where one small pump contained in its own housing supplied fuel to one cylinder). Individual "jerk" pumps, that are contained in a single injection pump housing with the same number of pumping plungers being the same as that of the engine cylinders, are commonly referred to as in-line multiple-plunger pumps.

Sleeve Metering Fuel System

The sleeve metering fuel system (fig. 5-9) was designed to have the following seven advantages:



1. Reverse flow check valve
2. Chamber
3. Barrel
4. Spring
5. Fuel inlet
6. Retainer
7. Plunger
8. Sleeve
9. Fuel outlet
10. Sleeve control lever
11. Lifter
12. Camshaft

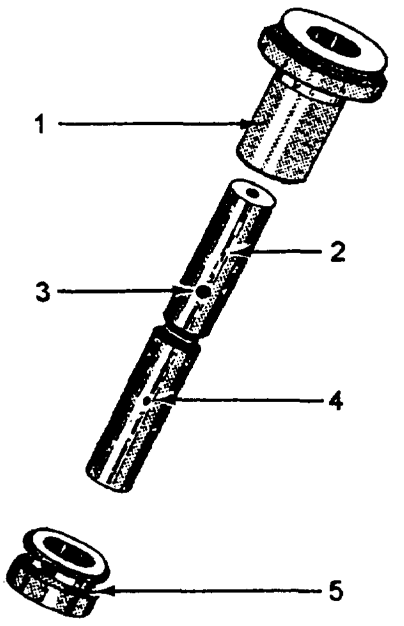
CMB10192

Figure 5-9.—Sleeve metering fuel pump assembly.

1. To have fewer moving parts and fewer total parts.
2. Simple design with compactness.
3. It can use a simple mechanical governor. No hydraulic assist required.
4. The injection pump housing is filled with fuel oil, rather than crankcase oil for lubrication of all internal parts.
5. The plunger, barrel, and sleeve design used in all Caterpillar sleeve metering units follows a common style.
6. The transfer pump, governor, and injection pump are mounted in one unit.
7. Uses a centrifugal timing advance for better fuel economy and easier starts.

The term *sleeve metering* comes from the method used to meter the amount of fuel sent to the cylinders—a sleeve system (fig. 5-10). Rather than rotate the plungers to control the amount of fuel to be injected, like most pump and nozzle injection systems, the use of a sleeve is incorporated with the plunger. The sleeve blocks a spill port that is drilled into the plunger. The amount of plunger travel with its port blocked determines the amount of fuel to be injected. Basic operation is as follows:

- Fuel is drawn from the fuel tank by the transfer pump through the fuel/water separator and the primary and secondary filters.
- Fuel from the transfer pump fills the injection pump housing at approximately 30 to 35 psi with the engine operating under full load. Any pressure in excess of this will be directed back to the inlet side of the transfer pump by the bypass valve. A constant-bleed valve is also used to allow a continuous return of fuel back to the tank at a rate of approximately 9 gallons per hour, so the temperature of the fuel stays cool for lubrication purposes and assist in maintaining housing pressure.
- Since the injection pump is constantly filled with diesel from the transfer pump under pressure, any time the fill port is uncovered, the internal drilling of the plunger will be primed by the incoming fuel caused by the downward moving plunger relative to pump camshaft rotation (fig. 5-11).
- At the correct moment, the rotation of the pump cam lobe begins to force the plunger upward until the fill port is closed, as it passes into the barrel. At the same time the sleeve closes the spill port. The pump, line, and fuel valves are subjected to a buildup in fuel pressure and injection will begin (fig. 5-11).



1. Barrel
2. Plunger
3. Fill port
4. Spill port
5. Metering sleeve

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Figure 5-10.—Sleeve metering barrel and plunger assembly.

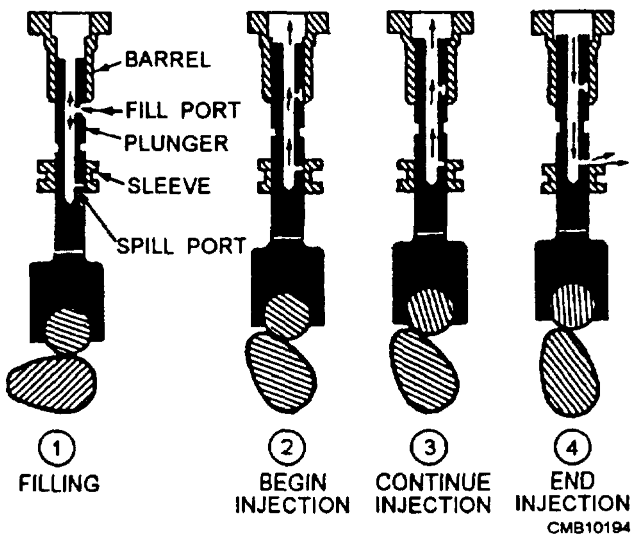


Figure 5-11.—Injection pump operating cycle.

- Injection of the fuel will continue as long as both the fill port and spill ports are completely cover by the barrel and sleeve (fig. 5-11).

- Injection ends the moment that the spill port starts to edge above the sleeve, releasing the pressure in the plunger and letting fuel escape from the pump back into the housing. Also, at the end of the stroke, the check valve closes to prevent the fuel from flowing back from the injector fuel line (fig. 5-11).

To increase the amount of fuel injected, raise the sleeve through the control shaft and fork so that the sleeve is effectively positioned higher up on the plunger. This means that the spill port will be closed for a longer period of time, as the cam lobe is raising the plunger. Increasing the effective stroke of the plunger (time that both ports are closed) will increase the amount of fuel delivered.

NOTE

For procedures on removing, replacing, and servicing the injection pumps in a sleeve metering fuel system, refer to the manufacturer's service manual.

GOVERNOR ACTION.—The governor on a Caterpillar sleeve metering fuel system is a mechanical governor and acts throughout the entire speed range of the engine. The majority of the sleeve metering fuel system uses three springs-a low-idle (inner) spring, a high-idle (outer) spring, and a dashpot spring. When the operator requires more power from the engine, he/she steps on the throttle. This causes the governor control lever to apply pressure that compresses the governor spring and to transfer this motion to the thrust collar. Since governor action from the spring and weight motion is of the back and forth variety, an additional linkage between the injection pumps and the governor transforms this sliding horizontal governor movement from the thrust collar into a rolling motion at the sleeve control shaft. A simple connecting lever commonly known as a bell crank lever accomplishes this action.

The bell crank lever contacts the thrust collar on one end and the governor sleeve control shaft on the other end. The bell crank pivots on a fixed vertical bell crankshaft to gain mechanical advantage through the lever principle. At the sleeve shaft end, it rides in a ball-and-socket joint that holds it in place and minimizes linkage movement. Therefore, any horizontal movement at the governor weight shaft and spring will cause an equally precise movement at the ball-and-socket joint, leading to reposition of the sleeves. If, in this case, the operator has increased the throttle position, the sleeves would be lifted, thereby covering the spill port for a longer overall effective plunger stroke.

As with any mechanical governor, an increase in either the throttle position or load will cause a speed change to the engine. Spring pressure is always trying to increase the fuel delivered to the engine, while centrifugal force of the rotating weights is always trying to decrease the amount of fuel going to the engine. Somewhere within the throttle range, however, a state of balance between these two opposing forces will exist as long as the engine speed is capable of overcoming the load placed on it to keep the spring and weight force in a state of balance.

When the engine is stopped, the action of the governor spring force places the thrust collar and the sleeve control shaft to the full-fuel position; therefore, easier starting is accomplished Once the operator cranks and starts the engine, centrifugal force will cause the flyweights to move outward, which now opposes the spring force, and the thrust collar and spring seat will come together, as they are pushed to a decreased fuel position. When the force of the weights equals the preset force of the spring established by the idle adjusting screw, these forces will be in a state of balance, and the engine will run at a steady idle speed with the throttle at a normal idle position.

Governor action will operate from idle throughout the speed range of the engine. A load stop pin controls the maximum speed of the engine. Rotation of the throttle lever causes the load stop lever to lift the load stop pin until it comes in contact with the stop bar or screw, thereby limiting any more fuel to the engine.

The purpose of the dashpot governor spring is to prevent any surging or irregular speed regulation of the engine by the fact that the piston either pulls fuel into or pushes fuel out of its cylinder through an orifice. The dashpot governor spring force varies with the piston movement, and as the engine load is increased or decreased, fuel is drawn into the piston cylinder through the orifice. This action gives the effect of a high governor spring rate that minimizes speed variations through oscillation during load changes of the engine. At any time the ignition switch is turned off or the governor speed control lever is moved to the OFF position, the sleeve levers move the sleeves down, cutting off fuel to the cylinders.

> **NOTE**
>
> Any and all adjustments to the governor and governor controls should be made according to the manufacturer's manual and specifications.

AUTOMATIC TIMING ADVANCE UNIT.— All current Caterpillar engines use some form of automatic timing for the fuel injection pump. On sleeve metering injection systems, this advance is mounted on the front end of the camshaft of the engine. The gear of the automatic advance unit meshes with and drives the fuel injection pump camshaft. The principal parts of the advance unit are the slides, the springs, and the weights. Operation of the automatic advance-timing unit is as follows:

- The slides are located and driven by two dowels, attached to the engine camshaft gear. 'The slides, in turn, fit into notches within the weights, thereby transferring their drive from the engine camshaft gear to the weights.
- With the engine running, centrifugal force exerted by the rotating weight assemblies cause them to act against the force of the springs.
- Since the weights are designed with notches in them, as they move outward under centrifugal force, they cause the slides to effect a change in the angle between the timing advance gear and the two drive dowels of the engine camshaft.
- This relative movement of the timing advance unit gear will, therefore, automatically advance or retard the timing of the fuel injection pump in relation to the engine speed and load.

However, built into the advance unit is a maximum timing variation of 5 degrees with the timing change starting at approximately low idle rpm and continuing on up to the rated speed of the engine; therefore, you cannot adjust the automatic timing advance unit. The timing unit is lubricated by engine oil under pressure from drilled holes at the engine camshaft front bearing.

Scroll Metering Fuel System

The scroll metering fuel system is similar to the sleeve metering fuel system in that it uses a plunger and barrel to create high pressure for injection. This system was designed to create higher injection pressure on direct-injection engines, offering an approximate 10 percent fuel economy improvement over precombustion-type engines, along with the ability to meet long-term EPA exhaust emissions regulations and better overall engine performance, as well as the ability to provide greater part commonality between different series engines.

In a scroll system two helix cut ports are used—the bypass closed port and the spill port Fuel is supplied from the transfer pump to an internal fuel manifold in the injection pump housing at approximately 35 psi. When the pump plunger is at the bottom of its stroke, fuel at transfer pump pressure flows around the pump barrel and to both the bypass closed port and spill port, which are both open at this time to allow fuel to flow into the barrel area above the plunger. The pump plunger is moved up and down by the action of a roller lifter, riding on the injection pump camshaft, which rotates at one-half of engine speed. As the injection pump camshaft rotates and the plungers rises, some fuel will be pushed back out of the bypass closed port until the top of the plunger eventually closes both the bypass closed port and the spill port. Further plunger movement will cause an increase in the trapped fuel pressure, and at approximately 100 psi, a check valve will open and fuel will flow into the injection line to the injection nozzle.

The fuel pressure of 100 psi is not enough to open the injection nozzle, which has an opening pressure of between 1,200 and 2,350 psi for a 3300 series engine and between 2,400 and 3,100 psi on 3406 engines. However, as the plunger continues to move up in its barrel, this fuel pressure is reached very quickly.

A high-pressure bleed-back passage and groove machined around the barrel are in alignment during the effective stroke to bleed off any fuel that leaks between the plunger and the barrel for lubrication purposes.

When the upward moving plunger uncovers the spill port, injection ceases, and although the plunger can still travel up some more, this is simply to allow most of the warm fuel (due to being pressurized) to spill back into the manifold. As the plunger moves downward in the barrel, it will once again uncover the bypass closed port and cool fuel will fill the area above the plunger for the next injection. When the spill port is opened, pressure inside the barrel is released and the check valve is seated by its spring.

Within the check valve assembly is a reverse flow check valve that opens when fuel pressure in the injection line remains above 1,000 psi and closes as soon as the fuel pressure drops to 1,000 psi. This will keep the fuel lines filled with fuel at 1,000 psi and ready for the next injection. This provides for a consistent and smooth engine power curve.

TRANSFER PUMP.—With the introduction of the scroll metering fuel system, the gear-type fuel transfer pump that had been used for years by Caterpillar was superseded by the use of a piston-type transfer pump. Current scroll metering fuel systems use a single-piston, double-acting pump with three one-way check valves.

The transfer pump is bolted to the low side of the injection pump housing. It is capable of delivering up to 51 gallons of fuel per hour at 25 psi. There is no need for a relief valve in this transfer pump due to the fact that maximum pressure is controlled automatically by the force of the piston return spring.

The transfer pump is activated by an eccentric (a device that converts rotary motion into reciprocating motion) on the injection pump camshaft, causing the pushrod to move in and out, as the engine is running. This action causes the piston to move down against the force of the piston return spring inside the transfer pump housing. The downward movement of the piston will cause the inlet check valve and the outlet check valve to close, while allowing the pumping check valve to open to allow fuel below the piston to flow into the area immediately above the downward piston.

As the injection pump camshaft eccentric rotates around to its low point, the transfer pump spring pushes the piston up inside its bore, causing the pumping check valve to close, and both the out and inlet valves are forced open. Fuel above the piston will be forced through the outlet check valve and the pump outlet port at approximately 35 psi. As this occurs, fuel will also flow through the pump inlet port and the inlet check valve to fill the area below the piston and the pump will repeat the cycle.

GOVERNOR.—The governor assembly used with the scroll metering fuel system is a hydra-mechanical servo-type unit. The reason for using a servo-valve is to provide a "boost" to the governor. Without the servo-valve, both the governor spring and flyweights would have to be very large and heavy. With the use of the servo assist, little force is required to move both the accelerator and the governor control lever. Basically, the governor assembly consists of three separate components:

1. The mechanical components of the governor, such as the weights, springs, and linkage.
2. The governor servo that provides hydraulic assistance through the use of pressurized engine oil to provide rapid throttle response and to reduce overall size requirement of the flyweights and springs.
3. The dashpot assembly that is designed to provide stability to the governor during rapid load/throttle changes.

FUEL INJECTOR NOZZLE.—The fuel injector nozzle, used with the scroll metering fuel system, is a multiple-hole design, inward-opening, non-leakoff type. There are minor changes between the earlier nozzles and current models. Older nozzles are identified by the use of a color-coded black or blue washer, while the newer ones use a copper washer.

The nozzle is a multiple-hole design since it is used in direct injection engines only. The number and size of the holes will vary between different series of engines. For example, the 3306 engine nozzle uses a nine-hole tip, while the nozzle in the 3406 uses a six-hole tip. These different nozzles cannot be intermixed in the same engine or switched from one series engine to another.

The nozzle is designed for injection pressures of 15,000 psi and short injection duration to prevent a loss in fuel economy due to stringent EPA emission requirements. The nozzle incorporates a carbon dam on the lower end of the pencil part of the body and a seal washer on the upper end. The carbon dam prevents carbon blow-by into the nozzle bore in the cylinder head, while the upper seal prevents compression leakage from the cylinder. Injector nozzle operation is as follows:

- The nozzle receives high-pressure fuel from the fuel pump through the inlet passage and filter screen and into the fuel passage.
- When fuel pressure is high enough, the injector valve is lifted against the force of the return spring and fuel is injected through the multiple holes in the spray tip. This causes an increase in fuel pressure and the fuel to be finely atomized spray for penetration of the compressed air in the combustion chamber.

- When fuel pressure drops below injection pressure, the return spring closes the fuel valve.

> **NOTE**
>
> For information on the removal and repair of the fuel injector nozzle, consult the manufacturer's service manual.

DISTRIBUTOR-TYPE FUEL SYSTEMS

The distributor-type fuel system is found on small- to medium-sized diesel engines. Its operation is similar to an ignition distributor found on gasoline engine. A rotating member, called a rotor, within the pump distributes fuel at high pressure to the individual injectors in engine firing-order sequence.

There are several manufacturers of distributor-type fuel injection systems. Operation of the fuel distribution is similar, in that a central rotating member forms the pumping and the distributing rotor is driven from the main drive shaft on which the governor is mounted.

The distributor-type fuel system that will be discussed is the DB2 Roosa Master diesel fuel-injection pump, manufactured by Stanadyne's Hartford Division.

Injection Pump

The Roosa Master fuel injection pump is described as an opposed plunger, inlet metering, distributor-type pump. Simplicity, the prime advantage of this design, contributes to greater ease of service, low maintenance cost, and greater dependability. Before describing the injection pump components and operation, let's familiarize ourselves with the model numbering system. For example, model number DB2833JN3000 breaks down like this:

D—Pump series

B—Rotor

2—Generation

8—Number of cylinders

33—Abbreviation of plunger diameter; 33, 0.330 in.

JN—Accessory code that relates to special pump options

3000—Specification number

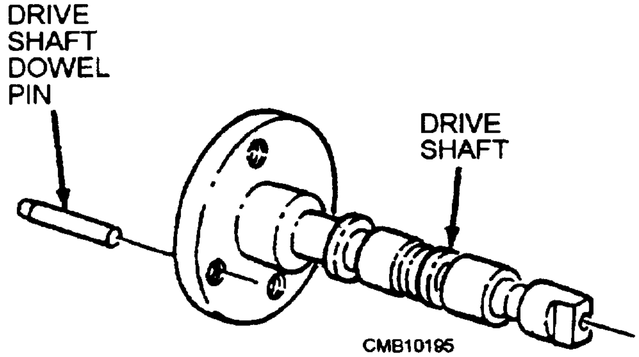


Figure 5-12.—Drive shaft.

> **NOTE**
>
> For information on the accessory code and the specification number for a particular pump, always refer to the manufacturer's service manual.

The main components of the DB2 fuel injection pump are the drive shaft, distributor rotor, transfer pump, pumping plungers, internal cam ring, hydraulic head, end plate, governor, and housing assembly with an integral advance mechanism. The rotating members that revolve on a common axis include the drive shaft, distributor rotor, and transfer pump.

DRIVE SHAFT (fig. 5-12)—The drive shaft is the driving member that rotates inside a pilot tube pressed into the housing. The rear of the shaft engages the front of the distributor rotor and turns the rotor shaft. Two lip type seals prevent the entrance of engine oil into the pump and retain fuel used for pump lubrication.

DISTRIBUTOR ROTOR (fig. 5-13)—The distributor rotor is the drive end of the rotor, containing

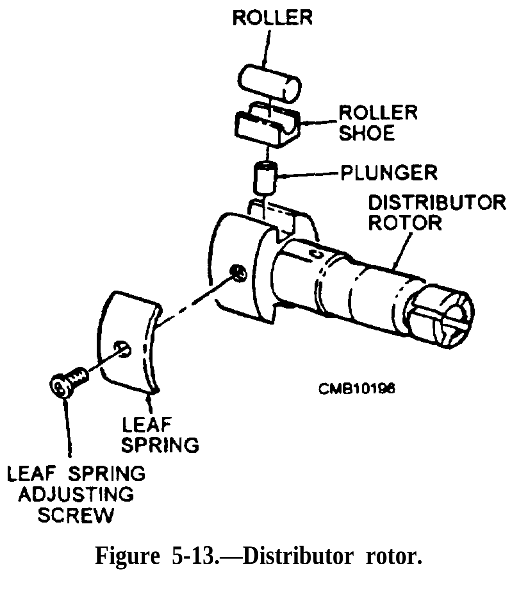
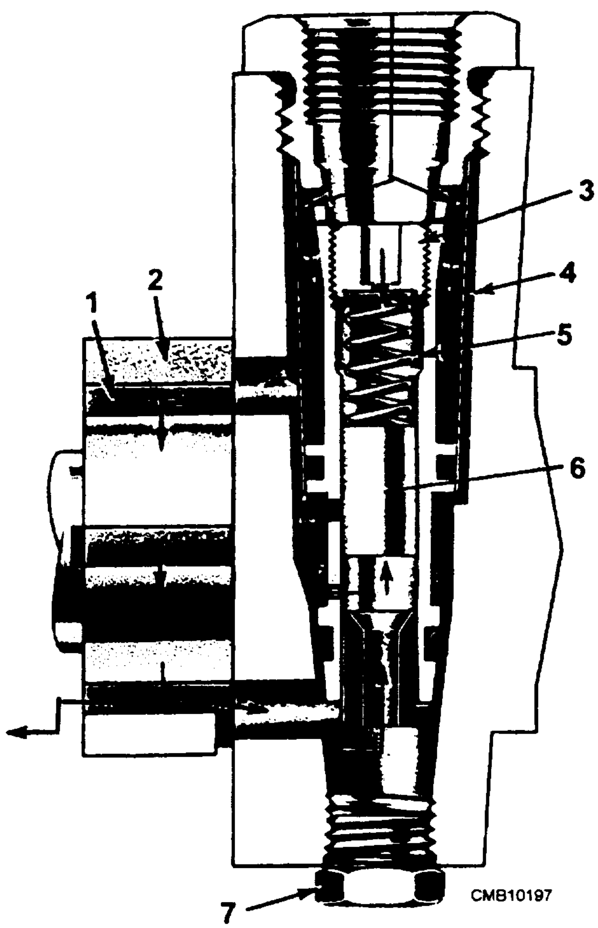


Figure 5-13.—Distributor rotor.

two pumping plungers located in the pumping cylinder. Slots in the rear of the rotor provide a place for two spring-loaded transfer pump blades. In the rotor, the shoe, which provides a large bearing surface for the roller, is carried in guide slots. The rotor shaft rotates with a very close fit in the hydraulic head. A passage through the center of the rotor shaft connects the pumping cylinder with one charging port and one discharging port The hydraulic head in which the rotor turns has a number of charging and discharging port, based on the number of engine cylinders. An eight-cylinder engine will have eight charging and eight discharging ports. The governor weight retainer is supported on the forwarded end of the rotor.

TRANSFER PUMP (fig. 5-14)—The transfer pump is a positive displacement, vane-style unit,



1. Transfer pump blade.
2. Transfer pump liner.
3. End plate adjusting plug.
4. Inlet strainer.
5. Regulating spring.
6. Regulating piston.
7. End plate plug.

Figure 5-14.—Transfer pump.

consisting of a stationary liner with spring-loaded blades that ride in slots at the end of the rotor shaft. The delivery capacity of the transfer pump is capable of exceeding both pressure and volume requirements of the engine, with both varying in proportion to engine speed. A pressure regulator valve in the pump end plate controls fuel pressure. A large percentage of the fuel from the pump is bypassed through the regulating valve to the inlet side of the pump. The quantity and pressure of the fuel bypassed increases, as pump speed increases.

The operation of the model DB2 injection is similar to that of an ignition distributor. However, instead of the ignition rotor distributing high-voltage sparks to each cylinder in firing order, the DB2 pump distributes pressurized diesel fuel as two passages align during the rotation of the pump rotor, also in firing order. The basic fuel flow is as follows:

- Fuel is drawn from the fuel tank by a fuel lift pump (mechanical or electrical) through the primary and secondary filters before entering the transfer pump.
- As fuel enters the transfer pump, it passes through a cone-type filter and on into the hydraulic head assembly of the injection pump.
- Fuel under pressure is also directed against a pressure regulator assembly, where it is bypassed back to the suction side should the pressure exceed that of the regulator spring.
- Fuel under transfer pump pressure is also directed to and through a ball-check valve assembly and against an automatic advance piston.
- Pressurized fuel is also routed from the hydraulic head to a vent passage leading to the governor linkage area, allowing any air and a small quantity of fuel to return to the fuel tank through a return line which self-bleeds air from the system. Fuel that passes into the governor linkage compartment is sufficient to fill it and lubricate the internal parts.
- Fuel leaving the hydraulic head is directed to the metering valve, which is controlled by the operator throttle position and governor ‘action. This valve controls the amount of fuel that will be allowed to flow on into the charging ring and ports.

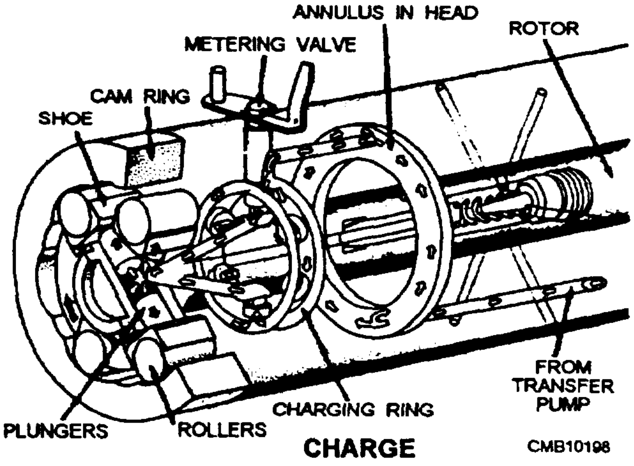


Figure 5-15.—Rotor in charge position.

- Rotation of the rotor by the drive shaft of the pump aligns the two inlet passages of the rotor with the charging ports in the charging ring, thereby allowing fuel to flow into the pumping chamber (fig. 5-15).
- The pumping chambers consists of a circular cam ring, two roller, and two plungers. As the rotor continues to turn, the inlet passages of the rotor will move away from the charging ports, allowing fuel to be discharged, as the rotor registers with one of the hydraulic head outlets.
- With the discharge port open (fig. 5-16), both rollers come in contact with the cam ring lobes, which forces them toward each other. This causes the plungers to pressurize the fuel between them and sending it on up to the injection nozzle and into the combustion chamber. The cam is relieved to allow a slight outward movement of the roller before the discharge port is closed off. This action drops the pressure in the injection line enough to give sharp cutoff injection and to prevent nozzle dribbling.

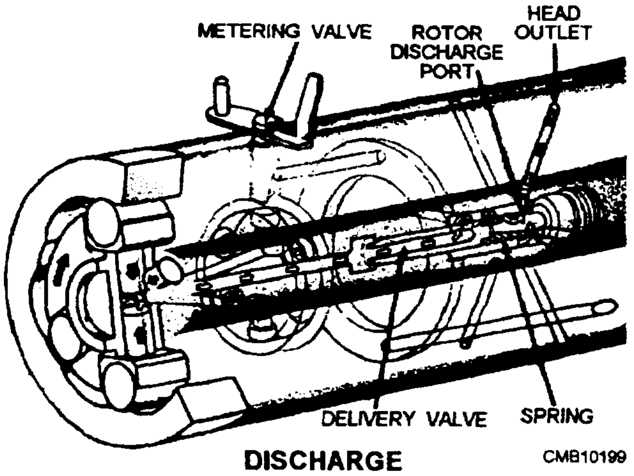


Figure 5-16.—Rotor in discharge position.

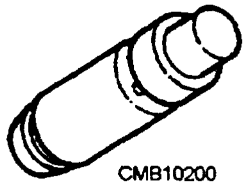


Figure 5-17.—Delivery valve.

The maximum amount of fuel that can be injected is limited by maximum outward travel of the plungers. The roller shoes, contacting an adjustable leaf spring, limit this maximum plunger travel. At the time the charging ports are in register, the rollers are between the cam lobes; therefore, their outward movement is unrestricted during the charging cycle except as limited by the leaf spring.

To prevent after-dribble and therefore unburnt fuel at the exhaust, the end of injection must occur crisply and rapidly. To ensure that the nozzle valve does, in fact, return to its seat as rapidly as possible, the **DELIVERY VALVE** (fig. 5-17). located in the drive passage of the rotor, acts to reduce injection line pressure. This occurs after fuel injection and the pressure is reduced to a value lower than that of the injector nozzle closing pressure. The valve remains closed during charging and opens under high pressure, as the plungers are forced together. Two small grooves are located on either side of the charging port or the rotor near its flange end. These grooves carry fuel from the hydraulic head charging posts to the housing. This fuel flow lubricates the cam, the rollers, and the governor parts. The fuel flows through the entire pump housing, absorbs heat, and is allowed to return to the supply tank through a fuel return line connected to the pump housing cover, thereby providing for pump cooling.

In the DB2 fuel pump, automatic advance is accomplished in the pump by fuel pressure acting against a piston, which causes rotation of the cam ring, thereby aligning the fuel passages in the pump sooner (fig. 5-18). The rising fuel pressure from the transfer pump increases the flow to the power side of the advance piston. This flow from the transfer pump passes through a cut on the metering valve, through a passage in the hydraulic head, and then by the check valve in the drilled bottom head locking screw. The check valve provides a hydraulic lock, preventing the cam from retarding during injection. Fuel is directed by a passage in the advance housing and plug to the pressure side of the advance piston. The piston moves the cam counterclockwise (opposite to the direction of the pump rotation). The spring-loaded side of the piston balances the force of the power side of the piston and limits the maximum movement of the cam. Therefore, with increasing speed, the cam is advanced and, with decreasing speed, it is retarded.

We know that a small amount of fuel under pressure is vented into the governor linkage compartment. Flow into this area is controlled by a small vent wire that controls the volume of fuel returning to the fuel tank, thereby avoiding any undue fuel pressure loss. The vent passage is located behind the metering valve bore and leads to the governor compartment by a short vertical passage. The vent wire assembly is available in several sizes to control the amount of vented fuel being returned to the tank. The vent wire should **NOT** be tampered with, as it can be altered only by removing the governor cover. The correct wire size would be installed when the pump assembly is being flow-tested on a pump calibration stand.

NOTE

For information concerning removal, installation, and servicing the injection pump, always refer to the manufacturer's service manual.

Injection Pump Accessories

The DB2 injection pump can be used on a variety of applications; therefore, it is available with several options as required. The options are as follows:

- The **flexible governor drive** is a retaining ring that serves as a cushion between the governor weight retainer and the weight retainer hub. Any torsional vibrations that may be transmitted to the pump area are absorbed in the flexible ring, therefore reducing wear of pump parts and allowing more positive governor control.

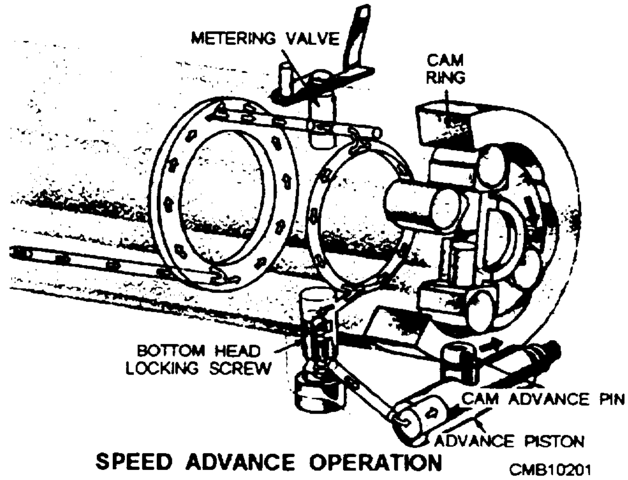


Figure 5-18.—Speed advance operation.

- The **electrical shutoff** (fig. 5-19) is available as either an energized to run (ETR) or energized to shut off (ETSO) model. In either case it will control the run and stop functions of the engine by positively stopping fuel flow to the pump plungers, thereby preventing fuel injection.

- The **torque screw,** used on DB2 pumps, allows a tailored maximum torque curve for a particular engine application. This feature is commonly referred to as torque backup, since the engine torque will generally increase toward the preselected and adjusted point as engine rpm decreases. The three factors that affect this torque are the metering valve opening area, the time allowed for fuel charging, and the transfer pump pressure curve.

Turning in the torque screw moves the fuel-metering valve toward its closed position. The torque screw controls the amount of fuel delivered at full-load governor speed.

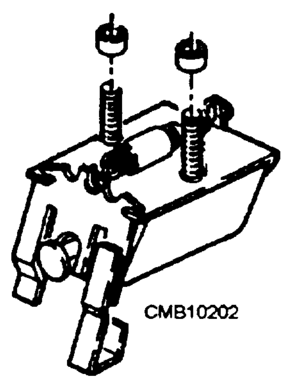


Figure 5-19.—Electrical shutoff.

If additional load is applied to the engine while it is running at full-load governed speed, there will be a reduction in engine rpm. A greater quantity of fuel is allowed to pass into the pumping chamber because of the increased time that the charging ports are open. Fuel delivery will continue to increase until the rpm drop to the engine manufacturer's predetermined point of maximum torque.

NOTE

Do **NOT** attempt to adjust the torque curve on the engine at any time. This adjustment can be done only during a dynamometer test where fuel flow can be checked along with the measured engine torque curve or on a fuel pump test stand.

Governor

The DB2 fuel injection pump uses a mechanical type governor (fig. 5-20). The governor function is that of controlling the engine speed under various load settings. As with any mechanical governor, it operates on the principle of spring pressure opposed by weight force, with the spring attempting to force the linkage to an increased fuel position at all times. The centrifugal force of the rotating flyweights attempts to pull the linkage to a decreased fuel position.

Rotation of the governor linkage varies the valve opening, thereby limiting and controlling the quantity of fuel that can be directed to the fuel plungers. The position of the throttle lever controlled by the operator's foot will vary the tension of the governor spring. This force, acting on the linkage, rotates the metering valve to an increased or decreased fuel position as required.

At any given throttle position the centrifugal force of the rotating flyweights will exert force back through the governor linkage which is equal to that of the spring, resulting in a state of balance. Outward movement of the weights acting through the governor thrust sleeve can turn the fuel-metering valve by means of the governor linkage arm and hook. The throttle and governor spring position will turn the metering valve in the opposite direction.

The governor is lubricated by fuel received from the fuel housing. Fuel pressure in the governor housing is

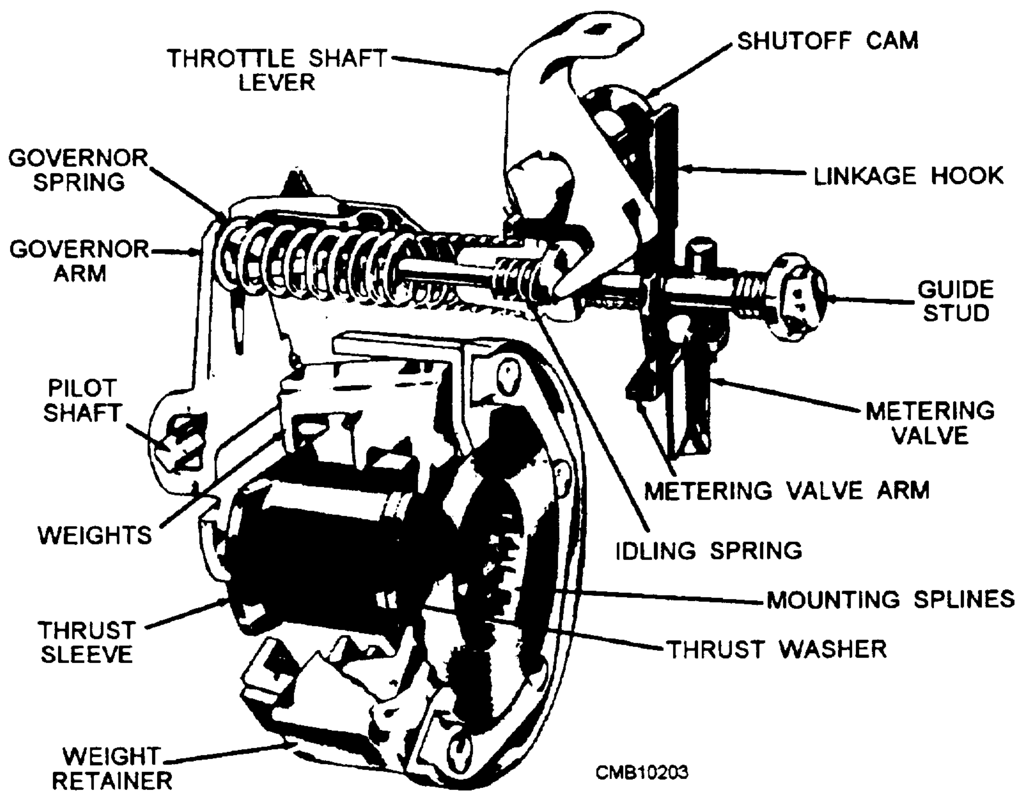


Figure 5-20.—Governor assembly.

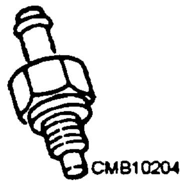


Figure 5-21.—Spring-loaded ball-check valve.

maintained by a spring-loaded ball-check return fitting (fig. 5-21) in the governor cover of the pump.

Nozzle

The injector nozzle, used with the DB2 fuel injection pump, is opened outward by high fuel pressure and closed by spring tension (fig. 5-22). It has a unique feature in that it is screwed directly into the cylinder head An outward opening valve creates a narrow spray that is evenly distributed into the precombustion chamber. Both engine compression and combustion pressure forces assist the nozzle spring in closing an outward opening valve. These factors allow the opening pressure settings of the nozzle to be lower than those of conventional injectors.

During injection, a degree of swirl is imparted to the fuel before it actually emerges around the head of the nozzle. This forms a closely controlled annular orifice with the nozzle valve seat, which produces a high-velocity atomized fuel spray, forming a narrow cone suitable for efficient burning of the fuel in the precombustion chamber.

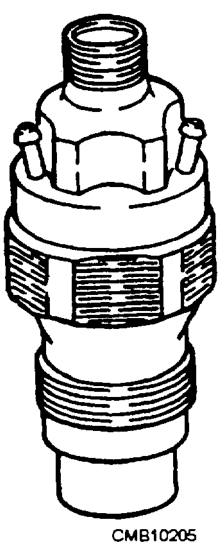


Figure 5-22.—Injector nozzle.

The nozzle has been designed as basically a throwaway item. After a period of service, the functional performance may not meet test specifications. Nozzle testing is comprised of the following checks:

- Nozzle opening pressure
- Leakage
- Chatter
- Spray pattern

Each test is done independently of the others (for example, when checking the opening pressure, do not check for leakage). If all the tests are satisfied, the nozzle can be reused. If any one of the tests is not satisfied, replace the nozzle. For testing procedures, consult the manufacturer's service manual.

CAUTION

When testing nozzles, do not place your hand or arms near the top of the nozzle. The high-pressure atomized fuel spray from the nozzle has sufficient penetrating power to puncture flesh and destroy tissue and may result in blood poisoning. The nozzle tip should always be enclosed in a receptacle, preferably transparent, to contain the spray.

DETROIT DIESEL UNIT INJECTION SYSTEMS

The fuel system used by Detroit diesel is known as a low-pressure fuel system, owing to the fact that fuel delivered to the unit injectors averages 45 to 70 psi. This is much lower than the average 2,500 to 300 psi that passes through the fuel line from the injection pump and nozzles used in other systems.

The four main functions of the fuel system used with a Detroit diesel engine are as follows:

1. To supply clean, cool fuel to the system by passing it through at least a primary and secondary filter before the pump and injectors.
2. To cool and lubricate the injectors, as the fuel flows through them, and return to the tank (recirculatory system).
3. To maintain sufficient pressure at all times through the action of the positive displacement

gear pump and the use of a restricted fitting located at the cylinder head return fuel manifold.

4. To purge the fuel system of any air; the system is recirculator-y in operation, therefore allowing any air to be returned to the fuel tank.

Since the basic fuel system used on all Detroit diesel engines is identical as far as components used, the description of operation for one can be readily related to any other series of Detroit diesel engine (fig. 5-23).

The basic fuel system consists mainly of the following:

1. Fuel injectors.
2. Fuel pipes to and from the injectors (inlet and outlet).
3. Fuel manifolds, which are cast internally within the cylinder head. The upper manifold is the "inlet" and the lower is the "return" or "outlet." To prevent confusion, the words *in* and *out* are cast in the side of the head.

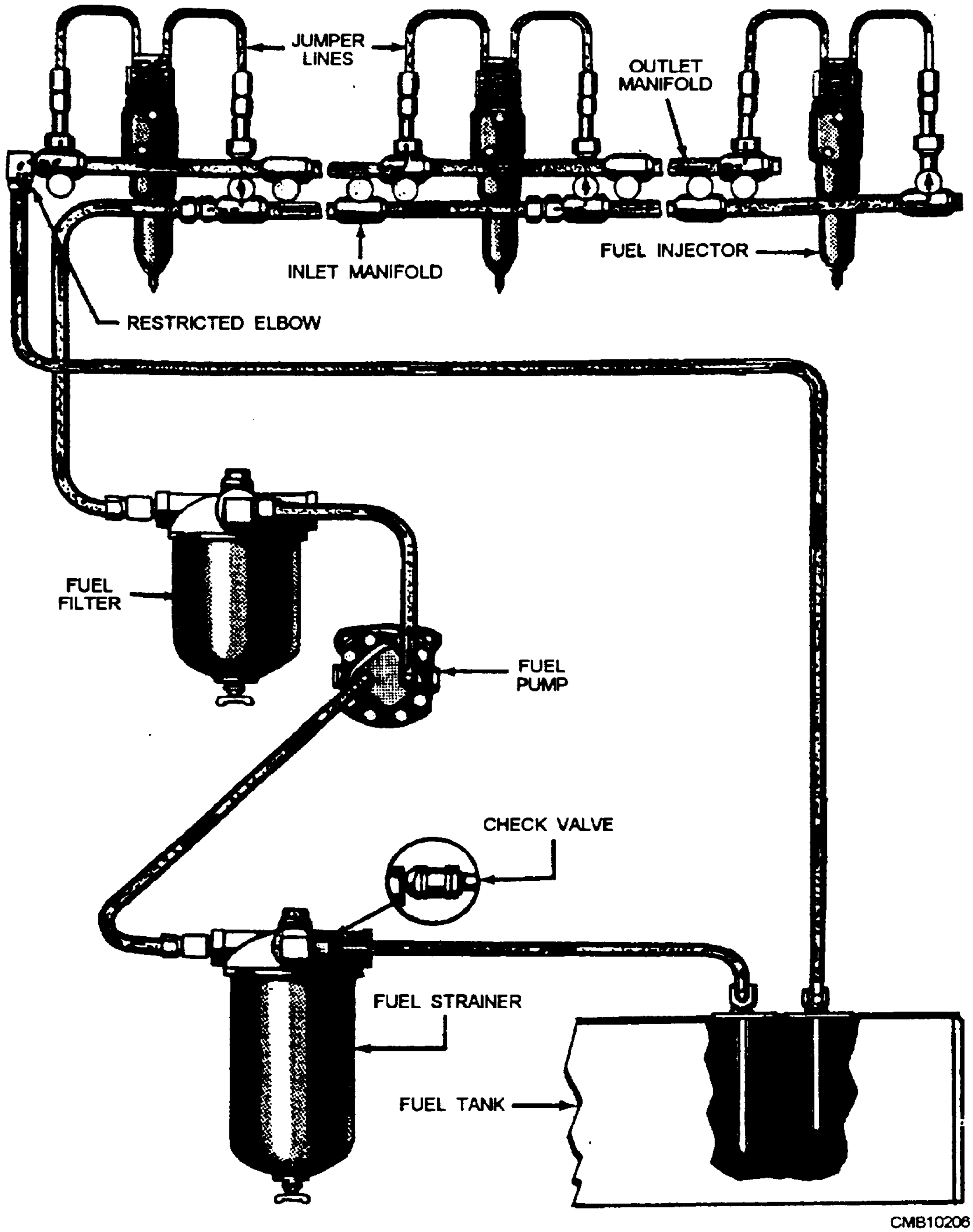


Figure 5-23.—Diagram of typical Detroit diesel fuel system.

4. Fuel pump (supply pump, not an injection pump).
5. Fuel strainer or primary filter.
6. Fuel filter (secondary).
7. Fuel lines.
8. One-way check valve.
9. Restricted fitting on in-line engines or a restricted TEE on V-type engines.

Fuel Pump

The fuel pump is a positive displacement gear-type unit that transfers fuel from the tank to the injectors at 65 to 75 psi (fig. 5-24). The standard pump has the ability to deliver 1.5 gallons per minute, or 90 gallons per hour.

The fuel pump body and cover are aligned by means of two dowels. The body and cover are machined surfaces that contain no gasket between them, although a thin coat of sealant applied to these surfaces is recommended at installation. A relief valve bypasses fuel back to the inlet side of the pump when pressure reaches above the 65 to 75 psi.

There are two oil seals pressed into the pump bore from the flanged end for the following purposes:

1. The seal closest to the drive coupling prevents lube oil from entering the fuel pump.
2. The inner seal closest to the pump gears prevents fuel leakage.

The installed seals do not butt up against each other, but have a small space between them. Drilled and taped

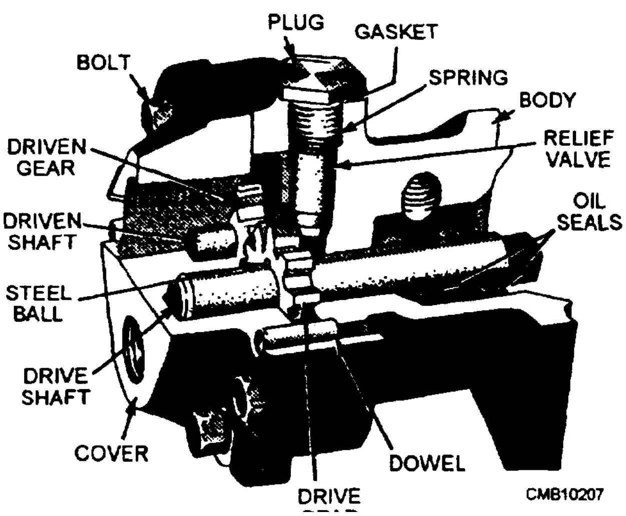


Figure 5-24.—Typical gear fuel pump assembly.

into this cavity in the fuel pump body are two small holes—one which is usually plugged and the other one is open to allow any fuel or lube oil to drain, thereby indicating damaged seals. Sometimes a small fitting and tube extend from one of these holes to direct any leakage to a noticeable spot. Acceptable leakage should not exceed 1 drop per minute.

If you are ever in doubt as to the rotation of the fuel pump, it can be identified as follows:

1. Stamped on the pump cover are the letters LH or RH, plus an arrow indicating the direction of rotation.
2. On in-line engines, the rotation of the fuel pump can be determined by its location on the engine. When viewed from the flywheel end: left-hand side location, LH pump rotation; right-hand side location, RH pump rotation.
3. A similar method would be to grasp the pump in your left or right hand, as it mounts on the engine. Whichever thumb covers the relief valves indicates the rotation of the pump.

The letter *I/L* (inlet) is also stamped on the pump cover; however, if not visible, the inlet side is the hole on the pump cover closest to the relief valve plug.

Since the pump constantly circulates a supply of fuel to and through the injectors, the unused fuel cools and lubricates the injectors and purges the system of any air, then returns to the fuel tank via the restricted fitting and return line.

All Detroit diesel engines are equipped with a return Line restricted fitting, the actual size varying with the engine injector size and application. Every restricted fitting has the letter *R* followed by a number that indicates its hole size in thousandths of an inch. Therefore, a fitting with R80 stamped on it indicates a 0.080-inch-diameter hole drilled within the fitting.

These fittings may look like an ordinary brass fittings externally; therefore, care must be taken to ensure that, in fact, the proper restricted fitting, and not just any fitting, is installed into the return line. Use of too large a fitting can lead to a low fuel pressure within the fuel manifold. This condition can cause poor engine performance. A small fitting can lead to increased fuel temperatures and some restriction against the fuel flow. Refer to the service manual of the engine for any particular specifications.

The basic fuel flow is as follows:

- The fuel pump draws fuel from the tank past a one-way no-return check valve into the primary filter. Here the fuel passes through a 30-micron-filtering-capacity, cotton-wound, sock-type element. From the primary filter it passes up to the suction side of the fuel pump. Here the fuel is forced out at 65 to 75 psi to the secondary filter that is a pleated paper element of lo-micron filtering capacity.

- Fuel then passes up to the inlet fuel manifold of the cylinder head where it is distributed through the fuel jumper lines into each injector.

- All surplus fuel (not injected) returns from the injectors through fuel jumper lines to the return fuel manifold, through the restricted fitting, which maintains adequate fuel pressure in the cylinder head at all times, then back to the tank.

Injectors

The fuel injector, or what is often referred to as a **unit injector** (fig. 5-25), is used by Detroit diesel in all series of engine that they build. Certainly, there are some variations in basic design and in the actual testing procedures used; however, the function and operation is the same for all.

Unit injectors were designed with simplicity in mind both from a control and adjustment outlook. They are used on direct-injection, open-type, two-cycle combustion chamber engines manufactured by General Motors. No high-pressure fuel lines or air-fuel mixing or vaporizing devices are required with these injectors. The fuel from the fuel pump is delivered to the inlet fuel manifold (cast internally within the cylinder head) at a pressure of 65 to 75 psi. The fuel then flows to the injectors through fuel pipes called jumper lines. Once the fuel from the pump reaches the injector, it performs the following functions:

1. **Times injection:** liming of the injector is accomplished by movement of the injector control rack, which causes rotation of the plunger within the injector bushing. Since the plunger is manufactured with a helical chamber area, this rotation will either advance or retard closing of the ports in the injector bushing, and therefore the start and end of the actual injection period. Pushrod adjustment establishes the height of the injector follower above the body. In turn, this factor establishes the point or time that the descending plunger closes the bushing ports, allowing injection to begin.

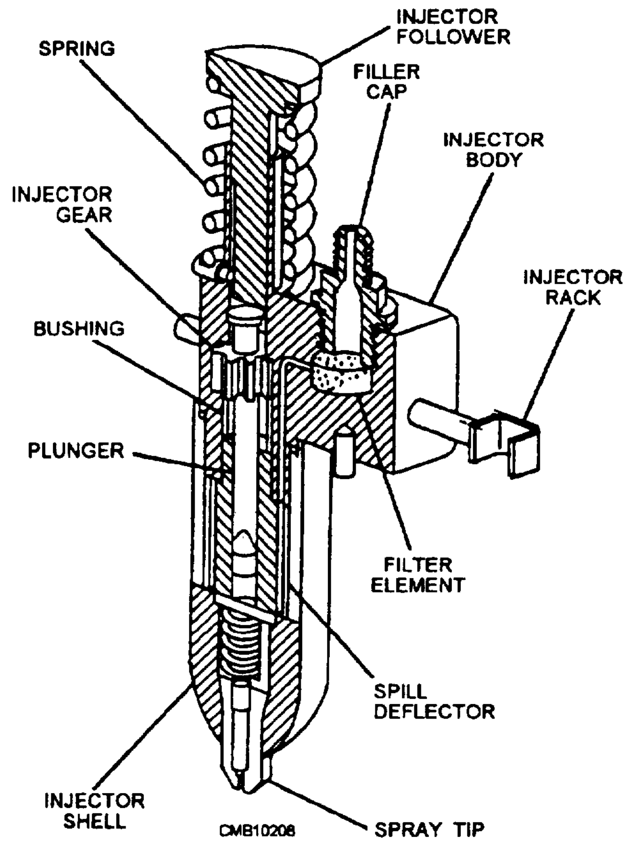


Figure 5-25.—Unit injector.

2. **Meter the fuel:** The rotation of the plunger by movement of the injector control rack will advance or retard the start and end of injection. If the length of time that the fuel can be injected is varied, the amount of fuel will be varied.

3. **Pressurizes the fuel:** Fuel that is trapped underneath the plunger on its downward stroke will develop enough pressure to force its way past the check valve or needle valve, therefore entering the combustion chamber.

4. **Atomizes the fuel:** Fuel under pressure that forces its way past the check or needle valve must than pass through small holes or orifices in the injector spray tip. This passage breaks the fuel down into a finely atomized spray, as it enters the combustion chamber.

The two-stroke Detroit diesel engine unit fuel injector is located in the cylinder head. The injector sits in a copper tube in the head that is surrounded by water for cooling purposes. The injector is placed in the cylinder head by a dowel pin on the underside of its body. The injector is held in place by a single bolt and clamp arrangement. The clamp sits low on the injector body, which allows clearance for the valve bridge operating mechanism. The injector is also known as an offset body because the fuel inlet and outlet are offset to one another. This arrangement allows sufficient clearance between the valves.

Each injector has a circular disc pressed into a recess at the front side of the injector for identification purposes. The identification tag indicates the nominal output of the injector in cubic millimeters. Both the plunger and bushing are marked with corresponding numbers to identify them as mating parts. Therefore, if either the plunger or bushing requires replacement, both must be replaced as an assembly.

The injector control rack for each injector is actuated by a lever on the injector control tube that, in turn, is connected to the governor by mean of a fuel rod. These levers can be adjusted, thus permitting a uniform setting of all injector racks. Basic operation of the unit injector is as follows:

- Fuel, under pressure, enters the injector at the inlet side through a filter cap and filter element. From the filter element, the fuel passes through a drilled passage into the supply chamber—that area between the plunger bushing and the spill deflector and the area underneath the injector plunger within the bushing. The plunger operates up and down in the bushing, the bore of which is open to the fuel supply in the annular chamber by two funnel-shaped ports in the plunger bushing.

- The plunger descends, under pressure of the injector rocker arm, first closing of the lower port and then the upper. Before the upper port is shut off, fuel being displaced by the descending plunger flows up through the "T" drilled hole in the plunger and escapes through the upper port and into the supply chamber.

- With the upper and lower ports closed off, the remaining fuel is subjected to increased pressure by the continued downward movement of the plunger. When sufficient pressure is built up, it opens the flat, non-return, check valve. The fuel is compressed until the pressure force acting on the needle valve is sufficient to open the valve against the downward force of the valve spring. As soon as the needle valve lifts off its seat, the fuel is forced through the small orifices in the spray tip and atomized into the combustion chamber.

- As the plunger continues to descend, it uncovers the lower port, so fuel pressure is relieved, and the valve spring closes the needle valve, ending injection. Then the plunger returns to its original position and waits for the next injection cycle.

Injector Timing

Whenever an injector has been removed and reinstalled or a new injector has been installed in an engine, the injector must be timed and the control rack positioned.

The injector plunger is timed by the fact that it meshes with a flat area on the internal rack gear inside the injector body. It is also timed to the fuel control rack—a dot on the gear that is centered between two dots on the injector control rack. Actual effective length that the plunger moves down in its bushing is controlled by the height of the injector follower above the injector body.

To time an injector properly, adjust the injector follower to a definite height in relation to the injector body (fig. 5-26). This will vary according to the size of the injector being used. This dimension is given in the engine tune-up section of the service manual. Current timing pin dimensions can also be found stamped on the valve rocker cover emissions decal. Be certain that you select the proper timing pin gauge (fig. 5-27); otherwise, the engine will run rough and fail to perform properly under load. In addition, continued operation of the injector set at the wrong timing height can result in engine damage.

All the injectors can be timed in firing-order sequence during one full revolution of the crankshaft on all two-cycle engines. A four-cycle engine requires two revolutions of the crankshaft. The sequence for injector timing is as follows:

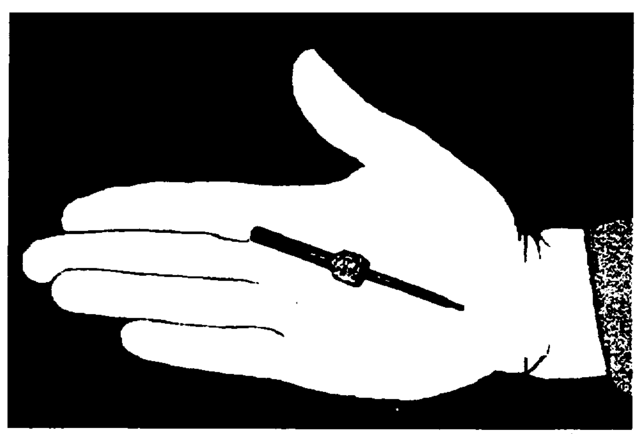
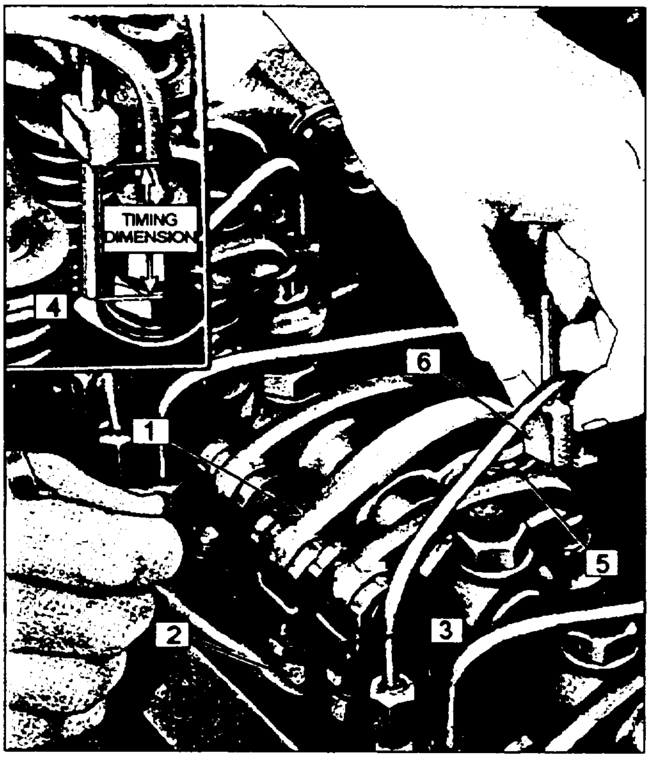


Figure 5-26.—Timing fuel injectors.



1. Rocker injector arm.
2. Push rod.
3. Lock nut.
4. Fuel injector.
5. Injector follower.
6. Injector timing gage.

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Figure 5-27.—Timing gauge.

1. The governor speed control lever should be in the IDLE position. If a stop lever is provided, secure it in the STOP position.
2. Rotate the engine crankshaft, using an engine barring tool, until the exhaust valves are fully depressed on the cylinder that you wish to set the injector. If a barring tool is not available, a 3/4-inch-square drive socket set with a suitable socket to fit over the crankshaft pulley will also do.
3. Insert the small end of the timing pin (gauge) into the hole provided in the top on the injector body, with the flat portion of the gauge facing the injector follower.
4. Gently push the gauge by holding the knurled stem with the thumb and forefinger towards the follower. There should be a slight drag between the gauge and the follower.
5. If this cannot be done, loosen the injector pushrod locknut and adjust it until the drag of the gauge (slight feel) has been determined. Hold the pushrod and tighten the locknut. Recheck the feel, and, if needed, readjust.
6. When hot setting this adjustment, wipe off the top of the injector follower and place a clean drop of oil on it. When properly adjusted, the gauge should just wipe off the oil film from the follower when the slight drag is felt.
7. Time remaining injectors in the same manner.

Equalizing Injectors

Since all the injector racks are connected to the fuel control tube and then to the governor by the fuel rod or rods, they must be set correctly. This ensures that they are equally related to the governor. Their positions determine the amount of fuel that will be injected into the individual cylinders, ensuring equal distribution of the load. Failure to set the racks properly will result in poor performance and a lack-of-power complaint.

Adjusting the inner and outer adjusting screws on the rack control lever (fig. 5-27) equalizes the injectors. This is a rather delicate adjustment. and it may be necessary to make these adjustments several times before the engine operates just right.

To increase the amount of fuel injected, loosen the outer adjusting screw and tighten the inner adjusting screw, thereby moving the control rack inward. To decrease fuel injection, loosen the inner adjusting screw slightly and tighten the outer adjusting screw which moves the control rack outward. In making the operating adjustments, never turn the adjusting screws more than one-fourth turn at a time; for if one injector is adjusted too far out of line with the others, it will prevent the full travel of the racks and reduce the maximum power to the engine.

NOTE

For exact procedures for adjusting the injector rack control levers, refer to the manufacturer’s service manual.

Sometimes smoother engine operation can be obtained by making slight changes to the adjustments after the engine is warmed to operating temperature (above 140°F). For example, one cylinder may not be carrying its share of the load as indicated by a comparatively cooler cylinder. Therefore, the control rack should be adjusted for more fuel. A slight knocking noise from another cylinder would indicate an adjustment for slightly less fuel.

Do not attempt to obtain a smooth running engine by changing control-rack settings without first timing and equalizing injection in the recommended manner.

Governor

Detroit diesel engines use both mechanical and hydraulic governors on the engines of the following type:

1. Mechanical limiting speed governor
2. Variable mechanical speed governor
3. Variable low-speed limiting speed mechanical governor
4. Mechanical constant speed governor (earlier engines)
5. Dual-range limiting speed mechanical governor
6. Woodward SG hydraulic governor
7. Woodward PSG hydraulic governor
8. Woodward electric governor

On Detroit diesel engines the type of governor used is dependent on the particular engine application; therefore, setup can vary slightly between engines. All Detroit diesel mechanical governors are easily identifiable by a nameplate attached to the governor housing. The following letters are typical examples.

DWLS: double-weight limiting speed (mobile equipment)

SWLS: single-weight limiting speed (mobile equipment)

SWVS: single-weight variable speed (industrial and marine)

VLSLS: variable low-speed limiting speed (highway vehicles)

DWDRG: double-weight dual range governor (highway vehicles)

SG, PSG, SGX, UG8: Woodward hydraulic-type governors (industrial and generator sets)

The functions of all these governors, whether mechanical or hydraulic, are to control engine speed and correct for any change in load applied or removed from the engine. They all work on the basic principle of weights against spring pressure; therefore, all governors are of the speed-sensing type.

Since the action of all these governors is the same, but with a difference only in purpose, we will discuss the two most common types found on a Detroit diesel engine—the limiting and variable speed governors.

The limiting speed type governor is found in both single- and double-weight version and can also be found on both in-line and V-type engines. Riveted on the side of the governor housing is an identification plate, which shows the following:

1. Governor part number
2. Date of manufacture
3. Idle speed range
4. Type, such as DWLS, meaning double-weight limiting speed
5. Drive ratio

Regardless of whether the limiting speed governor is of the single- or double-weight variety, the action of the governor is the same. The purpose of the limiting speed governor is as follows:

1. Controls engine idle speed
2. Limits the maximum speed of the engine

The application of the engine determines whether a single- or double-weight governor will be used. The most prominent application for the limiting speed governor is highway truck engines, since the governor has no control in the intermediate engine speed range. This allows the operator to have complete control of the injector rack movement through throttle action alone. This permits fast throttle response for engine acceleration or deceleration.

The variable speed mechanical governor is found extensively on industrial and marine applications, since it is designed for the following functions:

1. Controls the engine idle speed
2. Controls the maximum engine speed
3. Holds the engine speed at any position between idle and maximum as desired and set by the operator.

The response and reaction of the variable speed mechanical governor is similar to that of the limiting speed type with just a few exceptions. Since the variable speed mechanical governor controls speed throughout the total rpm range, there is no intermediate range as with the limiting speed governor. The variable speed governor uses only one set of weights and one spring.

In a variable speed mechanical governor, any given throttle setting or load from idle to maximum speed, a state of balance can exist. If, however, the load is increased or decreased, a corrective action will be initiated. The bell crank lever and pivoting differential lever will be moved by the action of the governor spring or weights to reestablish a state of balance.

Remember the governor can only react and change to the rpm of the engine.

The variable speed mechanical governor is readily identifiable from the limiting speed governor by the fact that it has only one lever on the top of the governor cover, which is the stop/run lever. The speed control lever is located vertically on the end of the governor spring housing. A large booster spring is attached between the speed control lever and a bracket on the cylinder head, used to assist the operator in overcoming governor resistance during throttle movement. The letters *SWVS* (single-weight variable speed) are stamped on the governor identification plate.

NOTE

Before performing any adjustments or repairs to the governor, it is recommended that you consult the manufacturer's service manual.

CUMMINS DIESEL FUEL SYSTEMS

Over the years Cummins has produced a series of innovations, such as the first automotive diesel, in addition to being the first to use supercharging and then turbocharging. All cylinders are commonly served through a low-pressure fuel line. The camshaft control of the mechanical injector controls the timing of injection throughout the operating range. This design eliminates the timing-lag problems of high-pressure systems.

To meet Environmental Protection Agency (EPA) exhaust emissions standards, Cummins offers the Celect (electronically controlled injection) system. Since the Celect system did not start production until 1989, there are literally thousands of Cummins with pressure-time (PT) fuel systems. We will discuss the operation of the PT system first, then discuss the basic operating concept of the Celect system.

Pressure-Time Fuel System

The pressure-time (PT) fuel system (fig. 5-28) is exclusive to Cummins diesel engines; it uses injectors that meter and injects the fuel with this metering based

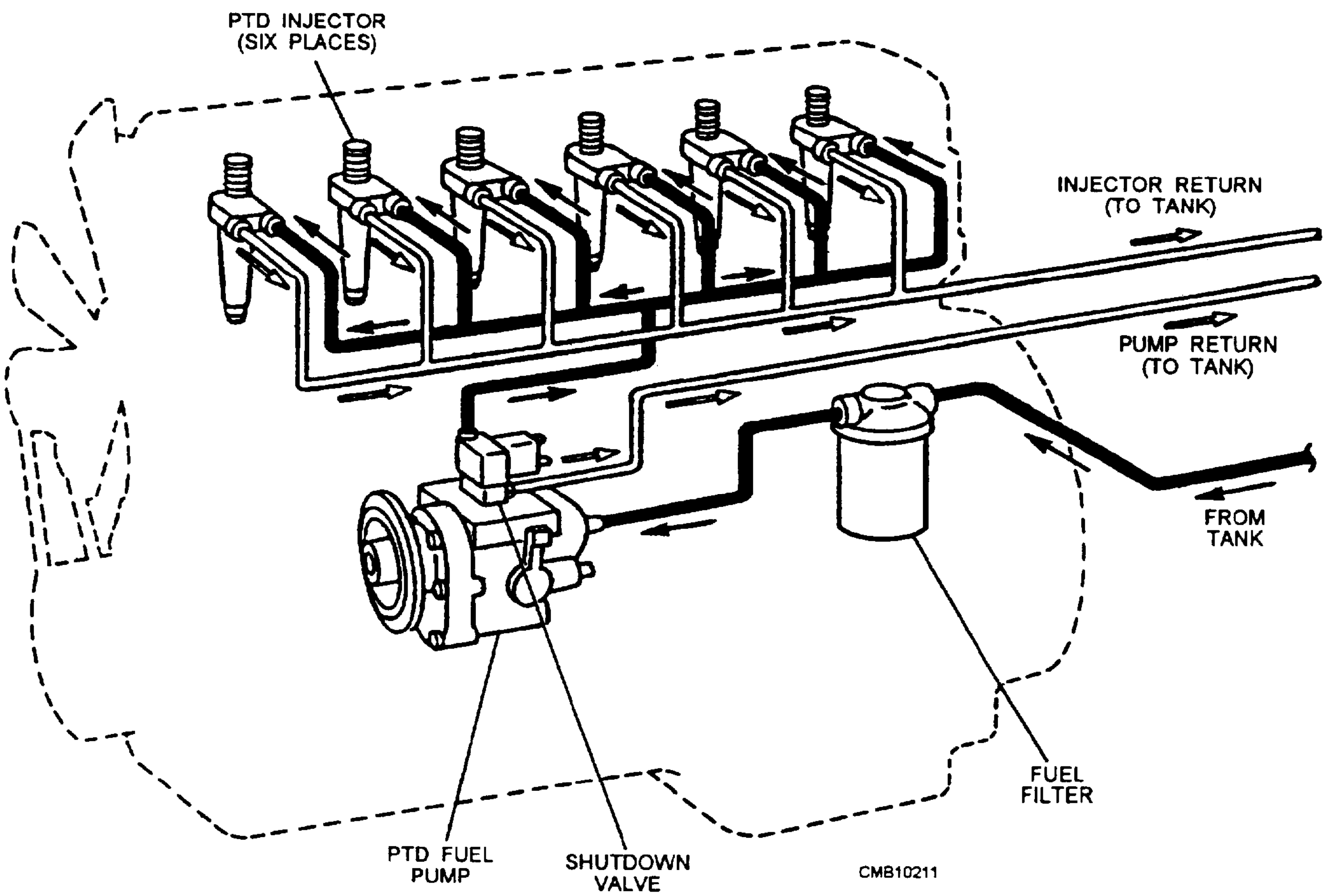


Figure 5-28.—Pressure-time fuel system.

on a pressure-time principle. A gear-driven positive displacement low-pressure fuel pump naturally supplies fuel pressure. The time for metering is determined by the interval that the metering orifice in the injector remains open. This interval is established and controlled by the engine speed, which determines the rate of camshaft rotation and consequently the injector plunger movement.

Since Cummins engines are all four-cycle, the camshaft is driven from the crankshaft gear at one-half of engine speed. The fuel pump turns at engine speed. Because of this relationship, additional governing of fuel flow is necessary in the fuel pump.

A flyball type mechanical governor controls fuel pressure and engine torque throughout the entire operating range. It also controls the idling speed of the engine and prevents engine overspeeding in the high-speed range. The throttle shaft is simply a shaft with a hole; therefore, the alignment of this hole with the fuel passages determines pressure at the injectors.

A single low-pressure fuel line from the fuel pump serves all injectors; therefore, the pressure and the amount of metered fuel to each cylinder are equal.

The fuel-metering process in the IT fuel system has three main advantages:

1. The injector accomplishes all metering and injection functions.
2. The injector injects a finely atomized fuel spray into the combustion chamber at spray-in-pressures exceeding 20,000 psi.
3. A low-pressure common-rail system is used, with the pressure being developed in a gear-type pump. This eliminates the need for high-pressure fuel lines running from the fuel pump to each injector.

FUEL PUMP.—The fuel pump (fig. 5-29) commonly used in the pressure-time system is the PTG-AFC pump (PT pump with a governor and an air-fuel control attachment). The "P" in the name refers to the actual fuel pressure that is produced by the gear pump

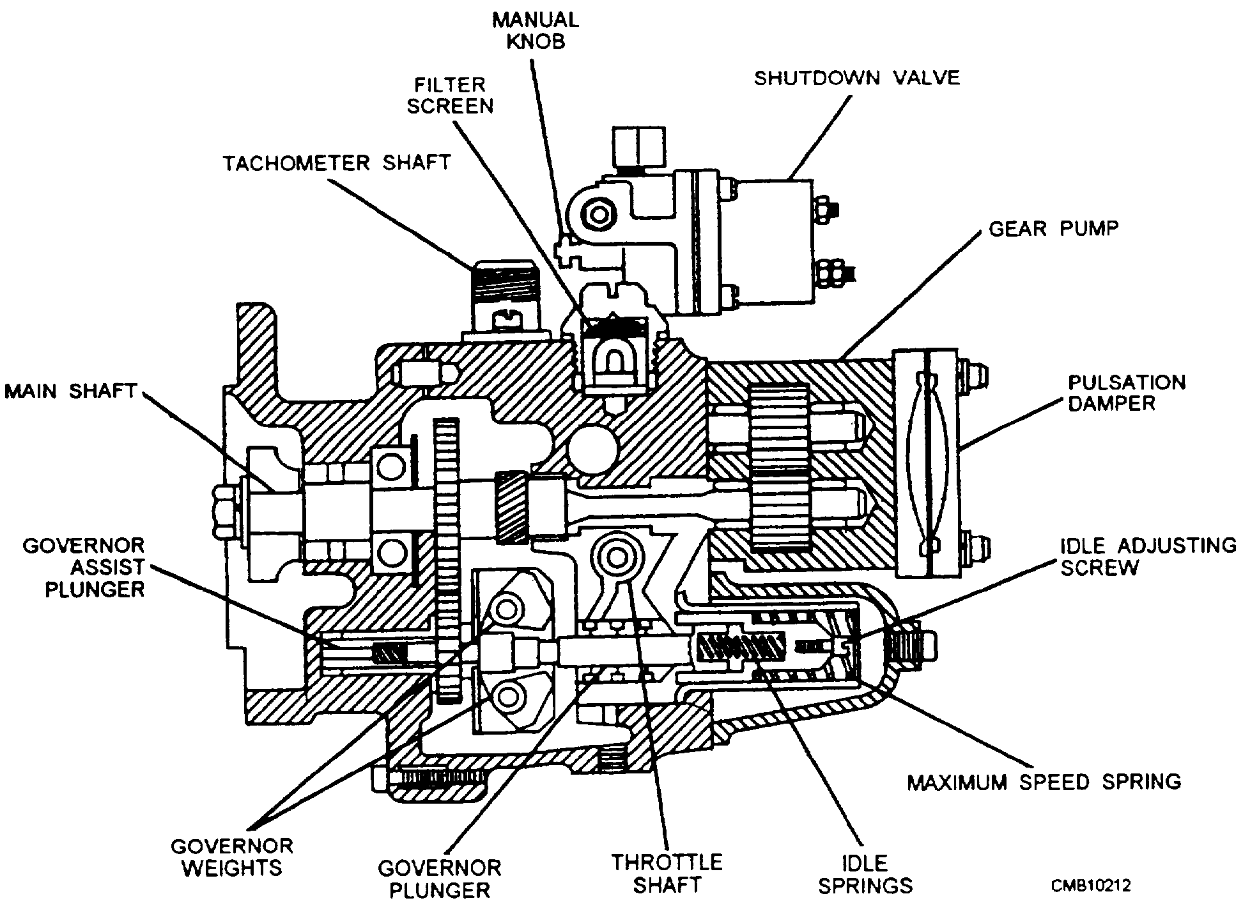


Figure 5-29.—Pressure-time (PT) gear pump.

and maintained at the inlet to the injectors. The "T" refers to the fact that the actual "time" available for the fuel to flow into the injector assembly (cup) is determined by the engine speed as a function of the engine camshaft and injection train components.

The air-fuel control (AFC) is an acceleration exhaust smoke control device built internally into the pump body. The AFC unit is designed to restrict fuel flow in direct proportion to the air intake manifold pressure of the engine during acceleration, under load, and during lug-down conditions.

Within the pump assembly a fuel pump bypass button of varying sizes can be installed to control the maximum fuel delivery pressure of the gear-type pump before it opens and bypasses fuel back to the inlet side of the pump. In this way the horsepower setting of the engine can be altered fairly easily. The major functions of the PTG-AFC fuel pump assembly are as follows:

1. To pull and transfer fuel from the tank and filter
2. To develop sufficient fuel pressure to the fuel rail (common fuel passage) to all of the injectors
3. To provide engine idle speed control (governing)
4. To limit the maximum no-load and full-load speed of the engine (governing)
5. To allow the operator to control the throttle position and therefore the power output of the engine
6. To control exhaust smoke emissions to EPA specifications under all operating conditions
7. To allow shutdown of the engine when desired

A major feature of the PT pump system is that there is no need to time the pump to the engine. The pump is designed simply to generate and supply a given flow rate at a specified pressure setting to the rail to all injectors. The injectors themselves are timed to ensure that the start of injection will occur at the right time for each cylinder.

The basic flow of fuel into and through the PT pump assembly will vary slightly depending on the actual model. A simplified fuel flow is as follows:

- As the operator cranks the engine, fuel is drawn from the fuel tank by the gear pump through the fuel supply line to the primary filter. This filter is normally a filter/water separator.
- The filter fuel then flows through a small filter screen that is located within the PT pump assembly, and then flows down into the internal governor sleeve.
- The position of the governor plunger determines the fuel flow through various governor plunger ports.
- The position of the mechanically operated throttle determines the amount of fuel that can flow through the throttle shaft.
- Fuel from the throttle shaft is then directed to the AFC needle valve.
- The position of the AFC control plunger within the AFC barrel determines how much throttle fuel can flow into and through the AFC unit and on to the engine fuel rail, which feeds the fuel rail.

The AFC plunger position is determined by the amount of turbocharger boost pressure in the intake manifold, which is piped through the air passage from the intake manifold to the AFC unit. At engine start-up, the boost pressure is very low; therefore, flow is limited. Fuel under pressure flows through the electric solenoid valve, which is energized by power from the ignition switch. This fuel then flows through the fuel rail pressure line and into the injectors.

A percentage of the fuel from both the PT pump and the injectors is routed back to the fuel tank in order to carry away some of the heat that was picked up cooling and lubricating the internal components of the pump and the injectors.

INJECTORS.—A PT injector is provided at each engine cylinder to spray the fuel into the combustion chambers. PT injectors are of the unit type and are operated mechanically by a plunger return spring and a rocker arm mechanism operating off the camshaft. There are four phases of injector operation, which are as follows:

- **Metering** (fig. 5-30)—The plunger is just beginning to move downward and the engine is on the beginning of the compression stroke. The fuel is trapped in the cup, the check ball stops the fuel flowing backwards, and fuel begins to be pressurized. The excess fuel flows around the lower annular ring, up the barrel, and is trapped there.

- **Pre-injection** (fig. 5-30)—The plunger is almost all the way down, the engine is almost at the end of the compression stroke, and the fuel is being pressurized by the plunger.

- **Injection** (fig. 5-30)—The plunger is almost all the way down, the fuel injected out the eight orifices, and the engine is on the end of the compression stroke.

- **Purging** (fig. 5-30)—The plunger is all the way down, injection is complete, and the fuel is flowing into the injector, around the lower annular groove, up a drilled passageway in the barrel, around the upper annular groove, and out through the fuel drain. The cylinder is on the power stroke. During the exhaust stroke, the plunger moves up and waits to begin the cycle all over.

Injector adjustments are extremely important on PT injectors because they perform the dual functions of metering and injecting. Check the manufacturer's manual for proper settings of injectors. On an engine where new or rebuilt injectors have been installed, initial adjustments can be made with the engine cold. Always readjust the injectors, using a torque wrench calibrated in inch-pounds after the engine has been warmed up. Engine oil temperature should read between 140°F and 160°F.

Anytime an injector is serviced, you must be certain that the correct orifices, plungers, and cups are used, as these can affect injection operation. You can also affect injection operation by any of the following actions:

- Improper timing.

- Mixing plungers and barrels during teardown (keep them together, since they are matched sets).

- Incorrect injector adjustments after installation or during tune-up adjustment.

- Installing an exchange set of injectors without taking time to check and correct other possible problems relating to injection operation. This is often overlooked.

Proper injector adjustment and maintenance will ensure a smooth running engine as long as the following factors are met:

1. Adequate fuel delivery pressure from the fuel pump to the fuel manifold.
2. Selection of the proper sizes of balance and metering orifices.
3. The length of time that the metering orifice is uncovered by the upward moving injector plunger.

NOTE

For required adjustments and maintenance schedules, always consult the manufacturer's service manual.

Celect System

The Celect system is a full electronic controlled injection and governing system. The major reason behind the adoption of electronic fuel injection control is to be able to meet not only the EPA (Environmental Protection Agency) exhaust emission controls but also ensure optimum fuel economy. This is done by constantly monitoring major engine operating parameters that have a direct bearing on engine combustion efficiency. A number of engine- and vehicle-mounted sensors are used to update timing and metering values continually. The Celect system controls the following major operating factors:

1. Engine torque and horsepower curves
2. AFC (air-fuel control) to limit exhaust smoke
3. Engine low idle and high speeds
4. Functions as a vehicle road speed governor
5. Optional vehicle/engine cruise control
6. PTO (power takeoff) operation
7. Idle shutdown, 3 to 60 seconds
8. Gear down protection

For the Celect system to operate, major components are required. These components are as follows:

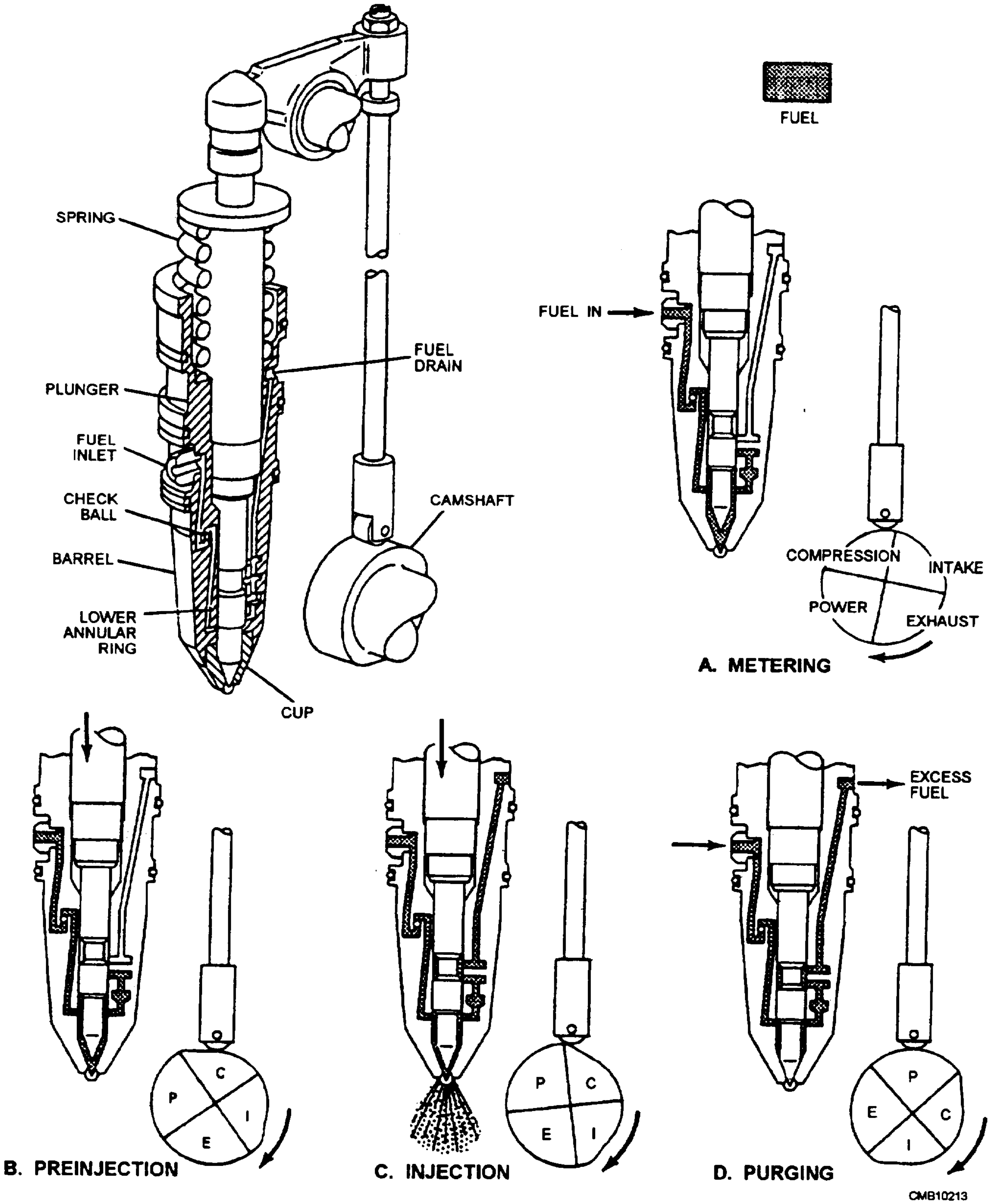


Figure 5-30.—Pressure-time injector operation.

1. The electronic control module (ECM) contains the hardware required to activate the ECI system. Within the ECM are such controls as the EPROM (electrically erasable programmable read-only memory), CPU (central processing unit), RAM (random access memory), and also contain in the ECM is the A/D (analog/digital) converter. The ECM sends electrical signals to the injectors, engine brake solenoids, the fuel shutoff valve, and other optional items. The ECM is mounted to a cooling plate which has diesel fuel continually routed through it from the pump in order to keep the internal solid-state components at a safe operating temperature.

2. The engine position sensor (EPS) is required to tell the ECM where the various pistons are and what stroke they are on, so the correct injector solenoid can be activated at the right time.

3. The oil temperature sensor (OTS) is used to advise the ECM of the oil temperature. The signal is used by the ECM to determine the engine idle speed at start-up as well as reducing the fueling rate any time the oil temperature rises to an undesirable level.

4. The oil pressure sensor (OPS) is used by the ECM to monitor engine oil pressure during operation.

5. The coolant temperature sensor (CTS) is used to monitor the temperature of the engine coolant.

6. The coolant level sensor (CLS) is used to tell the ECM of a coolant level loss.

7. The ambient air pressure sensor (APS) is used by the ECM to determine the basic operating altitude of the vehicle.

8. The intake manifold temperature sensor (IMTS) allows the ECM to determine air temperature and adjust fuel rate accordingly.

9. The throttle position sensor (TPS) is basically a potentiometer or variable resistor arrangement that is designed to a output voltage signal to the ECM, based on the degree of the throttle pedal depression. The ECM is able to determine how much fuel the operator is asking for.

10. The vehicle speed sensor (VSS) is required to tell the ECM the road speed of the vehicle. The VSS sensor is mounted into the transmission output shaft housing in order to monitor the output shaft speed.

11. The electronically controlled injectors receive low-pressure fuel from a simple engine-driven gear pump. Each injector is mechanically operated; however, timing and duration of injection is controlled electronically by a signal from the ECM. This signal is referred to as pulse-width-modulated (PWM). The longer the PWM signal is, the longer the injector will deliver fuel to the combustion chamber. The greater the fuel delivery, the greater the horsepower produced.

Two other major control switches are required with the Celect-ECI system in order to control the cruise control, the PTO (power takeoff), and the engine compression brake:

1. A clutch switch is used to allow cruise control or engine brake activation. It is mounted so that when the clutch pedal is pushed down (clutch disengaged), the clutch switch opens the switch and deactivates the engine brake or PTO.

2. A brake switch is located in the service air line and will remain in the closed position any time the brakes are released. Applying the brakes will cause the brake switch to open and break the electrical circuit to both the cruise control and PTO systems.

In addition to the engine-mounted components, there are several cab-mounted controls arranged on a small control panel that can be activated by the operator through a series of small toggle-type switches. This control panel contains the following:

- The idle-speed adjustment switch is used to adjust the engine idle speed between 550 and 800 rpm. Each time the switch is moved briefly to the + or – position, the idle speed will change by approximately 25 rpm.

- The cruise control panel has two toggle switches—one is a simple ON/OFF switch and the other is the actual cruise control position select switch that the operator uses to set and adjust the cruise control speed during operation.

- The engine brake panel has two toggle switches—one switch has an ON/OFF position to activate either a Jacobs or Cummins "C" brake system and the other switch, used with the engine brake control, can be placed into position 1, 2, or 3. In position 1 the compression brake is activated only on two cylinders; position 2 will activate the compression brake on four cylinders; position 3 will allow all six cylinders to provide compression braking.

On the right-hand side of the control panel are two warning lights—one yellow, the other one red. The yellow light is labeled warning, while the red light is labeled stop. When the yellow light comes on during engine operation, this indicates that a Celect system problem has been detected and recorded in the ECM memory. The problem is not serious enough to shut down the engine, but should be checked out at the earliest opportunity. If the red light comes on, the operator should immediately bring the vehicle to a stop and shut off the engine.

Celect System Operation

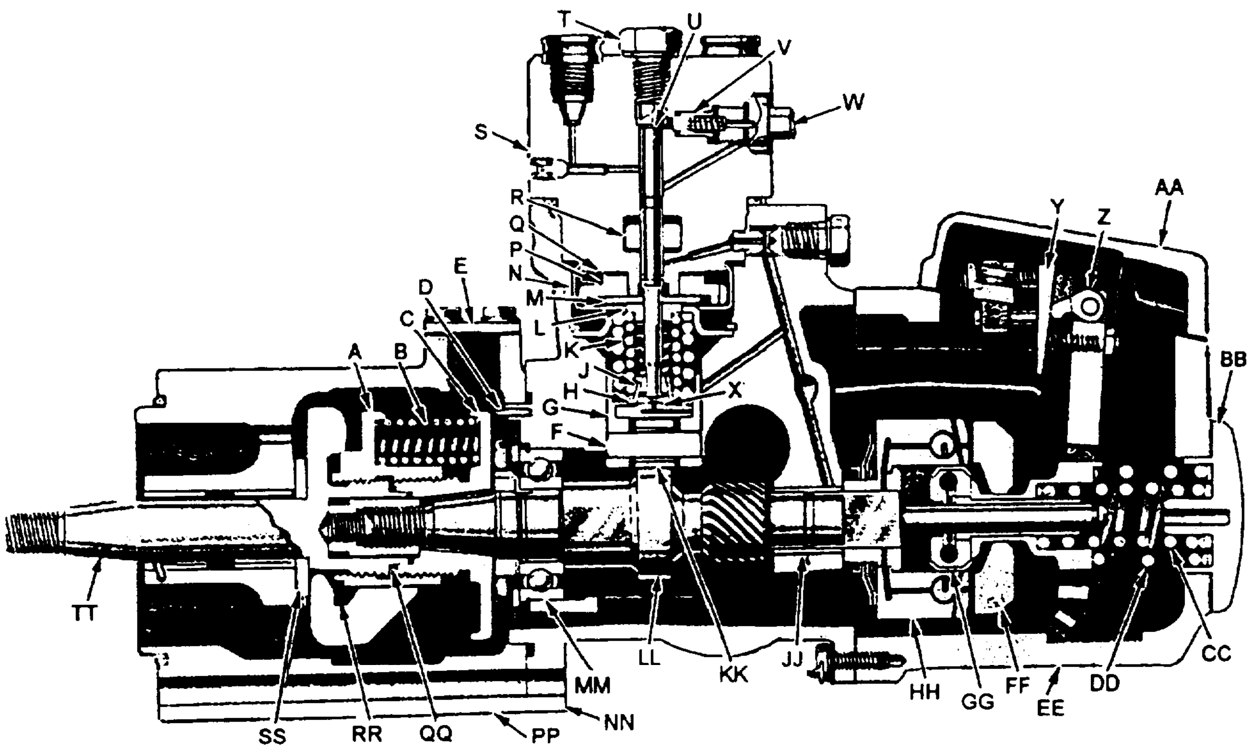
The ECI (electronically controlled injection) Celect system uses an engine-driven gear pump to pull fuel from the fuel tank. The fuel is passed through a primary filter or filter/water separator unit, then to the ECM where the fuel is circulated through a cooling plate. The cooling plate, mounted to the rear of-the ECM, ensures adequate cooling of the electronic package.

The gear pump is designed to deliver fuel to the fuel manifold at 140 psi, which supplies the electronically controlled injectors. A spring-loaded bypass valve allows excess fuel under pressure to return to the suction side of the pump to maintain maximum system pressure.

A rocker arm and pushrod assembly mechanically operates the injector. The injector requires rocker arm actuation of the plunger to create high fuel pressure for injection. To control both the start of injection timing and the quantity of fuel metered, the ECM sends out a pulse-width-modulated (PWM) electrical signal to each injector. The PWM signal determines the start of injection, while the duration of this signal determines how long the injector can effectively continue to spray fuel into the combustion chamber, as the plunger is forced down by the rocker arm assembly. A shorter PWM signal means that the effective stroke of the injector plunger will be decreased. A longer PWM signal means that the effective stroke will be increased. The start of injection and the duration of the PWM signal is determined by the ECM, based on the various input sensor signals and the preprogrammed PROM information within the ECM. Each PROM is designed for a specific engine/vehicle combination, based on the desired horsepower setting and rpm, the tire size, and gear ratios used in the vehicle.

Contained within the injector are a timing plunger, a return spring, and an injector control valve—that is the key to the operation. The control valve is electrically operated, receiving signals from the ECM to energize/de-energize, which determines the start of injection. The length of time that this solenoid is energized determines the quantity of metered fuel to be injected into the combustion chamber. Also within the injector body is a metering spill port which must be closed to allow injection, a metering piston, the bias spring, and the spill-timing port. The injection sequence of events occur as follows:

1. The injector receives a signal from the ECM; the injector control valve will close and the metering phase begins while the metering piston and timing plunger are bottomed in the injector.
2. As the camshaft rotates, the injector pushrod cam follower will ride down the cam ramp, thereby allowing the rocker arm and pushrod to be forced up by the energy of the timing plunger return spring. Fuel at gear pump pressure of 140 psi can flow into the fuel supply passage and unseat the lower check valve, allowing the metering chamber to be charged with pressurized fuel as long as the timing plunger is being pulled upward by the force of the large external spring. Fuel pressure, acting on the bottom of the metering piston, forces it to maintain contact with the timing plunger within the bore of the injector body.
3. Metering ends when the ECM energizes the injector control valve, causing it to open. Pressurized fuel can flow through the open injector control valve into the upper timing chamber, which stops the upward travel of the metering piston. To ensure that the metering piston remains stationary, the small bias spring in the timing chambers holds it in place, while the timing plunger continues upward due to camshaft rotation. Fuel and spring pressure, acting on the metering piston, will ensure fuel pressure is maintained below the piston to keep the lower metering ball-check valve closed. This allows a precisely metered quantity of fuel to be trapped in the metering chamber.
4. As long as the timing plunger moves upward due to the rotating camshaft lobe action and the



CMB10214

A - Sliding gear
B - Advance unit spring
C - Advance unit hub
D - Timing pointer
E - Timing cover
F - Tappet roller pin
G - Tappet guide
H-Spring lower seat
J - Plunger lock
K-Plunger inner spring
L - Spring upper seat
M - Plunger guide
N - Drive gear retainer
P-Plunger drive gear
Q-Gear thrust washer
R - Plunger sleeve
S - Hydraulic head
T -Plunger bore screw
U - Fuel plunger
V -Fuel delivery valve
W - Delivery valve screw
X - Plunger button
Y - Stop plate
Z - Smoke limit cam
AA - Governor cover
BB - Governor end cap
CC - Governor inner spring
DD - Governor outer spring
EE - Governor housing
FF - Governor weight
GG - Sliding sleeve
HH - Friction drive spider
JJ - Camshaft bushing type bearing
KK - Tappet roller
LL - Camshaft
MM - Camshaft ball bearing
NN - Injection pump housing
PP - Advance unit housing
QQ - End play spacer
RR - Sliding gear spacer
SS - Spider thrust plate
TT - Spider assembly

Figure 5-31.—Metering and distributing fuel pump assembly-left sectional view.

force of the external return spring on the ECI injector, the upper timing chamber will continue to fill with pressurized fuel.

5. When the engine camshaft lobe starts to lift the injector cam follower roller, the pushrod moves up and the rocker arm reverses this motion to push the timing plunger downward. On the initial downward movement, the injector control valve remains open and fuel flows from the timing chamber and through the control valve to the fuel supply passage. When the ECM closes the control valve, fuel is trapped in the timing chamber; this fuel acts as a solid hydraulic link between the timing plunger and metering piston. The downward movement of the timing plunger causes a rapid pressure increase in the trapped fuel within the metering chamber. At approximately 5,000 psi, the tapered needle valve in the tip of the injector will be lifted against the force of its return spring and injection begins.

6. Injection will continue until the spill passage of the downward-moving metering piston uncovers the spill port. Fuel pressure within the chamber is lost and the needle valve reseats by spring pressure. This terminates injection. Immediately after the metering spill port is uncovered, the upper edge of the metering piston also passes the timing spill port to allow fuel within the upper timing chamber to be spilled back to the fuel drain, as the timing plunger completes its downward movement. Injection has now been completed.

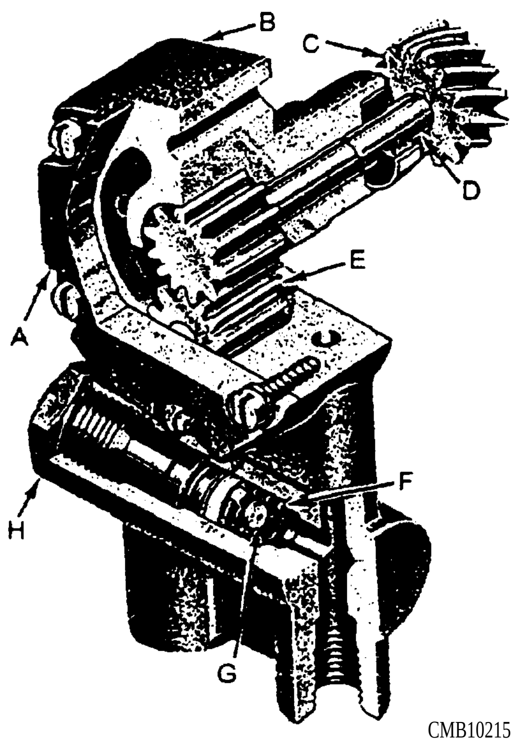
AMERICAN BOSCH FUEL INJECTION SYSTEMS

The American Bosch fuel injection system is used on multifuel engines. The pump meters and distributes fuel. It is a constant-stroke, distributing-plunger, and sleeve-control type of pump. As with other fuel systems, only clean fuel should be used. Good maintenance of the filtering system and reasonable care in fuel handling will give trouble-free operation. Fuels used in the multifuel engine must contain sufficient lubrication to lubricate the fuel pump and injectors. Because of close tolerances, extreme cleanliness and strict adherence to service instructions are required when it is time to service this system.

Fuel Pump

The PSB model fuel pump is similar to other distributor fuel system, in that a pump sends a measured amount of fuel to each injector at a properly timed interval. The difference in the PSB system is that the amount of fuel sent directly from the pump at high enough pressure needed for injection. This eliminates the need for unit-type injectors and the associated linkage and camshaft, making the system less cumbersome.

The purpose of the fuel pump (fig. 5-31) is to deliver measured quantities of fuel accurately under high pressure to the spray nozzle for injection. The positive displacement fuel supply pump (fig. 5-32) is gear-driven by the pump camshaft through an engine camshaft gear and provides fuel to the hydraulic head for injection and cooling.



A - Housing cover

B - Supply pump housing

C - Camshaft driven gear

D-Drive shaft

E - Idler gear

F -Check valve spring

G - Check valve

H - Valve screw

Figure 5-32.—Fuel supply pump assembly—sectional view.

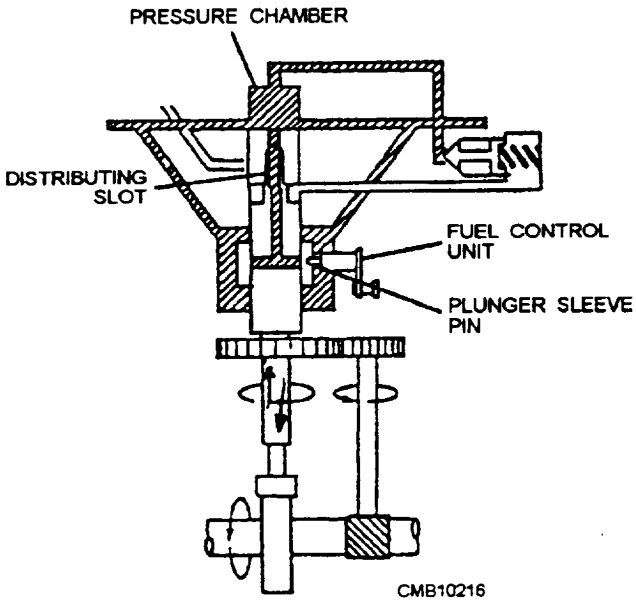


Figure 5-33.—Fuel intake flow diagram.

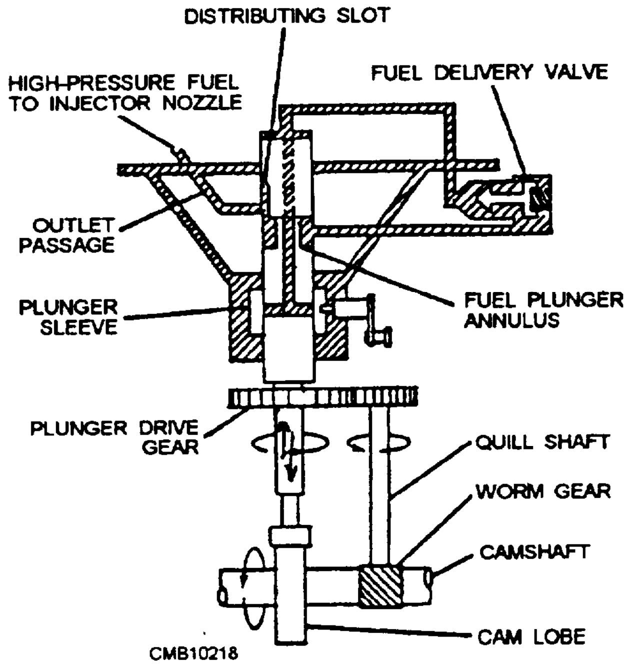


Figure 5-35.—Fuel delivery flow diagram.

Figure 5-33 shows fuel intake at the hydraulic head. Injection (fig. 5-34) begins when fuel flows around the fuel plunger annulus (fig. 5-35) through the open distributing slot to the injection nozzle. A continued upward movement of the fuel plunger causes the spill passage to pass through the plunger sleeve (fig. 5-36). This reduces pressure, allowing the fuel delivery valve to close, ending injection. This is accomplished through a single plunger, multi-outlet hydraulic head assembly (fig. 5-31).

The plunger is designed to operate at crankshaft speed on four-cycle engines. It is actuated by a camshaft and tappet arrangement. The pump camshaft, which also includes the gearing for fuel distribution, is supported on the governor end by a bushing-type bearing and by a ball roller bearing on the driven end. An integral mechanical centrifugal governor (fig. 5-37), that is driven directly from the pump camshaft without gearing, controls fuel delivery in relation to engine speed. This pump has a smoke limit cam within the governor housing to assist in controlling exhaust smoke of various fuels. The mechanical centrifugal advance unit of this pump provides up to g-degrees advance timing and is driven clockwise at crankshaft speed.

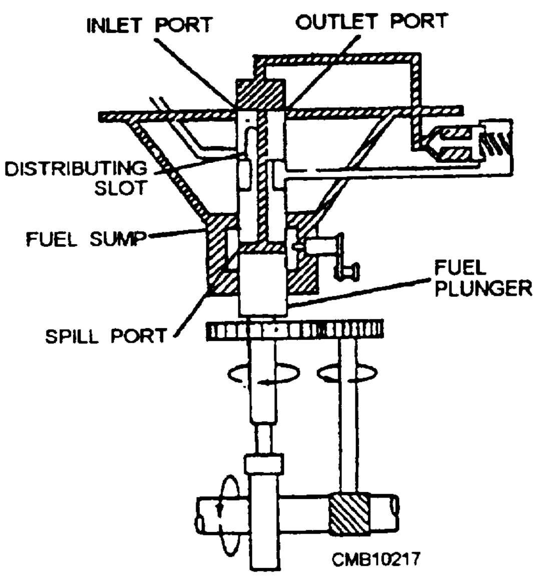


Figure 5-34.—Beginning of fuel delivery flow diagram.

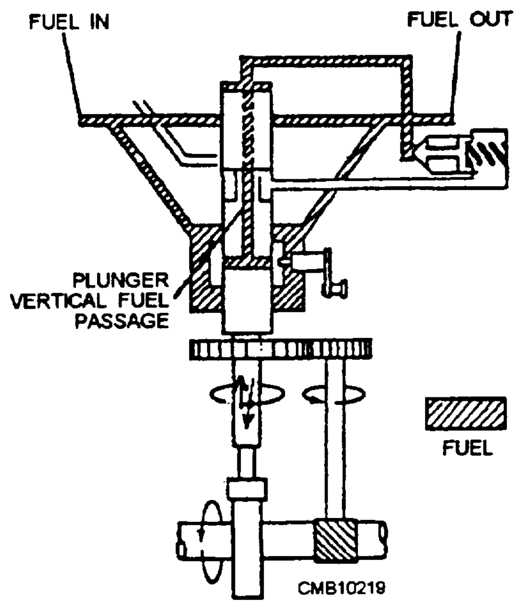
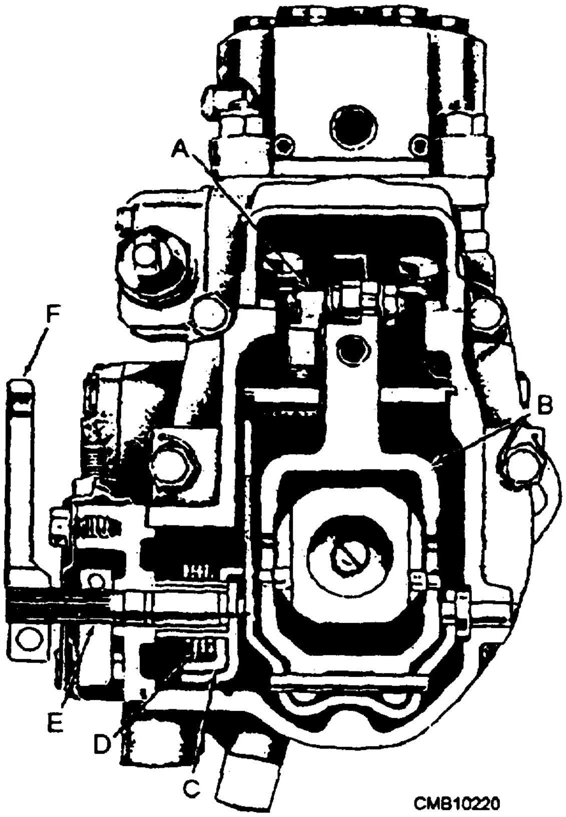


Figure 5-36.—End of fuel delivery flow diagram.



A - Fuel control rod
B - Fulcrum lever
C - Shaft spring plate
D - Operating shaft spring
E - Operating shaft
F - Operating lever

Figure 5-37.—Governor—sectional view.

Types of Nozzles

Bosch nozzles are inward opening with a multiple orifice and hydraulically operated nozzle valve. The two models of this nozzle in use are the American Bosch and Robert Bosch. They may be easily identified by either the length of the nozzle tip holding nut or the nozzle drilling code on the smaller diameter of the nozzle valve body. The American Bosch nozzle nut is 3 inches long, and the nozzle tip has a hand-printed drilling code. The Robert Bosch nozzle nut is 2 inches long, and the nozzle tip has a machined-etched drilling code. Component parts, although similar, are not interchangeable between the two nozzles.

Nozzle Operation

The pressurized fuel from the injection pump enters the top of the nozzle body and flows through a passage in the body and nozzle spring retainer. An annular groove in the top face of the nozzle valve body fills with fuel, and two passages in the nozzle valve body direct fuel around the nozzle valve. When the fuel in the pressure chamber reaches a predetermined pressure, the spring force (adjusted by shims) is overcome and injection occurs. Atomized fuel sprays from the orifice holes in the nozzle tip, as the nozzle valve is opened inward by pressurized fuel. When injection ends, spring pressure snaps the valve in its seat. During each injection, a small quantity of high-pressurized fuel passes between the nozzle valve stem and the nozzle valve body to lubricate and to cool the nozzle valve. A manifold that connects to all of the nozzles returns this fuel to the tank.

Fuel Density Compensator

The multifuel engine operates on a variety of fuels that have a broad range of viscosities and heat values. These variations in the fuels affect engine output. Because it is unacceptable for the power output of the engine to vary with fuel changes, the multifuel engine is fitted with a device known as a fuel density compensator (fig. 5-38). ‘The fuel density compensator is a device that serves to vary the quantity of fuel injected to the engine by regulating the full-load stop of the fuel pump. The characteristics of the fuels show that their heat values decrease almost inversely proportional to their viscosities. The fuel density compensator uses viscosity as the indicator for regulating fuel flow. Its operation is as follows:

- The fuel enters the compensator through the fuel pressure regulator where the fuel pressure is regulated to a constant 20 psi regardless of engine speed and load range.

- The pressure-regulated fuel then passes through a series of two orifices. The two orifices, by offering greatly different resistances to flow, form a system that is sensitive to viscosity changes. The first orifice is annular, formed by the clearance between the servo piston and its cylinder. This orifice is sensitive to viscosity. The second orifice is formed by an adjustable needle valve and is not viscosity sensitive.

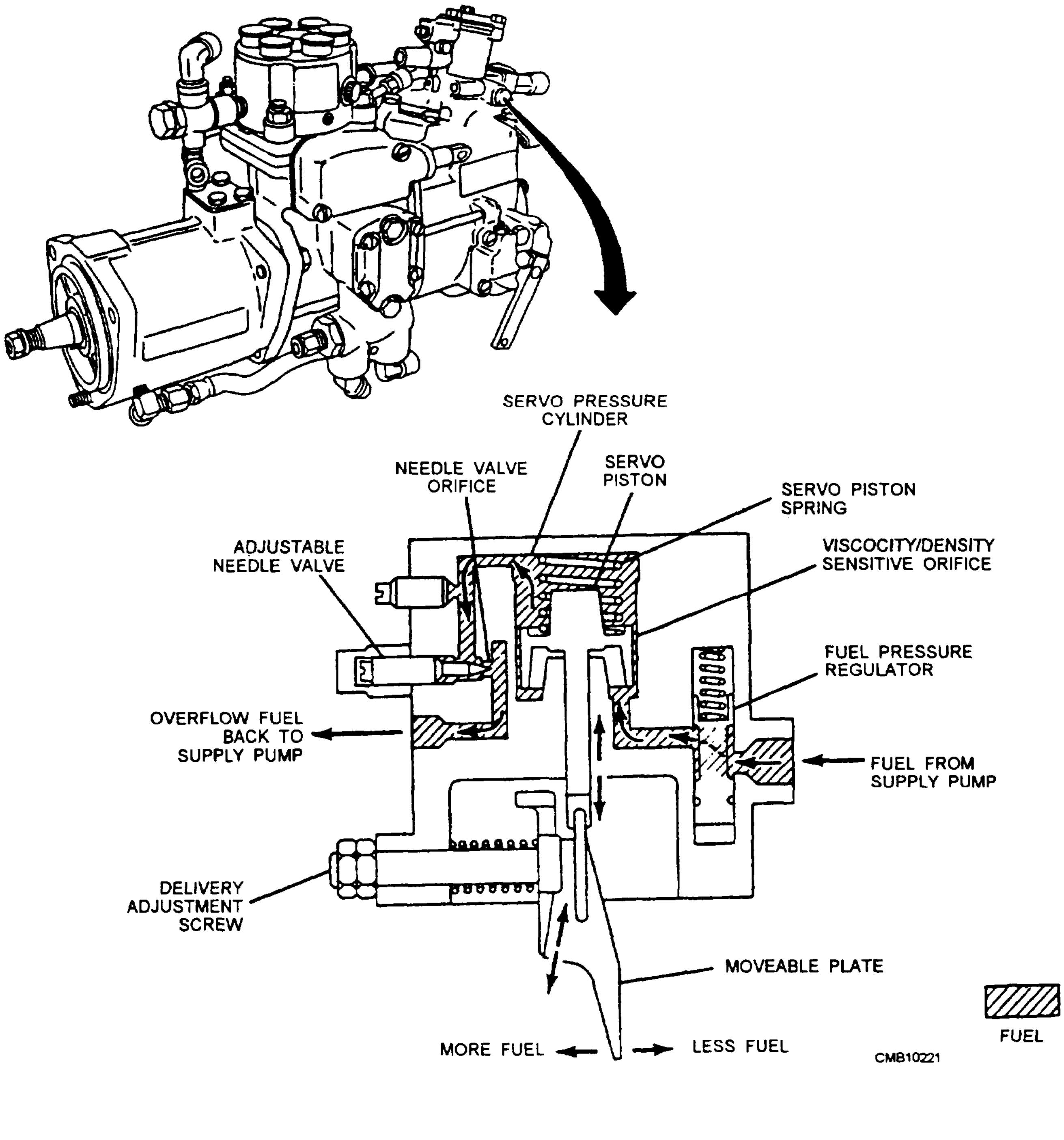


Figure 5-38.—Fuel density compensator.

- The higher the viscosity of the fuel, the more trouble that it will have passing through the first orifice. Because of this, the fuel pressure under the servo piston will rise proportionally with viscosity. Because the second orifice is not viscosity sensitive, the pressure over the servo piston will remain constant. This will cause a pressure differential that increases proportional with viscosity, in turn, causing the piston to seek a position in its bore that becomes higher as viscosity increases.

- The upward movement of the servo piston will move a wedge-shaped moveable plate, which will decrease fuel delivery. A lower viscosity fuel will cause the piston to move downward, causing the pump to increase fuel delivery.

- After the fuel passes through the two orifices, it leaves the compensator through an outlet port. From here the fuel passes back to the pump.

Q10. For what does MITAC stand?

Q11. In a sleeve metering injection system, at what rate does the constant bleed valve return fuel to the fuel tank?

Q12. In a sleeve metering injection system, where is the automatic advance unit mounted?

Q13. In a scroll metering fuel system, where is the transfer pump located?

Q14. What three rotating members revolve on a common axis within a distributor-type fuel injection system ?

Q15. In a distributor-type fuel injection system, what controls the maximum amount of fuel that can be injected?

Q16. What component maintains fuel pressure in the DB2 governor housing?

Q17. At what pressure range does the relief valve on a Detroit diesel engine bypass fuel back to the inlet side of the fuel pump?

Q18. What type of injector is used in a Detroit diesel engine?

Q19. What number of crankshaft revolutions is required to time all the injectors in a two-cycle Detroit diesel engine?

Q20. On a Cummins engine using a PT fuel system, what device is used to control exhaust smoke during acceleration?

Q21. How is the PT pump timed to the engine?

Q22. On a Cummins engine that has a Celect system, the ECM determines engine idle speed at start-up, based on data relayed by what sensor?

Q23. On a Cummins engine that has a Celect system, the gear pump delivers fuel to the fuel manifold at what pressure?

Q24. In the Celect system, what component within the injector receives signals from the ECM that controls the start of injection?

Q25. What type engine uses an American Bosch fuel injection system?

Q26. What device used with the PSB American Bosch fuel injection pump allows the use of fuels with different viscosities and heat ranges?

SUPERCHARGERS AND TURBOCHARGERS

LEARNING OBJECTIVE: *Describe the operation of and the differences between superchargers and turbochargers.*

Supercharging and turbocharging is a method of increasing engine volumetric efficiency by forcing the air into the combustion chamber, rather than merely allowing the pistons to draw it naturally. Supercharging and turbocharging, in some cases, will push volumetric efficiencies over 100 percent.

SUPERCHARGERS

A supercharger is an air pump that increases engine power by pushing a denser air charge into the combustion chamber. With more air and fuel, combustion produces more heat energy and pressure to push the piston down in the cylinder. There are three basic types of superchargers:

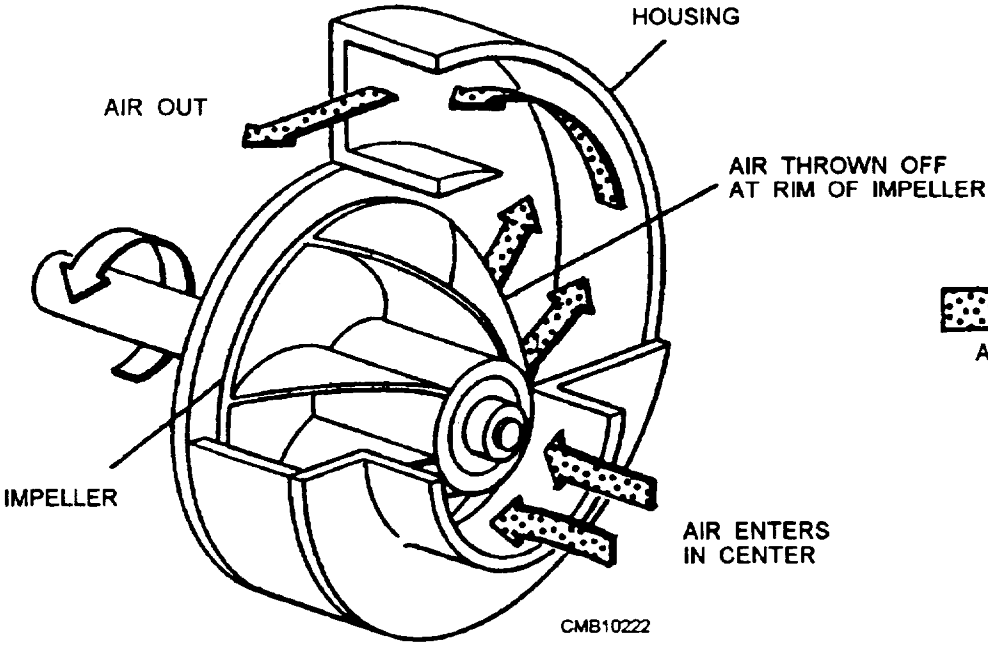


Figure 5-39.—Centrifugal supercharger.

1. **Centrifugal supercharger** (fig. 5-39). The centrifugal supercharger has an impeller equipped with curved vanes. As the engine drives the impeller, it draws air into its center and throws it off at its rim. The air then is pushed along the inside of the circular housing. The diameter of the housing gradually increases to the outlet where the air is pushed out.

2. **Rotor (Rootes) supercharger** (fig. 5-40). The Rootes supercharger is of the positive displacement type and consists of two rotors inside a housing. As the engine drives the rotors, air is trapped between them and the housing. Air is then carried to the outlet where it is discharged. The rotors and the housing in this type of supercharger must maintain tight clearances and therefore are sensitive to dirt.

3. **Vane-type supercharger** (fig. 5-41). The vane-type supercharger has an integral steel rotor and shaft, one end supported in the pump flange and the other end in the cover, and revolves in the body, the bore of which is eccentric to the rotor. Two sliding vanes are placed 180 degrees apart in slots in the rotor and are pressed against the body bore by springs in the slots. When the shaft rotates, the vanes pick up a charge of air at the inlet port, and it is carried around the body to the outlet where the air is discharged. Pressure is produced by the wedging action of the air, as it is forced toward the outlet port by the vane.

The term *supercharger* generally refers to a **blower** driven by a belt, chain, or gears. Superchargers are used on large diesel and racing engines.

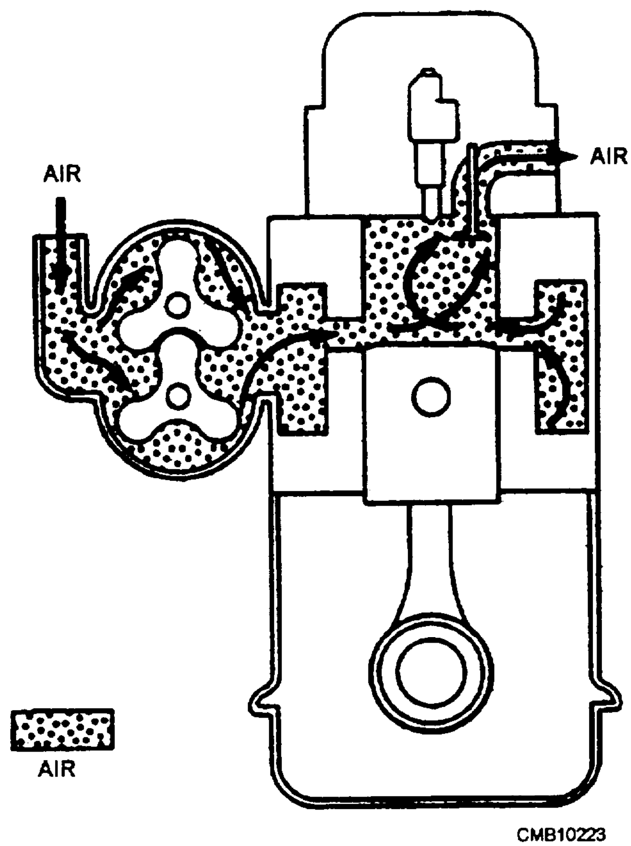


Figure 5-40.—Rootes supercharger.

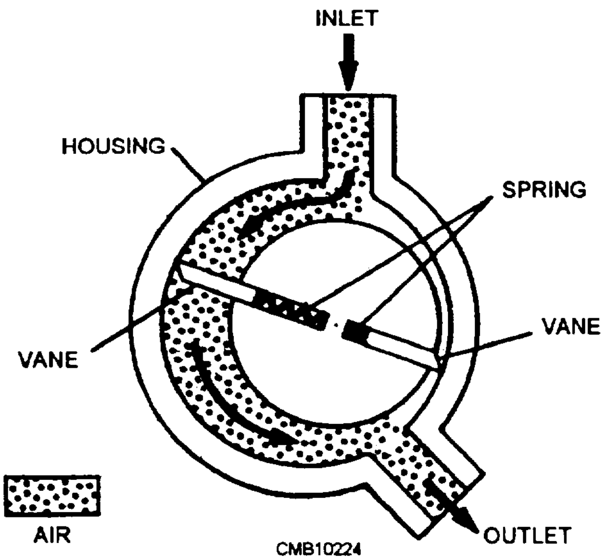


Figure 5-41.—Vane-type supercharger.

The supercharger raises the air pressure in the engine intake manifold. Then, when the intake valves open, more air-fuel mixture (gasoline engine) or air (diesel engine) can flow into the cylinders. An intercooler is used between the supercharger outlet and the engine to cool the air and to increase power (cool charge of air carries more oxygen needed for combustion).

A supercharger will instantly produce increased pressure at low engine speed because it is mechanically linked to the engine crankshaft. This low-speed power and instant throttle response is desirable for passing and entering interstate highways.

TURBOCHARGERS

A turbocharger is an exhaust-driven supercharger (fan or blower) that forces air into the engine under pressure. Turbochargers are frequently used on small gasoline and diesel engines to increase power output. By harnessing engine exhaust energy, a turbocharger can also improve engine efficiency (fuel economy and emissions levels).

The turbocharger (fig. 5-42) consists of three basic parts—a turbine wheel; an impeller or compressor; and housings that support the parts and direct the flow of exhaust gases and intake air. Basic operation of a turbocharger is as follows:

- When the engine is running, hot gases blow out the open exhaust valves and into the exhaust manifold. The exhaust manifold and connecting tubing route these gases into the turbine housing.

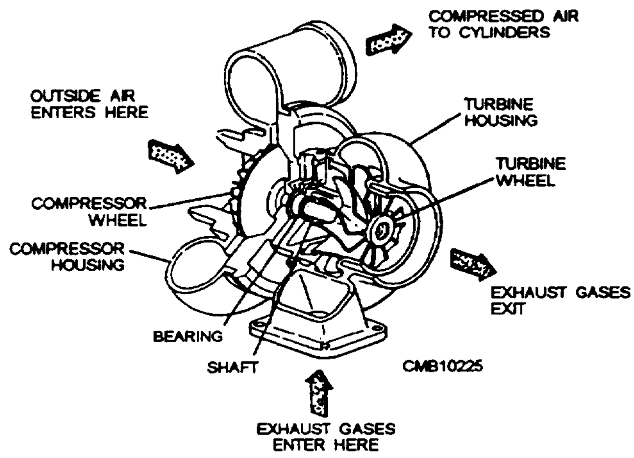


Figure 5-42.—Turbocharger (cutaway view).

- As the gases pass through the turbine housing, they strike the fins or blades on the turbine wheel. When engine load is high enough, there is enough exhaust gas flow to spin the turbine wheel rapidly.
- Since the turbine wheel is connected to the impeller by the turbo shaft, the impeller rotates with the turbine. Impeller rotation pulls air into the compressor housing. Centrifugal force throws the spinning air outward. This causes air to flow out of the turbocharger and into the engine cylinder under pressure.

A turbocharger is located on one side of the engine. An exhaust pipe connects the exhaust manifold to the turbine housing. The exhaust system header pipe connects to the outlet of the turbine housing.

Theoretically, the turbocharger should be located as close to the engine manifold as possible. Then a maximum amount of exhaust heat will enter the turbine housing. When the hot gases move past the spinning turbine wheel, they are still expanding and help rotate the turbine.

Turbocharger lubrication is required to protect the turbo shaft and bearings from damage. A turbocharger can operate at speeds up to 100,000 rpm. For this reason, the engine lubrication system forces oil into the turbo shaft bearings. Oil passages are provided in the turbo housing and bearings and an oil supply line runs from the engine to the turbocharger. With the engine running, oil enters the turbocharger under pressure. A drain passage and drain line allows oil to return to the engine oil pan after passing through the turbo bearings.

Sealing rings (piston-type rings) are placed around the turbo shaft at each end of the turbo housing, preventing oil leakage into the compressor and turbine housings.

Turbochargers require little maintenance between overhauls if the air cleaners are serviced regularly according to the manufacturer's recommendations. The turbocharger turbine requires periodic cleaning to remove carbon deposits that cause an unbalanced condition at the high relative speeds at which the turbine must rotate.

Turbocharging system problems usually show up as inadequate boost pressure (lack of engine power), leaking shaft seals (oil consumption), damaged turbine or impeller wheels (vibration and noise), or excess boost (detonation).

NOTE

Refer to a factory service manual for a detailed troubleshooting chart. It will list the common troubles for the particular turbocharging system.

There are several checks that can be made to determine turbocharging system conditions. These checks include the following:

- Check connection of all vacuum lines to the waste gate and oil lines to the turbocharger.
- Use regulated, low-pressure air to check for waste gate diaphragm leakage and operation.
- Use a dash gauge or a test gauge to measure boost pressure. If needed connect the pressure gauge to the intake manifold fitting. Compare to the manufacturer's specifications.
- Use a stethoscope to listen for bad turbocharger bearings.

Turbo Lag

Turbo lag refers to a short delay before the turbocharger develops sufficient boost (pressure above atmospheric pressure).

As the accelerator pedal is pressed down for rapid acceleration, the engine may lack power for a few seconds. This is caused by the impeller and turbine wheels not spinning fast enough. It takes time for the exhaust gases to bring the turbocharger up to operating speed. To minimize turbo lag, the turbine and impeller wheels are made very light so they can accelerate up to rpm quickly.

Turbocharger Intercooler

A turbocharger intercooler is an air-to-air heat exchanger that cools the air entering the engine. It is a radiator-like device mounted at the pressure outlet of the turbocharger.

Outside air flows over and cools the fins and tubes of the intercooler. As the air flows through the intercooler, heat is removed. By cooling the air entering the engine, engine power is increased because the air is more dense (contains more oxygen by volume). Cooling also reduces the tendency for engine detonation.

Waste Gate

A waste gate limits the maximum amount of boost pressure developed by the turbocharger. It is a butterfly or poppet-type valve that allows exhaust to bypass the turbine wheel.

Without a waste gate, the turbocharger could produce too much pressure in the combustion chambers. This could lead to detonation (spontaneous combustion) and engine damage.

A diaphragm assembly operates the waste gate. Intake manifold pressure acts on the diaphragm to control waste gate valve action. The valve controls the opening and closing of a passage around the turbine wheel.

Under partial load, the system routes all of the exhaust gases through the turbine housing. The waste gate is closed by the diaphragm spring. This assures that there is adequate boost to increase power.

Under a full load, boost may become high enough to overcome spring pressure. Manifold pressure compresses the spring and opens the waste gate. This permits some of the exhaust gases to flow through the waste gate passage and into the exhaust system. Less exhaust is left to spin the turbine. Boost pressure is limited to a preset value.

Q27. What device is used between the supercharger outlet and the engine to cool the air?

Q28. In a turbocharger, what prevents oil from leaking into the compressor and turbine housing?

COLD WEATHER STARTING

LEARNING OBJECTIVE: *Identify the different types of cold weather starting aids.*

Diesel fuel evaporates much slower than gasoline and requires more heat to cause combustion in the cylinder of the engine. For this reason, preheating devices and starting aids are used on diesel engines. These devices and starting aids either heat the air before it is drawn into the cylinder or allow combustion at a lower temperature than during normal engine operation.

GLOW PLUGS

The purpose of a glow plug is to beat up the air that is drawn into the precombustion chamber to assist starting, especially in cold weather. Glow plugs are common on precombustion chamber engines, but not on direct injection diesels because they use shaped piston crowns that produce a very effective turbulence to the air in the cylinder. Direct injection engines also have less immediate heat loss to the surrounding cylinder area than in a precombustion engine and generally have a higher injection spray-in pressure.

A glow plug is used for each cylinder located just below the injection nozzle and threaded into the cylinder head (fig. 5-43). The inner tip of the glow plug extends into the precombustion chamber. The glow plugs may be turned on using the ignition switch with the length of time being controlled from an electronic module. On some older vehicles and construction equipment, glow plugs are operated by manually depressing a switch or button for 15 to 30 seconds. During colder weather, the system may have to be cycled more than once to start the engine.

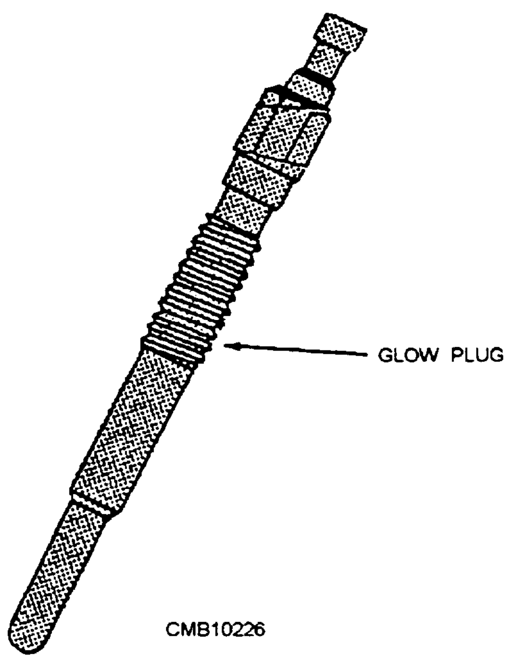


Figure 5-43.—Typcial diesel glow plug.

Glow plugs are not complicated and are easy to test. Disconnect the wire going to the glow plug and use a multimeter to read the ohms resistance of the glow plug. Specifications for different glow plugs vary according to the manufacturer. Be sure and check the manufacturer's service manual for the correct ohms resistance value.

MANIFOLD FLAME HEATER

The manifold flame heater (fig. 5-44) is another type of cold starting system found on diesel engines. This system is composed of a housing, spark plug, flow control nozzle, and two solenoid control valves. This system operates as follows:

1. The flame heater ignition unit energizes the spark plug.
2. The nozzle sprays fuel under pressure into the intake manifold assembly.
3. The fuel vapor is ignited by the spark plug and burns in the intake manifold. The heat from this fire warms the air before it enters the combustion chamber.

The flame fuel pump assembly is a rotary type, driven by an enclosed electric motor. The fuel pump receives fuel from the vehicle fuel tank through the supply pump of the vehicle and delivers it to the spray nozzle. The on/off switch, located on the instrument panel, energizes the pump.

The intake manifold flame heater system has a filter to remove impurities from the fuel before it reaches the nozzle.

The two fuel solenoid valves are energized (open) whenever the flame heater system is activated. The valves ensure that fuel is delivered only when the system is operating. These valves stop the flow of fuel the instant that the engine or heater is shut down.

NOTE

When troubleshooting or repairing these units, you should consult the manufacturer's service manual.

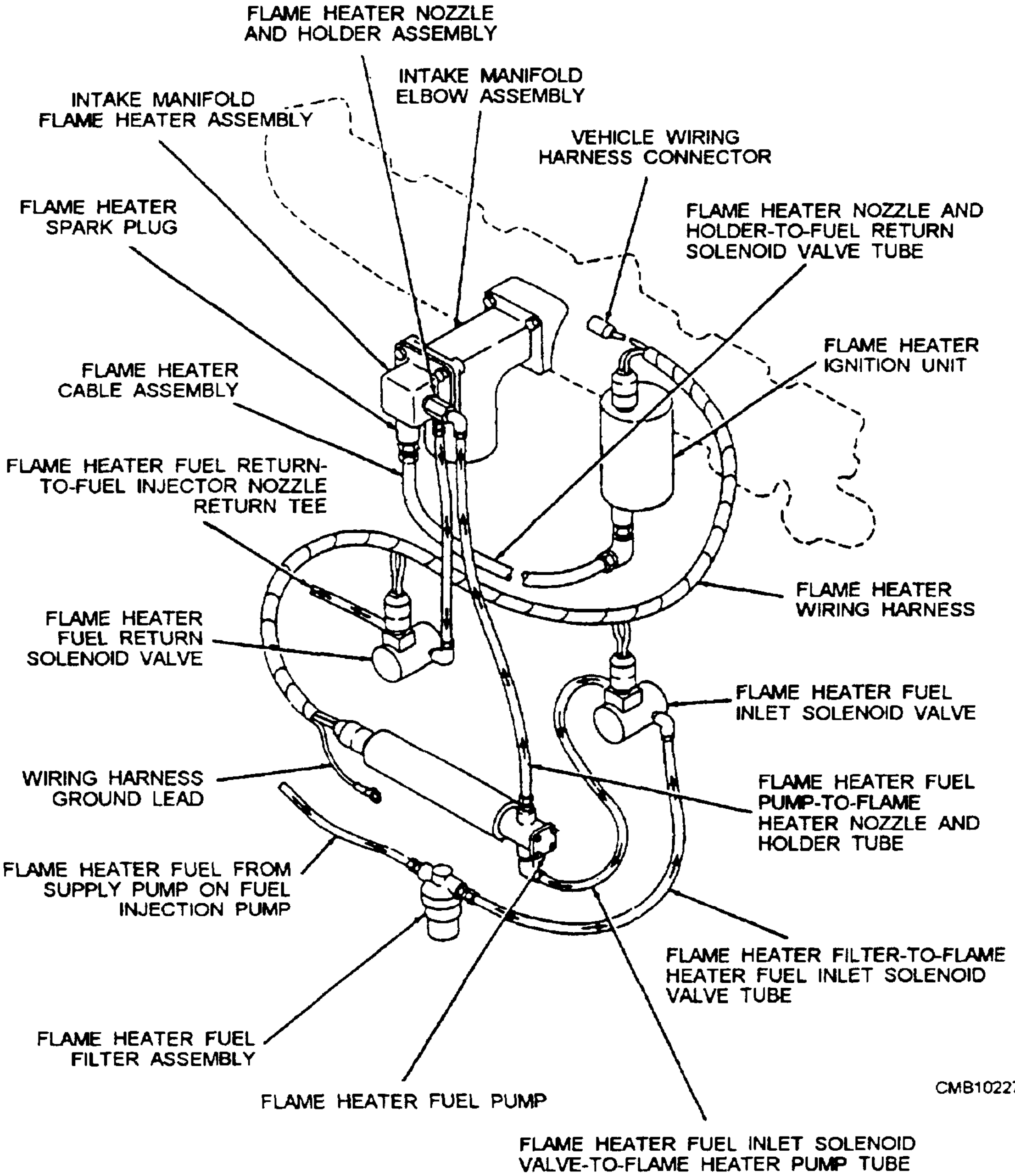


Figure 5-44.—Manifold flame beater system.

ETHER

Ether is a highly volatile fluid that is injected into the intake manifold, as you crank the engine. It is found in an aerosol or capsule type container. Since ether has a low ignition point, the heat generated in the combustion chamber is able to ignite it. Heat from this ignition then ignites the diesel fuel and normal combustion takes place. Once the diesel engine starts, no more fluid is required.

Cold starting aids, such as ether, should be used only in extreme emergencies. Too much ether may detonate in the cylinder too far before top dead center (BDTC) on the compression stroke. This could cause serious damage, such as broken rings, ring lands, pistons, or even cracked cylinder heads. If you must use ether, the engine has to be turning over before you spray it into the intake manifold.

Q29. What cold weather starting system uses a spark plug to ignite fuel vapors in the intakemanifold?

Q30. When should ether be used as a cold starting aid?

DIESEL FUEL SYSTEM MAINTENANCE

LEARNING OBJECTIVE: *Describe the basic maintenance required for a diesel fuel system.*

If all diesel engines had nearly identical fuel system trouble, diagnosis and maintenance procedures could follow a general pattern. But, with the exception of similar fuel tanks and basic piping system, diesel fuel systems differ considerably. Consequently, each engine manufacturer recommends different specific maintenance procedures. However, the tune-up and maintenance procedures described are representative of the job you will do. For all jobs, refer to the manufacturer's service manual for the fuel system you are servicing, even if you fully understand all procedures.

DIRT IN FUEL SYSTEM

Many diesel engine operating troubles result directly or indirectly from dirt in the fuel system. That is why proper fuel storage and handling are so important. One of the most important aspects of diesel fuel is cleanliness. The fuel should not contain more than a trace of foreign substance; otherwise, fuel pump and injector troubles will occur. Diesel fuel, because it is more viscous than gasoline, will hold dirt in suspension for longer periods. Therefore, every precaution should be made to keep the fuel clean.

If the engine starts missing, running irregularly, rapping, or puffing black smoke from the exhaust manifold, look for trouble at the spray nozzle valves. In this event, it is almost a sure bet that dirt is responsible for improper fuel injection into the cylinder. A valve held open or scratched by particles of dirt so that it cannot seat properly will allow fuel to pass into the exhaust without being completely burned, causing black smoke. Too much fuel may cause a cylinder to miss entirely. If dirt prevents the proper amount of fuel from entering the cylinders by restricting spray nozzle holes, the engine may skip or stop entirely. In most cases, injector or valve troubles are easily identified.

Improper injection pump operation, however, is not easily recognized It is more likely caused by excessive wear than by an accumulation of dirt or carbon, such as the spray nozzle is subjected to it in the cylinder combustion chambers. If considerable abrasive dirt gets by the filters to increase (by wear) the small clearance between the injector pump plunger and barrel, fuel will leak by the plunger instead of being forced into the injector nozzle in the cylinder. This gradual decrease in fuel delivery at the spray nozzle may remain unnoticed for some time or until the operator complains of sluggish engine performance.

Although worn injector pumps will result in loss of engine power and hard starting, worn piston rings, cylinder liners, and valves (intake and exhaust) can be responsible for the same conditions. However, with worn cylinder parts or valves, poor compression, a smoky exhaust, and excessive blow-by will accompany the hard starting and loss of power from the crankcase breather.

WATER IN FUEL SYSTEM

It requires only a little **WATER** in a fuel system to cause an engine to miss, and if present in large enough quantities, the engine will stop entirely. Many fuel filters are designed to clog completely when exposed to water, thereby stopping all fuel flow. Water that enters a tank with the fuel or that is formed by condensation in a partially empty tank or line usually settles to the lowest part of the fuel system. This water should be drained off daily.

AIR IN FUEL SYSTEM

Air trapped in diesel fuel systems is one of the main reasons for a hard starting engine. Air can enter the fuel system at loose joints in the piping or through a spray nozzle that does not close properly. Letting the vehicle run out of fuel will also cause air to enter the system. Like water, air can interfere with the unbroken flow of fuel from the tank to the cylinder. A great deal of air in a system will prevent fuel pumps from picking up fuel and pushing it through the piping system. Air can be removed by bleeding the system as set forth in the procedures described in the manufacturer's maintenance manual.

CLEANING INJECTORS

Unless special servicing equipment and repair instructions are available, defective nozzles and pumps are exchanged for new ones. However, in an emergency, and if spray valves or pumps are not too badly worn, they may be returned to a serviceable condition, with minor adjustment, after a thorough cleaning.

Injector spray nozzles or pumps should be disassembled in the field only when no other recourse is available. Whenever possible, they should be removed from the equipment and brought to the shop for repair. The first requirement for the cleaning job is a clean working area.

Use clean diesel fuel for washing the parts. Disassemble one nozzle at a time to prevent mixing of mating parts. Exercise care to prevent damage to nozzle parts. Inspect and clean all parts as they are disassembled. Carbon may be scraped from the outside of the nozzle, but be careful not to mar the edges of the holes (orifices). When cleaning fluid is used to clean the nozzle parts, dip the parts in diesel fuel immediately after cleaning. This will prevent moisture from the hands from marring the highly polished surfaces.

Reaming tools and special drills are provided for cleaning spray nozzle holes. No drills other than those recommended by the manufacturer should be used. The drills are hand-operated, using a cleaning needle that is held in place by a small chuck, called a pin vise (fig. 5-45). In performing reaming operations, remove only the foreign matter; be particularly careful not to burr the metal.

WARNING

Diesel fuel is a hazardous material. Avoid prolonged skin contact and wear goggles. Keep fire and flame away. Dispose of waste material and cleaning rags as hazardous waste. For more information, see OPNAVINST 4110.2, *Hazardous Material Control and Management.*

Q31. When should water be drained from the fuel system?

Q32. What is the first requirement when disassembling an injector for cleaning?

GENERAL TROUBLESHOOTING

LEARNING OBJECTIVE: *Describe general troubleshooting techniques used in the maintenance of a diesel fuel system.*

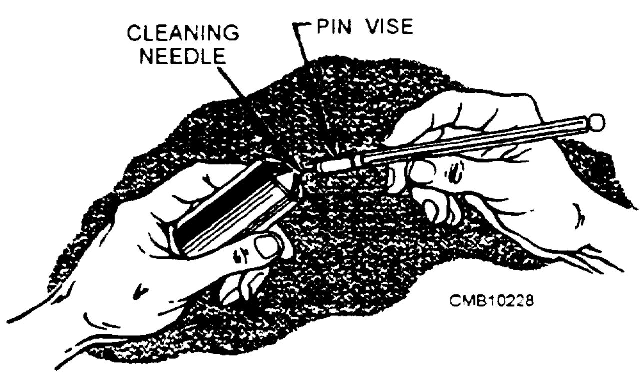


Figure 5-45.—Cleaning injector spray nozzle holes.

When troubleshooting a diesel engine, keep in mind that problems associated with one make and type of engine (two-stroke versus four-stroke) may not occur exactly in the same way as in another. Specifically, particular features of one four-stroke-cycle engine may not appear on another due the type of fuel system used and optional features on that engine. Follow the basic troubleshooting steps listed below before rolling up your sleeves and trying to pinpoint a problem area.

1. Obtain as much information from the operator as possible concerning the complaint.
2. Analyze the problem in detail first, beginning with the smallest and simplest things.
3. Relate the problem symptoms to the basic engine systems and components.
4. Consider any recent maintenance or repair job that might tie into the problem.
5. Always double-check and think about the problem before disassembling anything.
6. Solve the problem by checking the easiest and simplest things first.
7. If possible, use the special tools and diagnostic equipment at your disposal to verify acomplaint and pinpoint the general area.
8. Determine the cause(s) of the problem and carry out the repair.
9. Operate the engine and road test the vehicle to confirm that the problem is corrected.

EXHAUST SMOKE COLOR

One of the easiest methods to use when troubleshooting an engine for a performance complaint is to monitor the color of the smoke coming from the exhaust stack visually. There are four basic colors that may exit from the exhaust system at any time during engine operation—white, black, gray, or blue. The color of the smoke tips you off to just what and where the problem might lie.

- **White smoke** is generally most noticeable at engine start-up, particularly during cold conditions. As the combustion and cylinder temperatures increase during the first few minutes of engine operation the white smoke should start to disappear which indicates the engine is sound. However, if the white smoke takes longer than 3 to 5 minutes to disappear a problem exist. The problems white smoke may indicate are as follows:

- Low cylinder compression from worn rings
- Scored piston or liner
- Valve seating problems
- Water leaking into the combustion chamber
- Faulty injectors
- Use of a low cetane diesel fuel.

- **Black or gray smoke** generally is caused by the same conditions—the difference between the colors being one of opacity or denseness of smoke. Black or gray smoke should be checked with the engine at operating temperature of 160°F. Abnormal amounts of exhaust smoke emission is an indication that the engine is not operating correctly, resulting in a lack of power, as well as decreased fuel economy. Excessive black or gray exhaust smoke is caused by the following:

  - Improper grade of diesel fuel
  - Air starvation
  - High exhaust back pressure
  - Incorrect fuel injection timing
  - Faulty nozzles or injectors
  - Incorrect valve adjustment clearances
  - Faulty injection pump
  - Faulty automatic timing advance unit

- **Blue smoke** is attributed to oil entering the combustion chamber and being burned or blown through the cylinder and burned in the exhaust manifold or turbocharger. Remember always check the simplest things first, such as too much oil in the crankcase or a plugged crankcase ventilation breather. The more serious problems that can cause blue smoke are as follows:

  - Worn valve guides
  - Worn piston rings
  - Worn cylinder walls
  - Scored pistons or cylinder walls
  - Broken rings
  - Turbocharger seal leakage
  - Glazed cylinder liner walls due to use of the wrong type of oil

NOTE

With the engine stopped, the condition of the pistons, rings, and liners on a two-stroke cycle Detroit diesel engine can be checked visually by removing an air box inspection cover on the side of the engine block and accessing the components through the cylinder liner ports.

QUICK INJECTOR MISFIRE CHECK

Listed below are several quick and acceptable checks that can be performed on a running engine to determine if one or more injectors are at fault on any type of engine.

On four-stroke-cycle engines with a high-pressure in-line pump or distributor system, such as Caterpillar and Roosa Master, you can loosen off one injector fuel line, one at a time, about one-half turn as you hold a rag around it while noting if there is any change in the operating sound of the engine. If the injector is firing properly, there should be a positive change to the sound and rpm of the engine when you loosen the line, since it prevents the delivery of fuel to the cylinder.

On an engine with the PT fuel system, a cylinder misfire can be checked by running the engine to a minimum of 160°F, removing the rocker covers, then installing a rocker lever actuator over an injector rocker lever. Hold the injector plunger down while the engine is running at low idle. This will stop the fuel flow to that injector. If the engine speed decreases, the injector is good. If the engine rpm does not decrease, replace the injector.

On the two-stroke-cycle nonelectronic Detroit diesel engines, you can remove the rocker cover, then using a large screwdriver push and hold down the injector follower while the engine is idling. This action is like shorting out a spark plug on a gasoline engine, since it prevents fuel from being injected into the combustion chamber. If there is no change to the sound and speed of the engine, the injector is not firing. There should be a definite change to indicate that the injector was in fact firing.

Q33. After start-up of a cold diesel engine, white smoke dissipates in what number of minutes?

Q34. Oil entering the combustion chamber produces smoke of what color?

Q35. When checking a two-stroke nonelectronic Detroit diesel engine for proper operation, you follow what procedure?

CHAPTER 6

COOLING AND LUBRICATING SYSTEMS

LEARNING OBJECTIVE: *Explain the relationship of the cooling system to engine operation. Identify design and functional features of individual cooling system components. Identify maintenance procedures applicable to cooling systems. Identify types of lubrication systems and explain their operational charactetistics and maintenance requirements.*

All internal combustion engines are equipped with cooling and lubricating systems that work in conjunction with each other to promote efficient engine operation and performance. The cooling and lubricating systems discussed in this chapter, along with their respective components and maintenance requirements, are representative of the types of systems you will be expected to maintain.

Because of the variety of engines used, there are differences in the applications of features of their cooling and lubricating systems. Keep in mind that maintenance procedures and operational characteristics vary from engine to engine; therefore, always refer to the manufacturer's service manuals for specific information

ENGINE COOLING SYSTEMS

LEARNING OBJECTIVE: *Explain the relationship of the cooling system to engine operation. Identify, design and functional features of individual cooling system components. Identify maintenance procedures applicable to cooling systems.*

An internal combustion engine produces power by burning fuel within the cylinders; therefore, it is often referred to as a "heat engine." However, only about 25% of the heat is converted to useful power. What happens to the remaining 75 percent? Thirty to thirty five percent of the heat produced in the combustion chambers by the burning fuel are dissipated by the cooling system along with the lubrication and fuel systems. Forty to forty-five percent of the heat produced passes out with the exhaust gases. If this heat were not removed quickly, overheating and extensive damage would result. Valves would burn and warp, lubricating oil would break down, pistons and bearing would overheat and seize, and the engine would soon stop.

The necessity for cooling may be emphasized by considering the total heat developed by an ordinary six-cylinder engine. It is estimated that such an engine operating at ordinary speeds generates enough heat to warm a six-room house in freezing weather. Also, peak combustion temperatures in a gasoline engine may reach as high as 4500°F, while that of a diesel engine may approach 6000°F. The valves, pistons, cylinder walls, and cylinder head, all of which must be provided some means of cooling to avoid excessive temperatures, absorb some of this heat. Even though heated gases may reach high temperatures, the cylinder wall temperatures must not be allowed to rise above 400°F to 500°F. Temperatures above this result in serious damage as already indicated. However, for the best thermal efficiency, it is desirable to operate the engine at temperatures closely approximating the limits imposed by the lubricating oil properties.

The cooling system has four primary functions. These functions are as follows:

1. Remove excess heat from the engine.
2. Maintain a constant engine operating temperature.
3. Increase the temperature of a cold engine as quickly as possible.
4. Provide a means for heater operation (warming the passenger compartment).

Air is continually present in large enough quantities to cool a running engine; therefore, vehicle engines are designed to dissipate their heat into the air through which a vehicle passes. This action is accomplished either by direct air-cooling or indirectly by liquid cooling. In this chapter we will be concerned with both

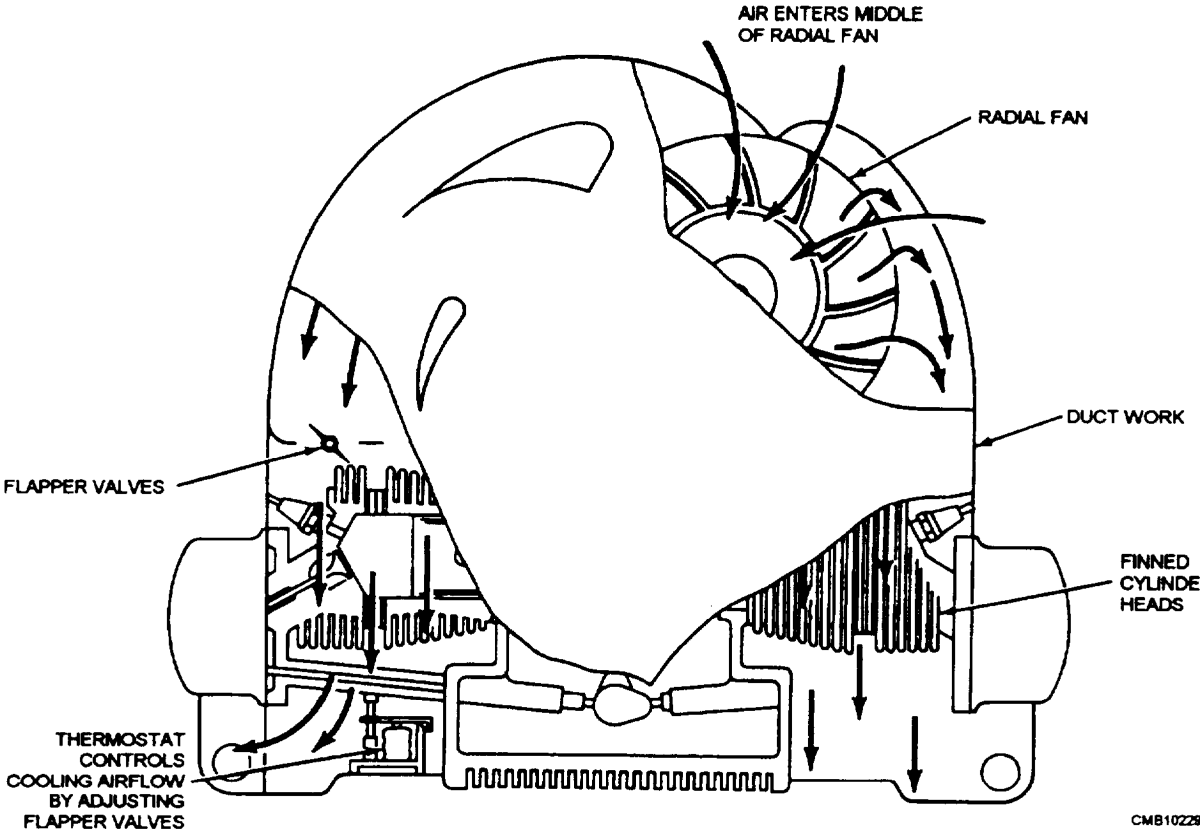


Figure 6-1.—Air-cooled system.

types, and the discussion will include a description of the various components of the systems and an explanation of their operation.

AIR-COOLED SYSTEM

The simplest type of cooling is the air-cooled, or direct, method in which the heat is drawn off by moving air in direct contact with the engine (fig. 6-1). Several fundamental principles of cooling are embodied in this type of engine cooling. The rate of the cooling is dependent upon the following:

- The area exposed to the cooling medium
- The heat conductivity of the metal used & the volume of the metal or its size in cross section
- The amount of air flowing over the heated surfaces
- The difference in temperature between the exposed metal surfaces and the cooling air

Some heat, of course, must be retained for efficient operation. This is done by use of thermostatic controls and mechanical linkage, which open and close shutters to control the volume of cooling air. You will find that air-cooled engines generally operate at a higher temperature than liquid-cooled engines whose operating temperature is largely limited by the boiling point of the coolant used. Consequently greater clearances must be provided between the moving parts of air-cooled engines to allow for increased expansion. Also, lubricating oil of a higher viscosity is generally required.

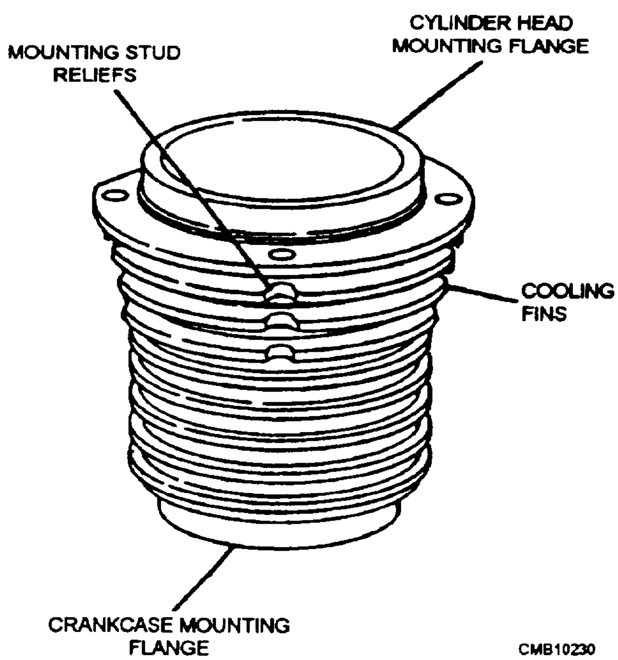


Figure 6-2.—Air-cooled cylinder.

In air-cooled engines the cylinders are mounted independently to the crankcase so an adequate volume of air can circulate directly around each cylinder, absorbing heat and maintaining cylinder head temperatures within allowable limits for satisfactory operation (fig. 6-2). In all cases, the cooling action is based on the simple principle that the surrounding air is cooler than the engine. The main components of an air-cooled system are the fan, shroud, baffles, and fins. A typical air-cooled engine is shown in figure 6-3.

Fan and Shroud

All stationary air-cooled engines must have a fan or blowers of some type to circulate a large volume of cooling air over and around the cylinders. The fan for the air-cooled engine shown in figure 6-3 is built into the flywheel. Notice that the shrouding, or cowling, when assembled will form a compartment around the engine so the cooling air is properly directed for effective cooling. Air-cooled engines, such as those used on motorcycles and outboard engines, do not require the use of fans or shrouds because their movement through the air results in sufficient airflow over the engine for adequate cooling.

Baffles and Fins

In addition to the fan and shroud, some engines use baffles or deflectors to direct the cooling air from the fan to those parts of the engine not in the direct path of the airflow. Baffles are usually made of light metal and are semicircular, with one edge in the air stream, to direct the air to the back of the cylinders.

Most air-cooled engines use thin fins that are raised projections on the cylinder barrel and head (fig. 6-3). The fins provide more cooling area or surface and aid in directing airflow. Heat, resulting from combustion, passes by conduction from the cylinder walls and cylinder head to the fins and is carried away by the passing air.

Maintaining the Air-cooled System

You may think that because the air-cooled system is so simple it requires no maintenance. Many mechanics think this way and many air-cooled engine failures occur as a result. Maintenance of an air-cooled system consists primarily of keeping cooling components clean. Clean components permit rapid transfer of heat and ensure that nothing prevents the continuous flow and circulation of air. To accomplish this, keep fans, shrouds, baffles, and fins free of dirt, bugs, grease, and other foreign matter. The engine may look clean from the outside, but what is under the shroud? An accumulation of dirt and debris here can cause real problems; therefore, keep this area between the engine and shroud clean.

Paint can cause a problem. Sometimes a mechanic will reduce the efficiency of the cooling system by the

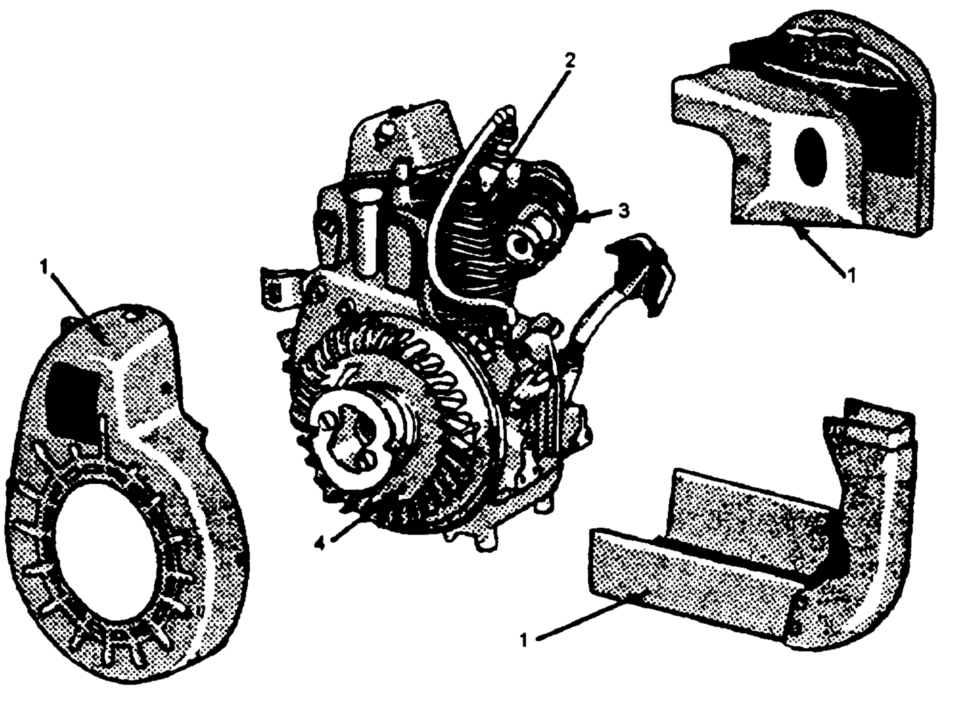


Figure 6-3.—Air-cooled engine.

careless use of paint. The engine may look good but most paints act as an insulator and hold in heat. In addition to keeping the cooling components clean, you must inspect them each time the engine is serviced. Replace or repair any broken or bent parts. Check the fins for cracks or breaks. When cracks extend into the combustion chamber area, the cylinder barrel must be replaced.

Now that we have studied the simplest method of cooling, let's look at the most common, but also the most complex system.

LIQUID-COOLED SYSTEM

Nearly all multicylinder engines used in automotive, construction, and material-handling equipment use a liquid-cooled system. Any liquid used in this type of system is called a COOLANT.

A simple liquid-cooled system consists of a radiator, coolant pump, piping, fan, thermostat, and a system of water jackets and passages in the cylinder head and block through which the coolant circulates (fig. 6-4). Some vehicles are equipped with a coolant distribution tube inside the cooling passages that directs additional coolant to the points where temperatures are highest. Cooling of the engine parts is accomplished by keeping the coolant circulating and in contact with the metal surfaces to be cooled. The operation of a liquid-cooled system is as follows:

- The pump draws the coolant from the bottom of the radiator, forcing the coolant through the water jackets and passages, and ejects it into the upper radiator tank.
- The coolant then passes through a set of tubes to the bottom of the radiator from which the cooling cycle begins.
- The radiator is situated in front of a fan that is driven either by the water pump or an electric motor. The fan ensures an airflow through the radiator at times when there is no vehicle motion.
- The downward flow of coolant through the radiator creates what is known as a thermosiphon action. This simply means that as the coolant is heated in the jackets of the engine, it expands. As it expands, it becomes less dense and therefore

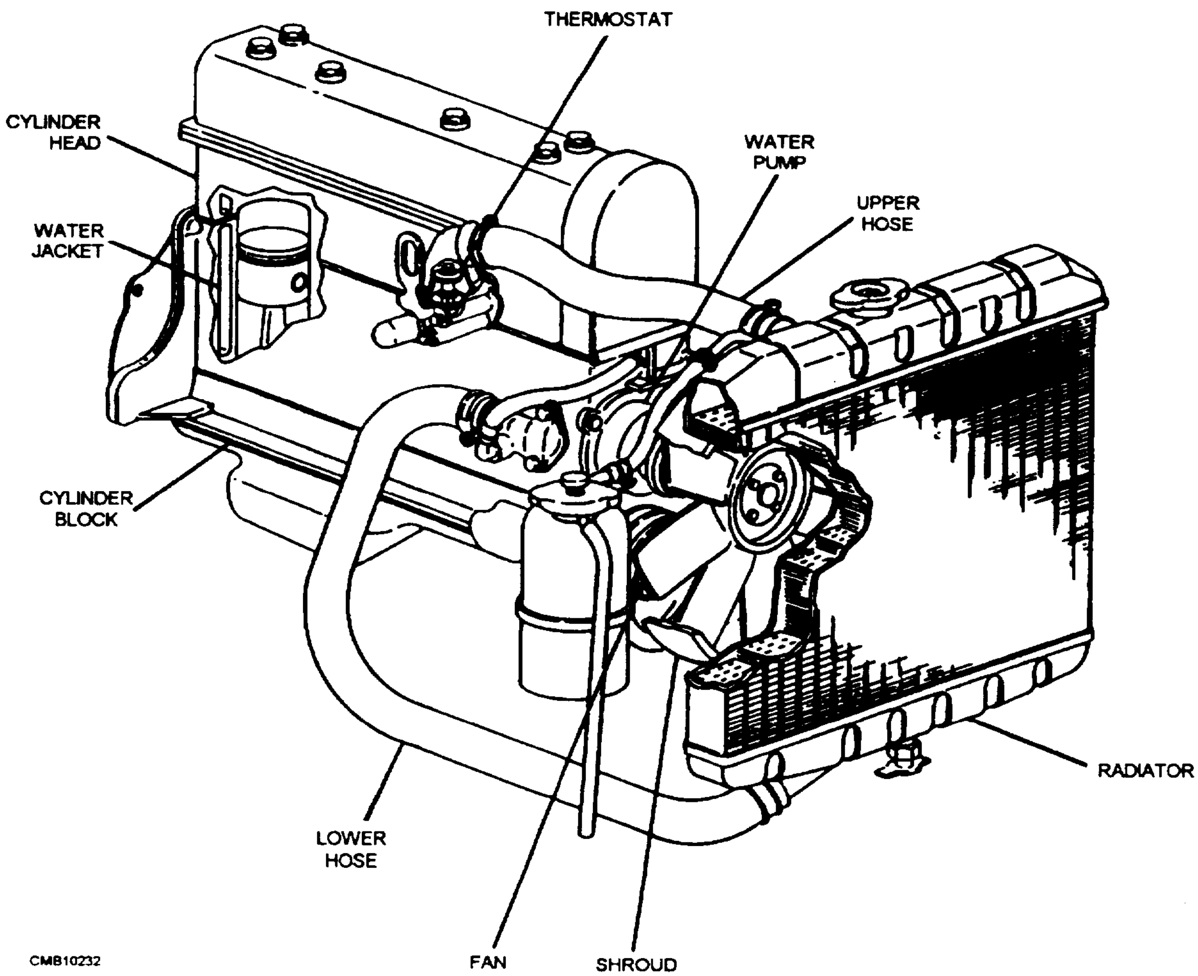


Figure 6-4.—Liquid-cooled engine.

lighter. This causes it to flow out of the top outlet of the engine and into the top tank of the radiator.

- As the coolant is cooled in the radiator, it again becomes more dense and heavier. This causes the coolant to settle to the bottom tank of the radiator.
- The heating in the engine and the cooling in the radiator therefore create a natural circulation that aids the water pump.

The amount of engine heat that must be removed by the cooling system is much greater than is generally realized. To handle this heat load, it may be necessary for the cooling system in some engine to circulate 4,000 to 10,000 gallons of coolant per hour. The water passages, the size of the pump and radiator, and other details are so designed as to maintain the working parts of the engine at the most efficient temperature within the limitation imposed by the coolant.

Radiator

In the cooling system, the radiator is a heat exchanger that removes the heat from the coolant passing through it. The radiator holds a large volume of coolant in close contact with a large volume of air so heat will transfer from the coolant to the air. The components of a radiator are as follows:

- CORE—The center section of the radiator made up of tubes and cooling fins.
- TANKS—The metal or plastic ends that fit over core tube ends to provide storage for coolant and fittings for the hoses.
- FILLER NECK—The opening for adding coolant. It also holds the radiator cap and overflow tube.
- OIL COOLER—The inner tank for cooling automatic transmission or transaxle fluid.
- PETCOCK—The fitting on the bottom tank for draining coolant.

A tube-and-fin radiator consists of a series of tubes extending from top to bottom or from side to side (fig. 6-5). The tubes run from the inlet tank to the outlet tank. Fins are placed around the outside of the tubes to improve heat transfer. Air passes between the fins. As the air passes by, it absorbs heat from the coolant. In a typical radiator, there are five fins per inch Radiators used in vehicles that have air conditioning have seven fins per inch. This design provides the additional cooling surface required to handle the added heat load imposed by the air conditioner.

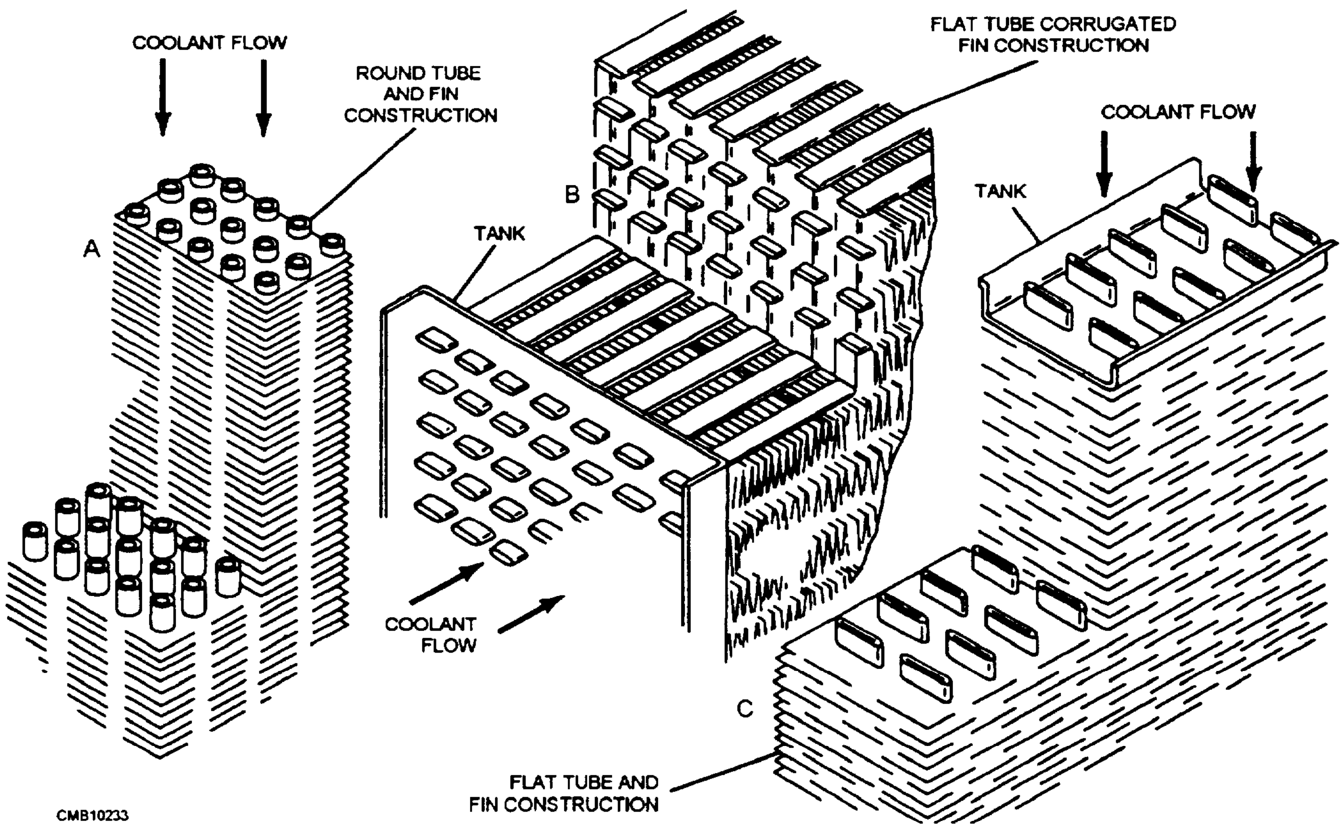


Figure 6-5.—Engine radiator construction.

Radiators are classified according to the direction that the coolant flows through them. The two types of radiators are the downflow and crossflow.

- The downflow radiator has the coolant tanks on the top and bottom and the core tubes run vertically. Hot coolant from the engine enters the top tank. The coolant flows downward through the core tubes. After cooling, coolant flows out the bottom tank and back into the engine.

- The crossflow radiator is a design that has the tanks on the sides of the core. The core tubes are arranged for horizontal coolant flow. The tank with the radiator cap is normally the outer tank. A crossflow radiator can be shorter, allowing for a lower vehicle hood.

The operation of a radiator is as follows:

- The upper tank collects incoming coolant and, through the use of an internal baffle, distributes it across the top of the core.

- The core is made up of numerous rows of small vertical tubes that connect the upper tank and the lower tank. Sandwiched between the rows of tubes are thin sheet metal fins. As the coolant passes through the tubes to the lower tank, the fins conduct the heat away from it and dissipate this heat into the atmosphere. The dissipation of the heat from the fins is aided by directing a constant air flow between the tube and over the fins.

- The lower tank collects the coolant from the core and discharges it to the engine through the outlet pipe.

- The overflow tube provides an opening from the radiator for escape of coolant if the pressure in the system exceeds the regulated maximum. This will prevent rupture of cooling system components.

A transmission oil cooler is often placed in the radiator on vehicles with automatic transmissions. It is a small tank enclosed in one of the main radiator tanks. Since the transmission fluid is hotter than engine coolant, heat is removed from the fluid as it passes through the radiator and cooler.

In downflow radiators, the transmission oil cooler is located in the lower tank. In a crossflow radiator, it is located in the tank having the radiator cap. Both tanks are coolant outlet tanks.

Line fittings from the cooler extend through the radiator tank to the outside. Metal lines from the automatic transmission connect to these fittings. The transmission oil pump forces the fluid through the lines and cooler.

Radiator Hoses

Radiator hoses carry coolant between the engine water jackets and the radiator. Being flexible, hoses can withstand the vibration and rocking of the engine without breaking.

The upper radiator hose normally connects to the thermostat housing on the intake manifold or cylinder head. The other end of the hose fits on the radiator. The lower hose connects the water pump inlet and the radiator.

A molded hose is manufactured into a special shape with bends to clean the parts especially the cooling fan. It must be purchased to fit the exact year and make of the vehicle.

A flexible hose has an accordion shape and can be bent to different angles. The pleated construction allows the hose to bend without collapsing and blocking coolant flow. It is also known as a universal type radiator hose.

A hose spring is used in the lower radiator hose to prevent its collapse. The lower hose is exposed to suction from the water pump. The spring assures that the inner lining of the hose does NOT tear away, close up, and stop circulation.

Radiator Pressure Cap

The radiator pressure cap (fig. 6-6) is used on nearly all of the modern engines. The radiator cap locks onto the radiator tank filler neck Rubber or metal seals make the cap-to-neck joint airtight. The functions of the pressure cap are as follows:

1. Seals the top of the radiator tiller neck to prevent leakage.
2. Pressurizes system to raise boiling point of coolant.
3. Relieves excess pressure to protect against system damage.
4. In a closed system, it allows coolant flow into and from the coolant reservoir.

The radiator cap pressure valve consists of a spring-loaded disc that contacts the filler neck. The spring pushes the valve into the neck to form a seal. Under

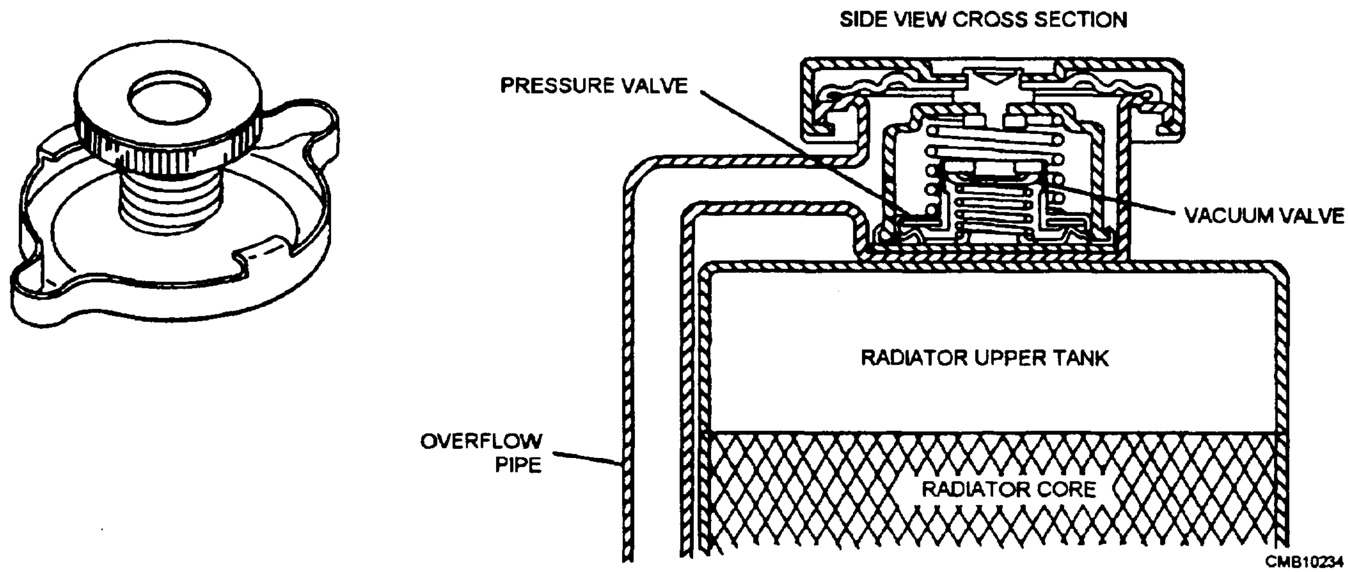


Figure 6-6.—Radiator pressure cap.

pressure, the boiling point of water increases. Normally water boils at 212°F. However, for every pound of pressure increase, the boiling point goes up 3°F.

Typical radiator cap pressure is 12 to 16 psi. This raises the boiling point of the engine coolant to about 250°F to 260°F. Many surfaces inside the water jackets can be above 212°F.

If the engine overheats and the pressure exceeds the cap rating, the pressure valve opens. Excess pressure forces coolant out of the overflow tube and into the reservoir or onto the ground. This prevents high pressure from rupturing the radiator, gaskets, seals, or hoses.

The radiator cap vacuum valve opens to allow reverse flow back into the radiator when the coolant temperature drops after engine operation. It is a smaller valve located in the center, bottom of the cap.

The cooling and contraction of the coolant and air in the system could decrease coolant volume and pressure. Outside atmospheric pressure could then crush inward on the hoses and radiator. Without a cap vacuum or vent valve, the radiator hose and radiator could collapse.

CAUTION

Always remove the radiator cap slowly and carefully. Removing the radiator cap from a hot pressurized system can cause serious burns from escaping steam and coolant.

Water Pump

The water pump is an impeller or centrifugal pump that forces coolant through the engine block, cylinder head, intake manifold, hoses, and radiator (fig. 6-7). It is driven by a fan belt running off the crankshaft pulley. The major parts of a typical water pump include the following:

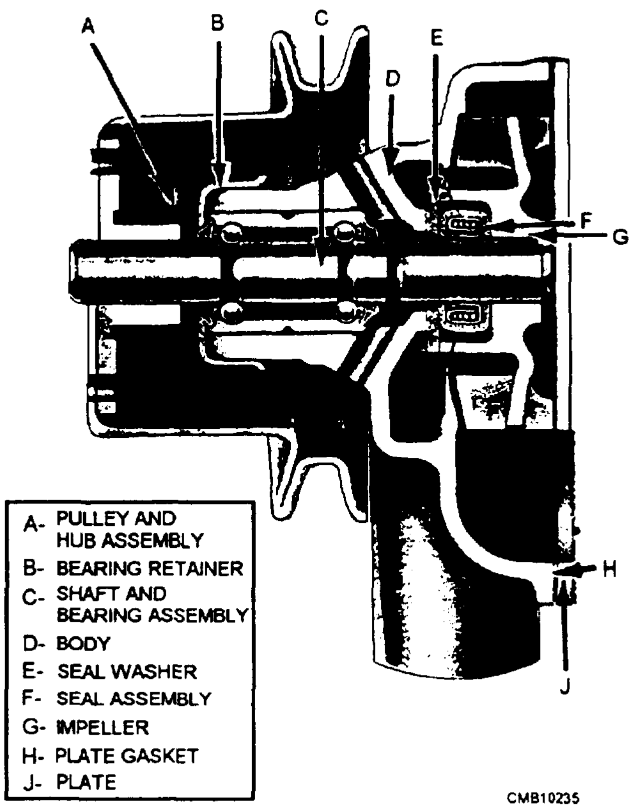


Figure 6-7.—Water pump.

- WATER PUMP IMPELLER—a disc with fanlike blades that spins and produces pressure and flow.
- WATER PUMP SHAFT—steel shaft that transfers turning force from the hub to impeller.
- WATER PUMP SEAL—prevents coolant leakage between pump shaft and pump housing.
- WATER PUMP BEARING—plain or ball bearing that allows the pump shaft to spin freely in the housing.
- WATER PUMP HUB—provides mounting place for the belt and fan.
- WATER PUMP HOUSING—iron or aluminum casting that forms the main body of the pump.

The water pump normally mounts on the front of the engine. With some transverse (sideways) mounted engines, it may bolt to the side of the engine and extend towards the front.

A water pump gasket fits between the engine and the pump housing to prevent coolant leakage. RTV sealer may be used instead of a gasket.

Operation of the water pump is as follows (fig. 6-8):

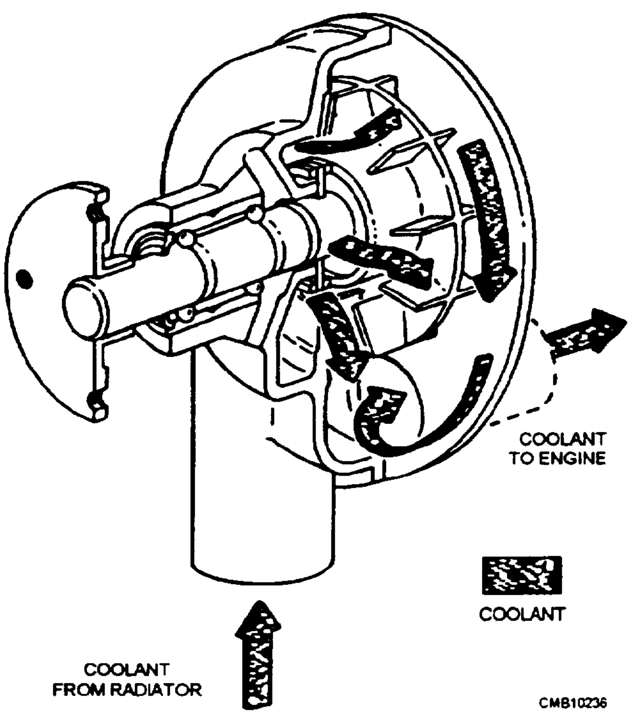


Figure 6-8.—Water pump operation.

- The spinning crankshaft pulley causes the fan belt to turn the water pump pulley, pump shaft, and impeller.
- Coolant trapped between the impeller blades is thrown outward, producing suction in the central area of the pump housing.
- Since the pump inlet is near the center, coolant is pulled out of the radiator, through the lower radiator hose.
- After being thrown outward and pressurized, the coolant flows into the engine. It circulates through the block, around the cylinders, up through the cylinder heads, and back into the radiator.

Fan and Shroud

The cooling system fan pulls a large volume of air through the radiator core that cools the hot water circulating through the radiator. A fan belt or an electric motor drives the fan A fan driven by a fan belt, is known as an engine-powered fan and is bolted to the water pump hub and pulley. Sometimes a spacer fits between the fan and pulley to move the fan closer to the radiator. Besides removing heat from the coolant in the radiator, the flow of air created by the fan causes some direct cooling of the engine itself.

Fan blades are spaced at intervals around the fan hub to aid in controlling vibration and noise. They are often curled at the tip to increase their ability to move air. Except for differences in location around the hub, most blades have the same pitch and angularity.

Bent fan blades are very common and result in noise, vibration, and excess wear on the water pump shaft. You should inspect the fan blades, pulleys, pump shaft end play, and drive belt at every preventive maintenance inspection.

A variable pitch (flex) fan has thin, flexible blades that alter airflow with engine speed (fig. 6-9). These fan blades are made to change pitch as the speed of the fan increases so that the fan will not create excessive noise or draw excessive engine power at highway speeds. At low speeds, the fan blades remain curved and pull air through the radiator. At higher speeds, the blades flex until they are almost straight. This reduces fan action and saves engine power.

The fluid coupling fan clutch is designed to slip at high speeds, performing the same function as a flexible fan. The clutch is filled with silicone-based oil. Fan

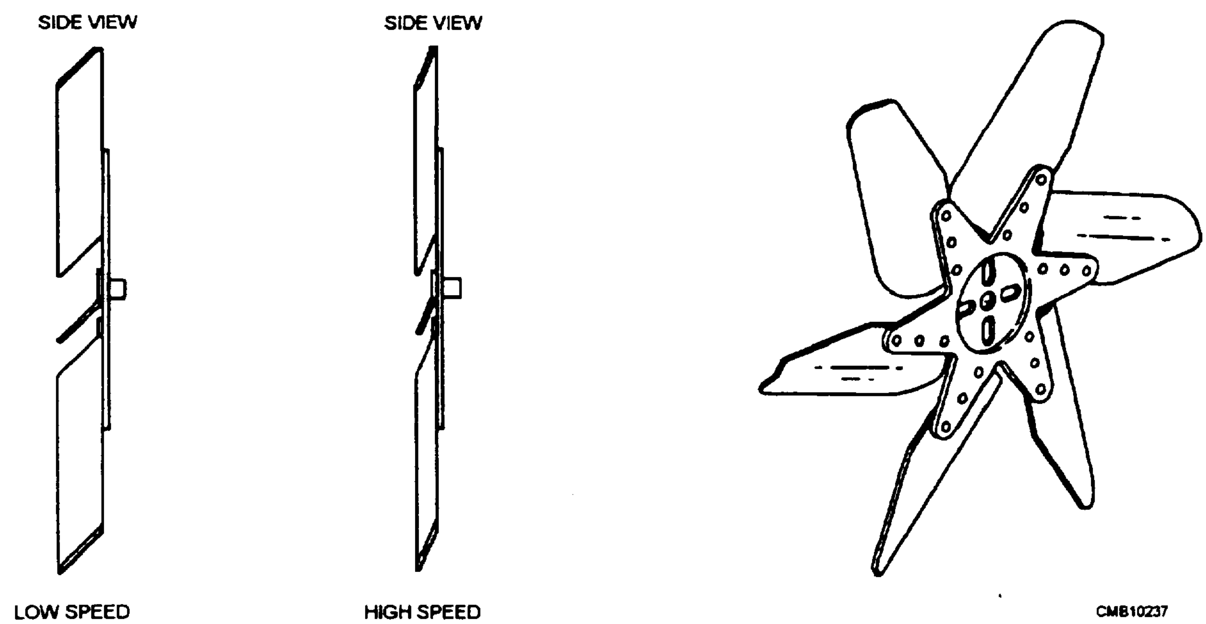


Figure 6-9.—Variable pitch fan.

speed is controlled by the torque-carrying capacity of the oil. The more oil in the coupling, the greater the fan speed; the less oil in the coupling, the slower the fan speed.

The thermostatic fan clutch has a temperature sensitive, bimetallic spring that controls fan action. The spring controls oil flow in the fan clutch When cold, the spring causes the clutch to slip, speeding engine warm-up. After reaching operating temperature, the spring locks the clutch, providing forced air circulation.

An electric engine fan uses an electric motor and a thermostatic switch to provide cooling action (fig. 6-10). An electric fan is used on front-wheel drive vehicles having transverse mounted engines. The water pump is normally located away from the radiator.

The fan motor is a small, direct current (dc) motor. It mounts on a bracket secured to the radiator. A metal or plastic fan blade mounts on the end of the motor shaft.

A fan switch or temperature-sensing switch controls fan motor operation. When the engine is cold, the switch is open, keeping the fan from spinning, and speeds engine warm-up. When coolant temperature reaches approximately 210°F, the switch closes to operate the fan and provide cooling.

An electric engine fan saves energy and increases cooling system efficiency. It only functions when needed. By speeding engine warm-up, it reduces emissions and fuel consumption. In cold weather, the electric fan may shut off at highway speeds. There may be enough cool air rushing through the grille of the vehicle to provide adequate cooling. On some models a timed relay may be incorporated that allows the fan to run for a short time after engine shutdown. This, in conjunction with thermosiphon action, helps to prevent boilover after engine shutdown.

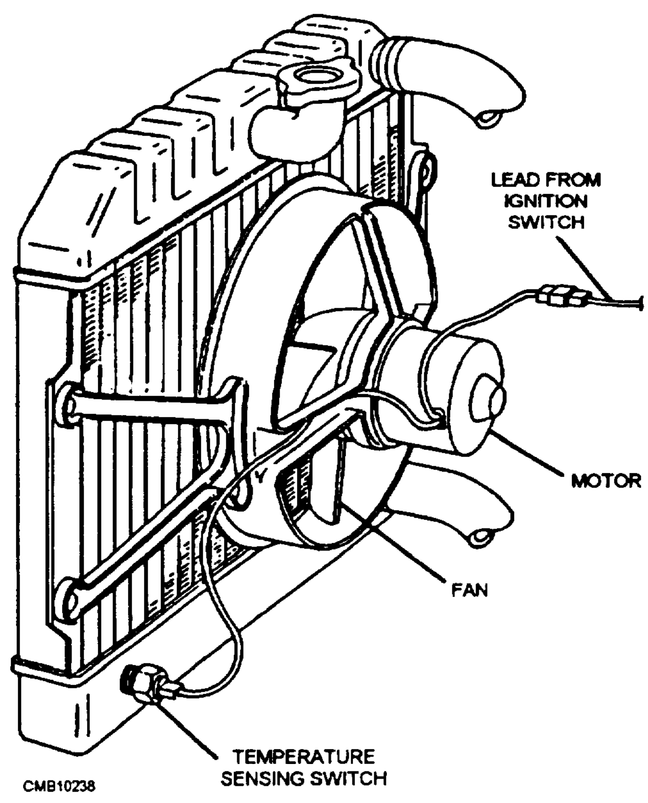


Figure 6-10.—Electrically motorized fan.

The radiator shroud ensures that the fan pulls air through the radiator. It fastens to the rear of the radiator and surrounds the area around the fan. When the fan is spinning, the shroud keeps air from circulating between the back of the radiator and the front of the fan. As a result, a large volume of air flows through the radiator core.

Water Jacket

The water passages in the cylinder block and cylinder head form the engine waterjacket (fig. 64). In the cylinder block, the water jacket completely surrounds all cylinders along their full length. Within the jacket, narrow passages are provided between the cylinders for coolant circulation around them. In addition, water passages are provided around the valve seats and other hot parts of the cylinder block In the cylinder head, the water jacket covers the combustion chambers at the top of the cylinders and contains passages around the valve seats when the valves are located in the head.

The passages of the water jacket are designed to control circulation of coolant and provide proper cooling throughout the engine. The pump forces coolant directly from the lower radiator tank connection into the forward portion of the cylinder block. This type of circulation would, obviously, cool the number one cylinder first; causing the rear cylinder to accept coolant progressively heated by the cylinders ahead. To prevent this condition, the L-head block is equipped with a coolant distribution tube that extends from front to rear of the block, having holes adjacent to (and directed at) the hottest parts of each cylinder. I-head engines are equipped with ferrule type coolant directors that direct a jet of coolant toward the exhaust valve seats.

Thermostats

Automatic control of the temperature of the engine is necessary for efficient engine performance and economical operation. If the engine is allowed to operate at a low temperature, sludge buildup and excessive fuel consumption will occur. On the other hand, overheating the engine or operating it above normal temperature will result in burnt valves and faulty lubrication. The latter causes early engine failure.

The thermostat senses engine temperature and controls coolant flow through the radiator. It allows coolant to circulate freely only withinthe blockuntil the desired temperature is reached. This action shortens the warm-up period. The thermostat normally fits under the thermostat housing between the engine and the end of the upper radiator hose. The pellet-type thermostat that is used in modern pressurized cooling systems incorporates the piston and spring principle (fig. 6-11). The thermostat consists of a valve that is operated by a piston or a steel pin that fits into a small case, containing a copper impregnated wax pellet. A spring holds the piston and valve in a normally closed position. When the thermostat is heated, the pellet expands and pushes the valve open. As the pellet and thermostat cools, spring tension overcomes pellet expansion and the valve closes.

Thermostats are designed to open at specific temperatures. This is known as thermostat rating. Normal ratings are between 180°F and 195°F for automotive applications and between 170°F and 203°F for heavy-duty applications. Thermostats will begin to open at their rated temperature and are fully open about 20°F higher, For example, a thermostat with a rating of 195°F starts to open at that temperature and is fully open at about 215°F.

Most engines have a small coolant bypass passage that permits some coolant to circulate within the cylinder block and head when the engine is cold and the thermostat is closed. This provides equal warming of the cylinders and prevents hot spots. When the engine warms up, the bypass must close or become restricted. Otherwise, the coolant would continue to circulate within the engine and too little would return to the radiator for cooling.

The bypass passage may be an internal passage or an external bypass hose. The bypass hose connects the cylinder block or head to the water pump. There are two internal bypass systems that can be used on an engine.

One internal bypass system uses a small, spring-loaded valve located in the back of the water pump. The valve is forced open by coolant pressure from the pump when the thermostat is closed. As the thermostat opens, the coolant pressure drops within the engine and the bypass valve closes.

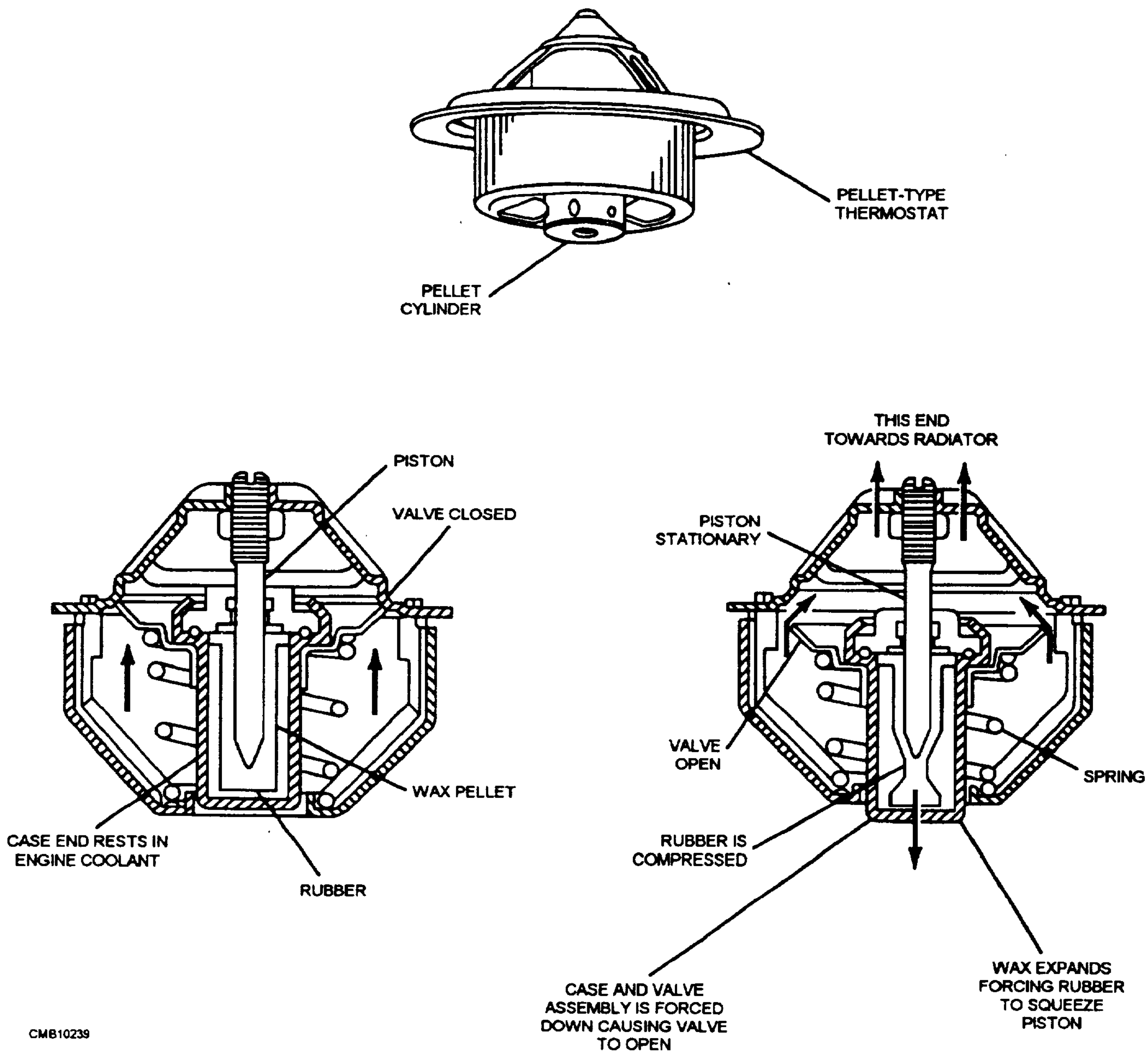


Figure 6-11.—Pellet-type thermostat.

Another bypass system has a blocking-bypass thermostat (fig. 6-12). This thermostat operates as previously described, but it also has a secondary, or bypass, valve. When the thermostat valve is closed, the circulation to the radiator is shut off. However, when the bypass valve is open, coolant is allowed to circulate through the bypass. As the thermostat valve opens, coolant flows into the radiator and the bypass valve closes.

Some stationary engines and large trucks are equipped with shutters that supplement the action of the thermostat in providing a faster warm-up and in maintaining proper operating temperatures. When the engine coolant is below a predetermined temperature, the shutters, located in front of the radiator, remain closed and restrict the flow of air through the radiator. Then as the coolant reaches proper temperature, the shutters start to open. Two methods are used to control

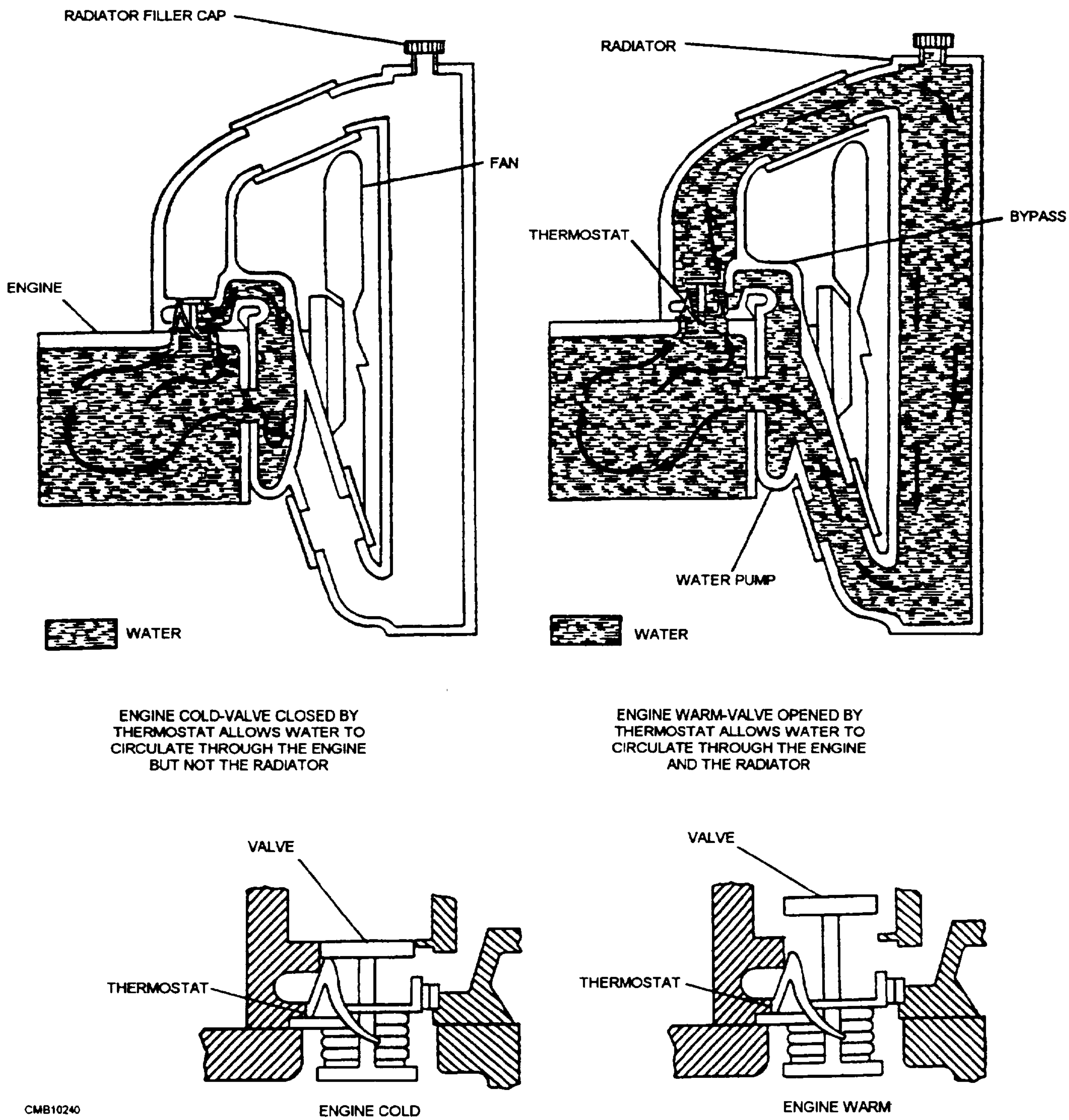


Figure 6-12.—Blocking-bypass thermostat.

the shutter opening. A stationary engine uses a SHUTTERSTAT (long thermostatic valve) connected to the engine cooling system with hoses or pipes that allow the coolant to circulate through the valve. The temperature of the coolant, when it reaches a predetermined temperature, causes the valve to expand extending a rod which through linkage forces the shutters open. Trucks, equipped with an air brake, use a smaller thermostatic valve that actuates an air valve. This air valve allows pressure from the air tank to enter the air cylinder attached to the shutter operating mechanism, forcing the shutters open.

Expansion (Recovery) Tank

Many cooling systems have a separate coolant reservoir or expansion tank, also called the recovery tank. It is partly filled with coolant and is connected to the overflow tube from the radiator filler neck. The coolant in the engine expands, as the engine heats up. Instead of dripping out of the overflow tube onto the ground and being lost out of the system completely, the coolant flows into the expansion tank.

When the engine cools, a vacuum is created in the cooling system. The vacuum siphons some of the coolant back into the radiator from the expansion tank. In effect, a cooling system with an expansion tank is a closed cooling system (fig. 6-13). Coolant can flow back and forth between the radiator and the expansion tank. This occurs as the coolant expands and contracts from the heating and cooling. Under normal conditions, no coolant is lost. Coolant is added in this system through the expansion tank that is marked for proper coolant level. NEVER remove the cap located on the radiator unless you are positive the system is cold. If there is any pressure in the radiator, it will spray you with hot steam and coolant. Use extreme caution whenever you work around a closed cooling system.

An advantage to the use of an expansion tank is that it eliminates almost all air bubbles from the cooling system. Coolant without bubbles absorbs heat better. Although the coolant level in the expansion tank goes up and down, the radiator and cooling system are kept full. This results in maximum cooling efficiency.

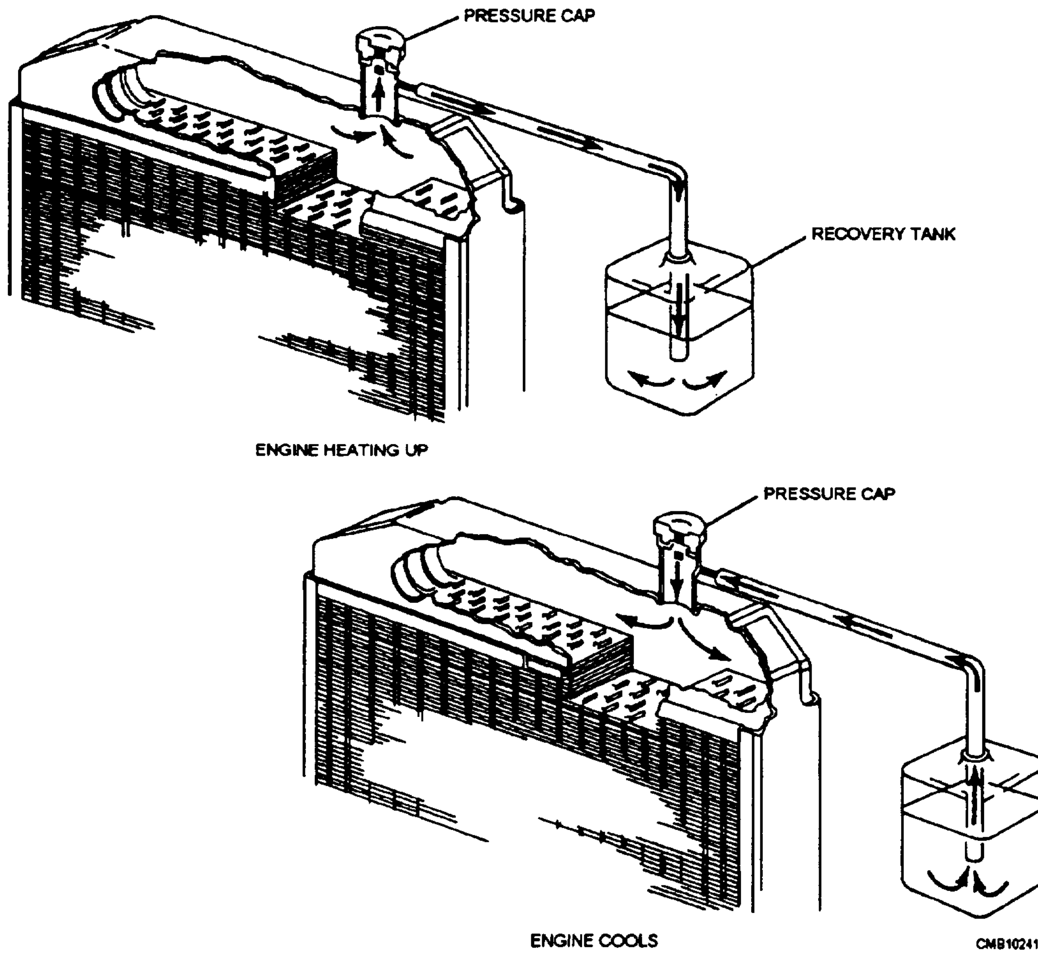


Figure 6-13.—Closed cooling system.

Temperature Gauge and Warning Light

The operator should be warned if the temperature of the coolant in the cooling system goes too high. For this reason, a temperature gauge or warning light is installed in the instrument panel of the vehicle. An abnormal heat rise is a warning of abnormal conditions in the engine. The warning lights alert the operator to stop the vehicle before serious engine damage can occur. Temperature gauges are of two general types—the balancing-coil (magnetic) type and the bimetal-thermostat (thermal) type.

1. The balancing-coil consists of two coils and an armature to which a pointer is attached. An engine-sending unit, that changes resistance with temperature, is placed in the engine so that the end of the unit is in the coolant. When the engine is cold, only a small amount of current is allowed to flow through the right coil; the left coil has more magnetism than the right coil. The pointer, attached to the armature, moves left indicating that the engine is cold. As the engine warms up, the sending unit passes more current. More current flows through the right coil, creating a stronger magnetic field. Therefore, the pointer moves ‘to the right to indicate a higher coolant temperature.
2. The bimetal-thermostat is similar to the balancing-coil type except for the use of a bimetal thermostat in the gauge. This thermostat is linked to the pointer. As the sending unit warms up and passes more current, the thermostat heats up and bends. This causes the pointer to swing to the right to indicate that the engine coolant temperature is rising.

A temperature warning light informs the operator when the vehicle is overheating. When the engine coolant becomes too hot, a sending unit in the engine block closes, completing the circuit and the dash indicating light comes ON. The indicating light warns of an overheating condition about 5°F to 10°F below coolant boiling point.

In some construction equipment a "prove-out" circuit is incorporated in the system. When the ignition switch is turned from OFF to RUN, the light comes on, proving that the system is operating. If the light does not come on, either the bulb is burned out or the sending unit or connecting wire is defective. The light will go out normally after the engine starts.

Coolants and Antifreeze

Since water is easily obtained, cheap, and has the ability to transfer heat readily, it has served as a basic coolant for many years. Some properties of water, such as its boiling point, freezing point, and natural corrosive action on metals, limit its usefulness as a coolant. To counteract this, use an antifreeze.

Antifreeze, usually ethylene glycol, is mixed with water to produce the engine coolant. Antifreeze has several functions.

- Prevents winter freeze up, which can cause serious damage to the engine and cooling system.
- Prevents rust and corrosion by providing a protective film on the metal surfaces.
- Lubricates the water pump, which increases the service life of the pump and seals.
- Cools the engine; prevents overheating in hot weather.

For ideal cooling and winter protection, a 50/50 mixture of antifreeze and water is recommended. It will provide protection from ice formation to about –34°F. Higher ratios of antifreeze produce even lower freezing temperatures; for example, a 60/40 mixture will protect the cooling system to about –62°F. However, this much protection is not normally needed.

WARNING

Ethylene glycol is a toxic material- Avoid prolonged skin contact or accidental ingestion. Wear protective gloves and goggles while handling antifreeze and coolants.

SERVICING THE LIQUID-COOLED SYSTEM

A cooling system is extremely important to the performance and service life of the engine. Major engine damage could occur in a matter of minutes without proper cooling because combustion heat collects in metal engine parts. This heat can melt pistons, crack or warp the cylinder head or block, cause valves to burn, or the head gasket to "blow." To prevent these costly problems, keep the cooling system in good condition.

As a mechanic, you must be able to locate and correct cooling system problems quickly and accurately. It is equally important that you know how to service a cooling system.

Flushing the System

The original additives in antifreeze fight rust and corrosion breakdown and are ineffective after 1 to 2 years. This is because of the continual exposure to the heat in the cooling system. After the additives break down, rust begins to form rapidly. Therefore, a rust-colored antifreeze is an indication that the cooling-system service is required.

The cooling system should be cleaned periodically to remove rust, scale, grease, oil, and any acids formed by exhaust-gas leakage into the coolant. Recommendations vary; for example, Chevrolet recommends that the cooling system be drained and flushed every 2 years.

Flushing (cleaning) of a cooling system should be done based on the manufacturer's recommendations or when rust and other contaminants are found in the system. Flushing involves running water or a cleaning chemical through the cooling system to wash out contaminants. Rust is very harmful to the cooling system because it causes premature water pump wear and can collect and clog the radiator or heater core tubes. There are three methods of flushing-fast flushing, reverse flushing, and chemical flushing.

Fast flushing is a common method of cleaning a cooling system because the thermostat does not have to be removed from the engine. A water hose is connected to a heated hose fitting. The radiator cap is removed and the petcock is opened. When the water hose is ON and water flows through the system, loose rust and scale are removed.

Reverse flushing of a radiator requires a special flushing gun device that is connected to the radiator outlet tank by a piece of hose (fig. 6-14). Another hose is attached to the inlet tank, so the water and debris can be directed to the floor drains. Compressed air, under low pressure, is used to force water through the radiator core backwards. The air pressure is used intermittently to loosen scale and sediment. Excessive air pressure should be avoided to prevent damage to the radiator. Starting and stopping the water flow produces a fluctuation in pressure and tends to loosen all foreign matter clinging to the passages in the radiator core.

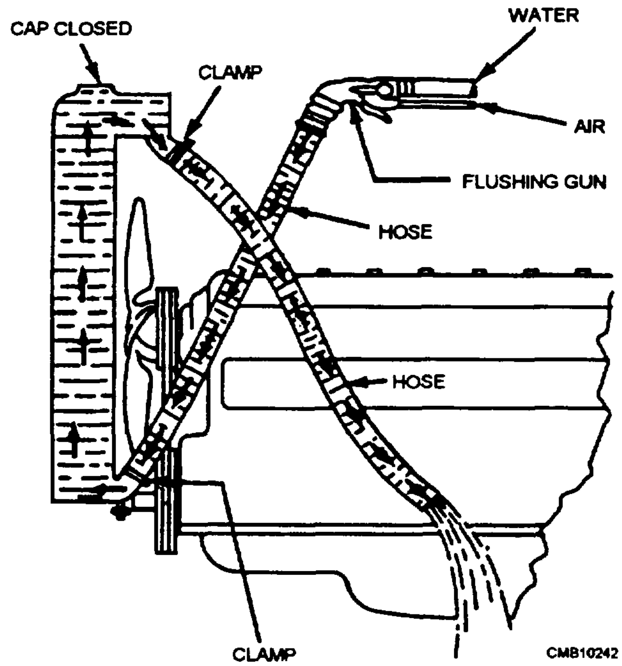


Figure 6-14.—Reverse flushing of a radiator.

Reverse flushing can also be used on the engine block and head (fig. 6-15). First, remove the thermostat and disconnect the upper radiator hose. Then disconnect the lower radiator hose at the water pump. Insert the flushing equipment in the upper radiator hose. Reverse flush the system by sending water and air through the water jackets and coolant passages. Following the flushing, replace the thermostat and hoses so the system can be refilled.

When reverse flushing equipment is not available, you can still reverse flush the system with a garden hose. This is often effective following the use of a chemical cleaner.

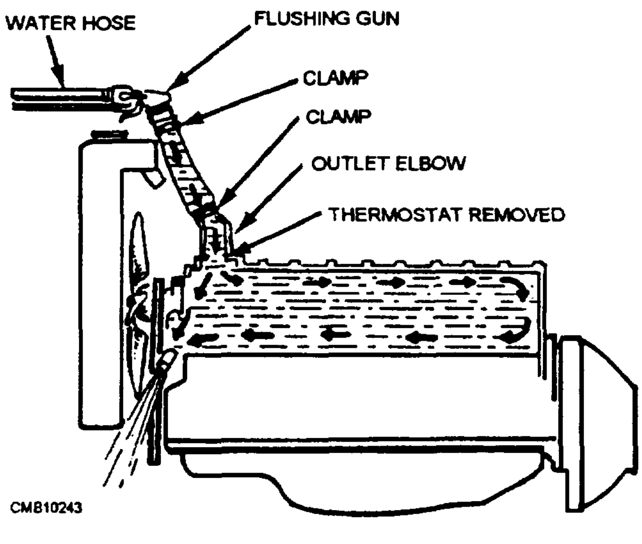


Figure 6-15.—Reverse flushing of water jackets.

Chemical flushing is needed when a scale buildup in the system is causing engine overheating. Add the chemical cleaner to the coolant. Run the engine at fast idle for about 20 minutes. Wait for the engine to cool. Then drain out the coolant and cleaner solution. Using a garden hose, flush out the loosened rust and scale. Continue to flush until the water runs clear.

> **CAUTION**
>
> Always follow manufacturer's instructions when using a cooling system cleaning agent. Wear protective gloves and goggles when handling cleaning agents. Chemicals may cause eye and skin burns.

Antifreeze Service

Antifreeze should be checked and changed at regular intervals. After prolonged use, antifreeze will break down and become very corrosive. It can lose its rust preventative properties and the cooling system can fill rapidly with rust.

A visual inspection of the antifreeze will help determine its condition. Rub your lingers inside the radiator filler neck. Check for rust, oil (internal engine leak), scale, or transmission fluid (leaking oil cooler).

Also check to find out how long the antifreeze has been in service. If contaminated or too old, replace the antifreeze. If badly rusted, you may need to flush the system. Antifreeze should be changed when contaminated or when 2 years old. Check the service manual for exact change schedules.

Antifreeze strength is a measurement of the concentration of antifreeze compared to water. It determines the freeze-up protection of the solution. There are two devices used to check antifreeze strength—the antifreeze hydrometer and the refractometer.

- The antifreeze hydrometer is used to measure the freezing point of the cooling system. A squeeze and release bulb draws coolant into the tester, and a needle floats to show the freeze protection point.
- With the refractometer, you draw coolant into the tester. Then place a few drops of coolant on the measuring window (surface). Aim the tester at a light and view through the tester sight. The scale in the refractometer indicates the freeze protection point.

Minimum antifreeze strength should be several degrees lower than the lowest possible temperature for the climate of the area. For example, if the lowest normal temperature for the area is 10°F, the antifreeze should test to -20°F. A 50/50 mixture of antifreeze and water is commonly used to provide protection for most weather conditions.

> **NOTE**
>
> Vehicles, using an aluminum cooling system and engine parts, can be corroded by some types of antifreeze. Use only antifreeze designed for aluminum components. Check the vehicles service manual or antifreeze label for details.

COOLING SYSTEM TESTS

It is often necessary to check the cooling system for cooling system problems. Cooling system problems can be grouped into three general categories:

1. COOLANT LEAKS—crack or rupture, allowing pressure cap action to push coolant out of the system.
2. OVERHEATING—engine operating temperature too high, warning light on, temperature gauge shows hot, or coolant and steam is blowing out the overflow.
3. OVERCOOLING—engine fails to reach full operating temperature, engine performance poor or sluggish.

To diagnose and repair cooling system problems, perform several tests. These tests include the following—cooling system pressure test, combustion leak test, thermostat test, engine fan test, and fan belt test.

Cooling System Pressure Test

A cooling system pressure test is used to locate leaks quickly. Low air pressure is forced into the system, causing coolant to pour or drip from any leak in the system.

A pressure tester is a hand-operated air pump used to pressurize the system for leak detection. Install the pressure tester on the radiator filler neck. Then pump the tester until the pressure gauge reads radiator cap pressure.

CAUTION

Do not pump to much pressure into the cooling system or part damage may result.

With pressure in the system, inspect all parts for coolant leakage. Check at all fittings, at gaskets, under the water pump, around the radiator, and at engine freeze (core) plugs. Once the leak is located, tighten, repair, or replace parts as needed

A pressure test can also be applied to the radiator cap. The radiator pressure test measures cap-opening pressure and checks condition of the sealing washer. The cap is installed on the cooling system pressure tester.

Pump the tester to pressurize the cap. Watch the pressure gauge. The cap should release pressure at its rated pressure (pressure stamped on cap). It should also hold that pressure for a least 1 minute. If not, install a new cap.

Combustion Leak Test

A combustion leak test is designed to check for the presence of combustion gases in the engine coolant. It should be performed when signs (overheating, bubbles in the coolant, rise in coolant level upon starting) point to a blown head gasket, cracked block, or cracked cylinder head.

A block tester, often called a combustion leak tester, is placed in the radiator filler neck. The engine is started and the test bulb is squeezed and then released. This will pull air from the radiator through the test fluid.

The fluid in the block tester is normally blue. The chemicals in the exhaust gases cause a reaction in the test fluid, changing its color. A combustion leak will turn the fluid yellow. If the fluid remains blue, there is no combustion leak.

Combustion leakage into the cooling system is very damaging. Exhaust gases mix with the coolant and form corrosive acids. The acids can cause holes in the radiator and corrode other components.

An exhaust gas analyzer will also detect combustion pressure leakage into the coolant. By placing the analyzer probe over the filler neck and accelerating the engine, the probe will pick up any hydrocarbons (HC) leaking from the system, which indicates combustion leakage.

Thermostat Test

To check thermostat action, watch the coolant through the radiator neck. When the engine is cold, coolant should not flow through the radiator. When the engine warms, the thermostat should open. Coolant should begin to circulate through the radiator. If this action does not occur, the thermostat may be defective.

There are several ways to test a thermostat. The most common is to suspend the thermostat in a container of water together with a high-temperature thermometer (fig. 6-16). Then by heating the container on a stove or hot plate, the temperature at which the thermostat begins to open, as well as when full open, can be determined. If the thermostat fails to respond at specified temperatures, it should be discarded. Specifications vary on different thermostats. For example, a thermostat with an opening temperature of 180°F to 185°F, full-open temperature is 200°F to 202°F. If the test is satisfactory, the thermostat can be reinstalled.

A digital thermometer can also be used to check the operating temperature of an engine and thermostat. Simply touch the tester probe on the engine next to the thermostat housing and note its reading. If the thermostat does not open at the correct temperature, it is defective and should be replaced.

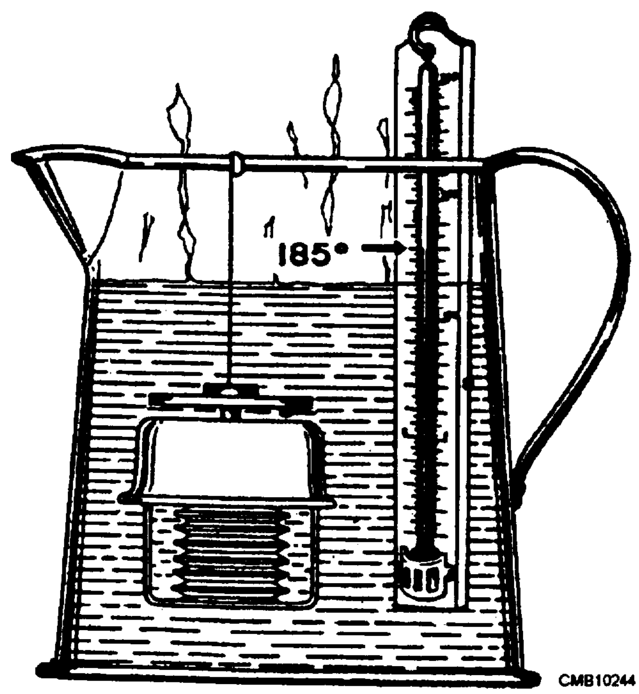


Figure 6-16.—Testing a thermostat.

The use of a temperature stick is another way to test a thermostat quickly. The temperature stick is a pencil-like device that contains a wax material containing certain chemicals that melt at a given temperature. Using two sticks (one for opening temperature and the other for full-open temperature), rub the sticks on the thermostat housing. As the coolant warms to operating temperature, the wax-like marks will melt. If the marks do not melt, the thermostat is defective and needs to be replaced.

Engine Fan Test

A faulty engine fan can cause overheating, overcooling, vibration, and water pump wear, or damage. Testing the fan ensures that it is operating properly.

To test a thermostatic fan clutch, start the engine. The fan should slip when cold; as the engine warms up, the clutch should engage. Air should begin to flow through the radiator and over the engine. You will be able to hear and feel the air when the fan clutch locks up.

If the fan clutch is locked all the time (cold or hot), it is defective and must be replaced. Excessive play or oil leakage also indicates fan clutch failure.

When testing an electric cooling fan, observe whether the fan turns ON when the engine is warm. Make sure the fan motor is spinning at normal speed and forcing enough air through the radiator.

If the fan does not function, check the fuse, electrical connections, and supply voltage to the motor. If the fan motor fails to operate with voltage applied, replace it.

If the engine is warm and no voltage is supplied to the fan motor, check the action of the fan switch. Use either a voltmeter or test light. The switch should have almost zero resistance (pass current and voltage) when the engine is warm. Resistance should be infinite (stop current and voltage) when the engine is cold.

If these tests do not locate the trouble with the electric cooling fan, refer to the manufacturer's service manual for instructions. There may be a defective relay, connection, or other problem.

SERVICE AND REPAIR OF COOLING SYSTEM COMPONENTS

The individual components of the cooling system which require servicing and repair include the water pump, thermostat, hoses, fan and fan belt, and the radiator and pressure cap. Proper service of the components ensures an efficient cooling system and extends the life of the vehicle.

Water Pump

A bad water pump may leak coolant, fail to circulate coolant, or it may produce a grinding sound. Rust in the cooling system or lack of antifreeze is the most common causes for pump failure. These conditions can accelerate seal, shaft, and bearing wear. An over-tightened fan belt will also cause water pump failure.

To check for a worn water pump seal, pressure test the system and watch for coolant leakage. Coolant will leak out of the small drain hole at the bottom of the pump or at the end of the pump shaft.

Worn water pump bearings are checked by wiggling the fan or pump pulley up and down. If the pump shaft is loose in its housing, the pump bearings are badly worn. A stethoscope can also be used to listen for worn, noisy water pump bearings.

Water pump action can be checked with a warm engine. Squeeze the top radiator hose while someone starts the engine. You should feel a pressure surge (hose swelling) if the pump is working. If not, pump shaft or impeller problems are indicated. You can also watch for coolant circulation in the radiator with the engine at operating temperature.

Whether a defective pump is replaced or rebuilt depends on parts supply and cost. A water pump rebuild involves disassembly, cleaning, part inspection, worn part replacement, and reassembly. Few mechanics rebuild water pumps because rebuilding takes too much time and is not cost effective.

The removal and installation of the water pump varies with different vehicles. Therefore, the applicable shop manual must be consulted for the step-by-step procedures.

When you replace a pump, install a new gasket. Make sure the mating surfaces are clean and smooth. The application of a gasket sealer to both sides of the gasket is recommended. Then after refilling the cooling system, the pump should be checked for leaks, noise, and proper operation.

Thermostat

There are no repairs or adjustments to be made on the thermostat. The unit must be replaced when it fails to operate properly. A stuck thermostat can either cause engine overheating or overcooling.

If a thermostat is stuck closed, coolant will not circulate through the radiator. As a result, overheating could make the coolant boil.

When a thermostat is stuck open, too much coolant may circulate through the radiator and the engine may not reach proper operating temperature. The engine may run poorly for extended periods in cold weather. Engine efficiency (power, fuel mileage, and driveability) will be reduced.

The procedure for thermostat replacement is as follows:

- To remove the thermostat, drain the coolant and remove the upper radiator hose from the engine.
- Remove the retaining cap screws holding the thermostat housing to the engine. Tap the housing free with a rubber hammer. Lift off the housing and thermostat.
- Scrape all of the old gasket material off the thermostat housing and sealing surface of the engine.
- Make sure that the housing is not warped. Place it on a flat surface and check the gaps between the housing and the surface. If warped, file the surface flat. This action will prevent coolant leakage.
- Make sure the temperature rating is correct. Then place the thermostat into the engine. Normally, the pointed end on the thermostat should face the radiator hose. The pellet chamber should face the inside of the engine.
- Position the new gasket with approved sealer. Start the cap screws by hand. Then torque them to the manufacturer's specifications in an alternating pattern DO NOT overtighten the housing bolts or warpage and or breakage may result. Most housings are made of soft aluminum or "pot metal."

Hoses

Old radiator hoses and heater hoses are frequent causes of cooling system problems. Hoses should be checked periodically for leakage and general condition. The leakage may often be corrected by tightening or replacing hose clamps. After a few years of use, hoses deteriorate. They may become soft and mushy, or hard and brittle. Deteriorated hoses should be replaced to preclude future troubles. Cooling system pressure can rupture the hoses and result in coolant loss.

Inspect the radiator and heater hoses for cracks, bulges, cuts, or any other sign of deterioration. Squeeze the hoses to check whether they are hardened or softened and faulty. Flex or bend heater hoses and watch for signs of surface cracks. If any problem is detected, the affected hose should be replaced. However, where spiral spring stiffeners are used to control the tendency to collapse, such test will not work and the hose must be removed for inspection.

Fan and Belt

One of the easiest and quickest checks to the cooling system is the fan and fan belt. Check the fan for bent blades, cracks, and other problems. A bent or distorted fan on one with a loose blade should be replaced. Where the fan is just loose on its mounting, tightening is in order.

Fan belts, or drive belts, should be checked for wear and tension. Most wear occurs on the underside of the belt. To check a V-belt, twist the belt with your fingers. Check for small cracks, grease, glazing, and tears or splits. Small cracks will enlarge as the belt is flexed. Grease rots the rubber and makes the side slick so that the belt slips easily. A high-pitched squeal results from slippage. Large tears or splits in a belt allow it to be tossed from the pulley. On vehicles with a set of two belts, replace both if one is worn and requires replacement.

Use a belt tension gauge to check and adjust the fan belt tension. When you do not have a gauge or if space does not allow use of a gauge, you can make a quick check of belt tension. Press down on the free span of the belt, a point midway between the alternator or generator pulley and the fan pulley. Measure the amount of deflection. When free span is less than 12 inches between pulleys, belt deflection should be 1/8 to 1/4 inch. When free span is longer than 12 inches, belt deflection should be 1/4 to 1/2 inch.

A slipping belt can cause overheating and a run-down battery. These troubles result because a slipping belt cannot drive the water pump and alternator fast enough for normal operation. Sometimes a belt will slip and make noise even after it is adjusted to the proper tension. Several types of belt dressing are available which can be applied to both sides of the belt to prevent this problem. Belt dressing helps to eliminate noise and increase belt friction.

The fan belt should be checked every time a vehicle comes in for preventive maintenance (PM) to make sure it is in good condition. A fan belt that has become frayed, or has separated plies, should be replaced.

Replacement of a defective belt is usually made by loosening the alternator or generator mounting bolts. With the mounting bolts loose, push the alternator or generator closer to the engine. This action provides enough slack in the belt so it can be removed and a new one installed. After installing a new belt, adjust it to the proper tension and tighten the mounting bolts.

Radiator and Pressure Cap

When overheating problems occur and the system is not leaking, check the radiator and pressure cap. They are common sources of overheating. The pressure cap could have bad seals, allowing pressure loss. The radiator may be clogged and not permitting adequate air flow or coolant flow.

Bent fins should he straightened and the radiator core checked for any obstructions tending to restrict the airflow. Radiator air passages can be cleaned by blowing them out with an air hose in the direction opposite to the ordinary flow of air. Water can also be used to soften obstructions before applying the air blast. In any event, the cleaning gets rid of dirt, bugs, leaves, straw, and other debris which otherwise would clog the radiator and reduce its cooling efficiency. Sometimes screens are used in front of the radiator core to reduce this type of clogging.

The radiator can be checked for internal clogging by removing the hose connections and draining the coolant. Use a garden hose to introduce a stream of water into the top of the radiator. If the flow is sluggish, the radiator is partially clogged. Another way to check for this condition is to feel the radiator with your hand. The radiator should be warm at the bottom and hot at the top, with the temperature uniformly increasing from bottom to top. Any clogged sections will feel cool.

CAUTION

Be sure the engine is not running when making this test to avoid injury from the fan.

When the use of cleaning compounds and reverse flushing fails to relieve a clogged core, the radiator must be removed for mechanical cleaning. This requires the removal of upper and lower radiator tanks and rodding out the accumulated rust and scale from the water passages of the core.

The radiator pressure cap should also be checked for condition and proper operation. If it is dirty, the cap can be cleaned with soap and water, then rinsed. The seating surface of the vacuum and pressure valves should be smooth and undamaged The valves should operate freely when pressed against their spring pressure and should seal properly when closed.

During the vehicles preventive maintenance (PM) inspection, the radiator should be checked for leaks, particularly where the tanks are soldered to the core, since vibration and pulsation from pressure can cause fatigue of soldered joints or seams. Neglect of small leaks may result in complete radiator failure, excessive leakage, rust clogging, and overheating. Thus it is extremely important to keep the radiator mounting properly adjusted and tight at all times and to detect and correct even the smallest leaks.

A leak usually reveals its presence by scale marks or watermarks below the leak on the outside of the core. Permanent antifreeze does not leak through spaces where water cannot pass. The antifreeze leak is more noticeable, since it does not evaporate as quickly as water.

Stop-leak compounds can be effective to stop small leaks at least temporarily. Stop-leak compounds harden upon contact with the air, thus sealing off any small openings. The main problem is that they give the mechanic a sense of false security. For example, stop leak may prevent seepage at a hose connection through the inner lining, but finally the hose will rot and burst, losing coolant and overheating the engine.

Stop-leak compounds can lead to radiator clogging if water tubes already contain deposits that act as a strainer. If coolant level gets too low, some stop-leak ingredients may harden in the upper radiator and block it.

NOTE

Before using stop leak, check your service manual. The compound must be compatible with the antifreeze and the inhibitors and must be installed correctly and in the right quantity.

When large leaks or considerable damage is present, removal of the radiator for extensive repair or replacement is usually required.

Q1. *What type of cooling system is the simplest?*

Q2. *In a liquid-cooled system, what component acts as a heat exchanger?*

Q3. What are the two types of radiators?

Q4. Where is the vacuum valve located in the radiator cap?

Q5. What type of fan clutch uses a bimetal spring to control fan action?

Q6. What component of a liquid-cooled system senses engine temperature and controls coolant flow through the radiator?

Q7. When replacing antifreeze, what is the ideal mixture you recommend?

Q8. What are the three methods of flushing a liquid-cooled system?

Q9. What two devices am used to check antifreeze strength?

Q10. What device is used to perform a cooling system pressure test?

ENGINE LUBRICATING SYSTEMS

LEARNING OBJECTIVE: *Identify types of lubricating (oil) systems. Point out their operational characteristics and maintenance requirements.*

All internal combustion engines are equipped with an internal lubricating system (fig. 6-17). Without

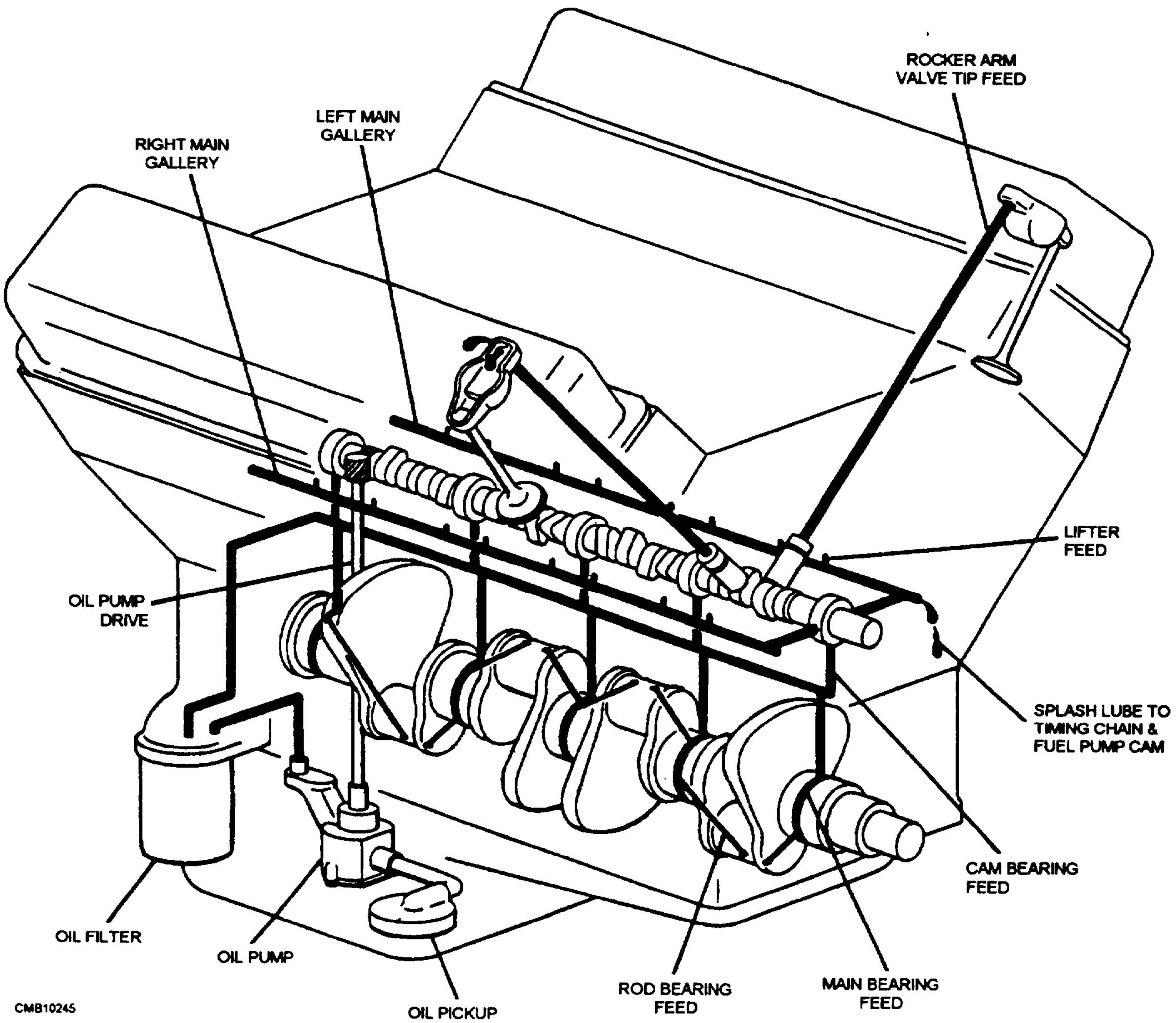


Figure 6-17.—Typical engine lubrication system.

lubrication, an engine quickly overheats and its working parts seize due to excessive friction. All moving parts must be adequately lubricated to assure maximum wear and long engine life.

PURPOSES OF LUBRICATION

The functions of an engine lubrication system are as follows:

- Reduces friction and wear between moving parts (fig. 6-18).
- Helps transfer heat and cool engine parts.
- Cleans the inside of the engine by removing contaminants (metal, dirt, plastic, rubber, and other particles) (fig. 6-19).
- Absorbs shocks between moving parts to quiet engine operation and increase engine life.

The properties of engine oil and the design of modern engines allow the lubrication system to accomplish these functions.

ENGINE OIL

Engine oil, also called motor oil, is used to produce a lubricating film on the moving parts in an engine. The military specification for this type of oil prescribes that the oil shall be a petroleum or synthetic petroleum product or a combination thereof. This oil is intended for lubrication of internal-combustion engines other than aircraft engines or for general-purpose lubrication.

Oil Viscosity and Measurements

Oil viscosity, also called oil weight, is the thickness or fluidity (flow ability) of the oil. A high viscosity oil is very thick and resists flow. A low viscosity oil is very thin and flows easily.

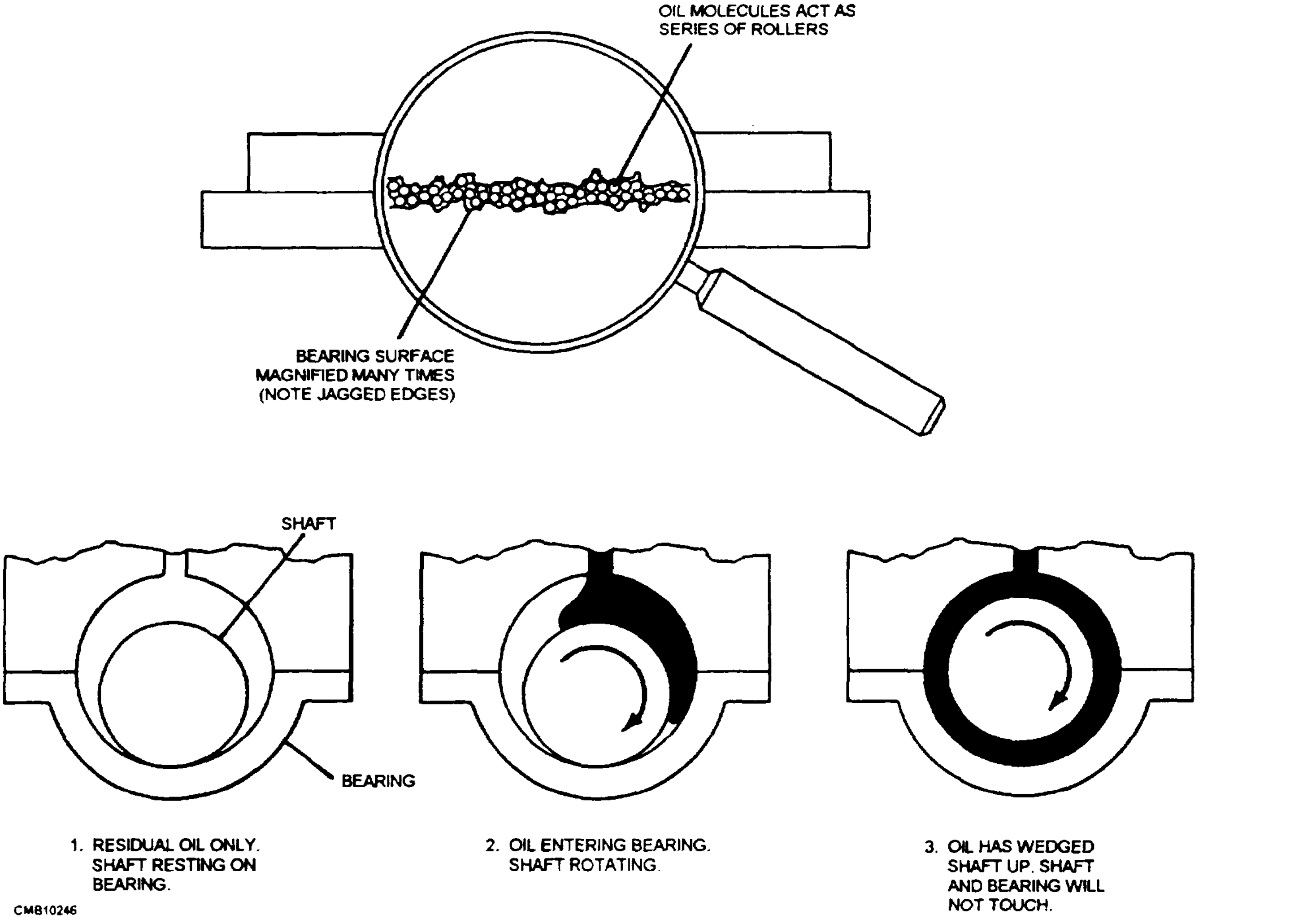


Figure 6-18.—How oil lubricates.

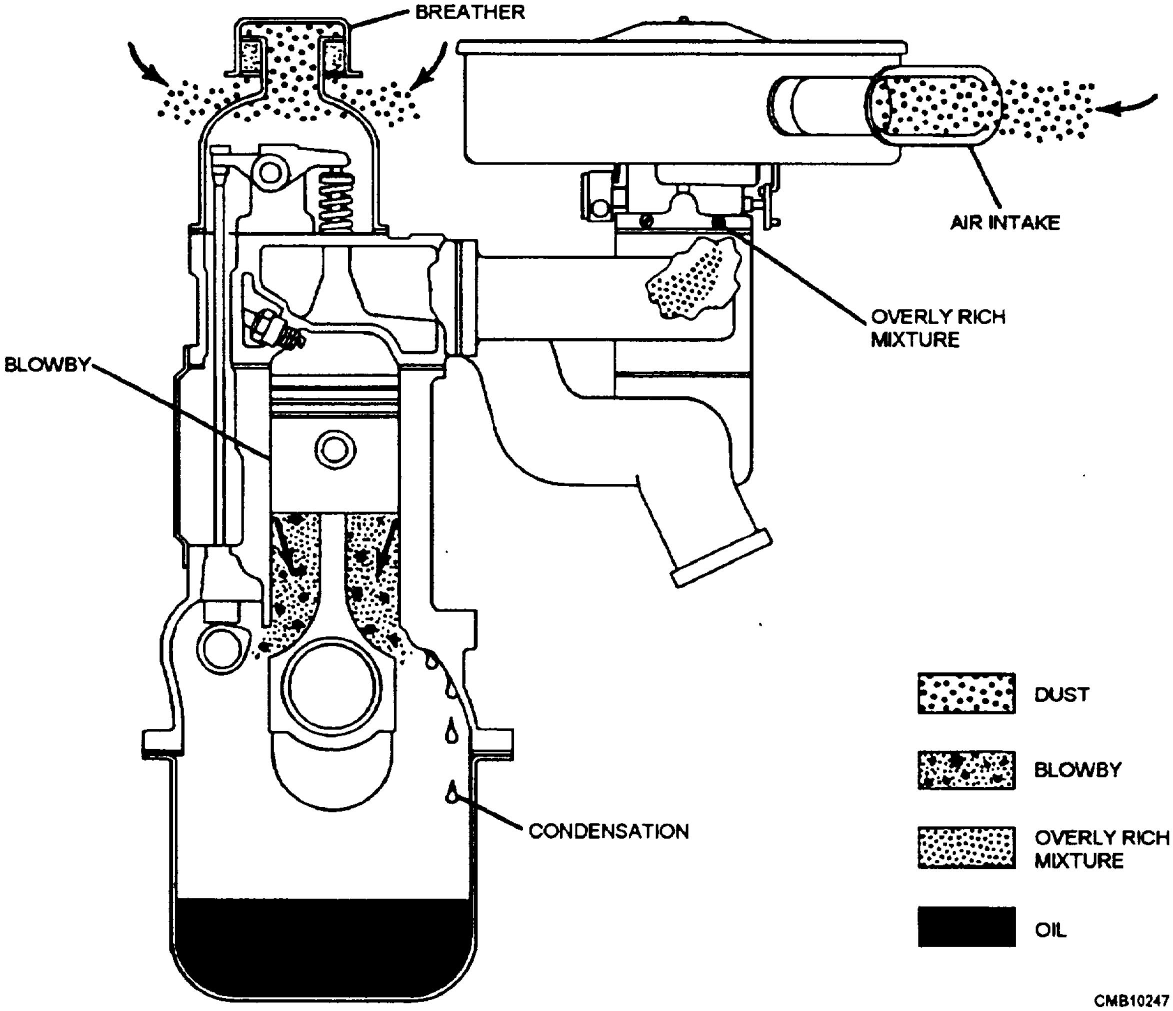


Figure 6-19.—Sources of oil contamination.

Oils are graded according to their viscosity by a series of Society of Automotive Engineers (SAE) numbers. The viscosity of the oil increases progressively with the SAE number. An SAE 4 oil would be very light (low viscosity) and SAE 90 oil would be very heavy (high viscosity). The viscosity of the oil used in internal-combustion engines ranges from SAE 5 (arctic use) to SAE 60 (desert use). It should be noted that the SAE number of the oil has nothing to do with the quality of the oil.

The viscosity number of the oil is determined by heating the oil to a predetermined temperature and allowing it to flow through a precisely sized orifice while measuring the rate of flow. The faster an oil flows, the lower the viscosity. The testing device is called a viscosimeter. The viscosity of the oil is printed on top of the oil can. Oil viscosity is written SAE 10, SAE 20, SAE 30, and so on. The letter W will follow any oil that meets SAE low-temperature requirements. An example would be SAE 10W.

Multi-viscosity oil or multi-weight oil has the operating characteristics of a thin, light oil when cold and a thicker, heavy oil when hot. A multi-weight oil is numbered SAE 10W-30, 10W-40, 20W-50, and so on. For example, a 10W-30 oil will flow easily (like 10W oil) when starting a cold engine. It will then act as a thicker oil (like 30 weight) when the engine warms to operating temperature. This will make the engine start more easily in cold weather. It will also provide adequate film strength (thickness) when the engine is at full operating temperature.

Normally, you should use the oil viscosity recommended by the manufacturer, However, in a very cold, high mileage, worn engine, higher viscosity may be beneficial. Thicker oil will tend to seal the rings and provide better bearing protection. It may also help cut engine oil consumption and smoking.

Oil Service Rating

The oil service rating is a set of letters printed on the oil can to denote how well the oil will perform under operating conditions. The American Petroleum Institute (API) sets this performance standard.

The API system for rating oil classifies oil according to its performance characteristics. The higher rated oils contain additives that provide maximum protection against rust, wear, oil oxidation, and thickening at high temperatures. The oil service ratings are as follows:

1. SA—adequate for utility engines subjected to light loads, moderate speeds, and clean conditions. Contains no additives.
2. SB—adequate for automotive use under favorable conditions (light loads, low speeds, and moderate temperatures) with relatively short oil change intervals. Generally offers only minimal protection to the engine against bearing scuffing, corrosion, and oil oxidation.
3. SC—meets oil warranty requirements for 1964 through 1967 automotive gasoline engines.
4. SD—meets oil warranty requirements for 1968 through 1970 automotive gasoline engines. Offers additional protection over SC oils that are necessary with the introduction of emission controls.
5. SE—meets oil warranty requirements for 1972 through 1979 automotive gasoline engines. Stricter emission requirements created the need for this detergent oil.
6. SF—meets oil warranty requirements for 1980 through 1988 automotive gasoline engines. The SF oil is designed to meet the demands of small, high-revving engines. A SF oil can be used in all automotive vehicles requiring detergent oil.
7. SG—meets oil warranty requirements for 1989 through present automotive gasoline engines. Contains more additives than SF oils. Can be used as CC or diesel type oils. It is a detergent oil.
8. CA—meets all requirements for naturally aspirated diesel engines operated on low sulfur fuel.
9. CB—meets all requirements for naturally aspirated diesel engines operated on high sulfur fuel.
10. CC—meets all requirements for lightly supercharged diesel engines.
11. CD—meets all requirements for moderately supercharged diesel engines.

The operator's manual provides the service rating recommended for a specific vehicle. You can use a better service rating than recommended, but NEVER a lower service rating. A high service rating (SG, for example) can withstand higher temperatures and loads while still maintaining a lubricating film. It will have more oil additives to prevent oil oxidation, engine deposits, breakdown, foaming, and other problems.

LUBRICATING (OIL) SYSTEM COMPONENTS

It must be remembered that the lubricating system is actually an integral part of the engine and the operation of one depends upon the operation of the other. Thus the lubricating system, in actual practice, cannot be considered as a separate and independent system; it is part of the engine. The lubricating system basically consists of the following:

- Oil Pan—reservoir or storage area for engine oil.
- Oil Level Gauge—checks the amount of oil in the oil pan.
- Oil Pump—forces oil throughout the system.
- Oil Pickup and Strainers—carries oil to the pump and removes large particles.
- Oil Filters—strains out impurities in the oil.
- Oil Galleries—oil passages through the engine.
- Oil Pressure Indicator—warns the operator of low oil pressure.
- Oil Pressure Gauge—registers actual oil pressure in the engine.
- Oil Temperature Regulator—controls engine oil temperature on diesel engines.

Oil Pan

The oil pan, normally made of thin sheet metal or aluminum, bolts to the bottom of the engine block. It

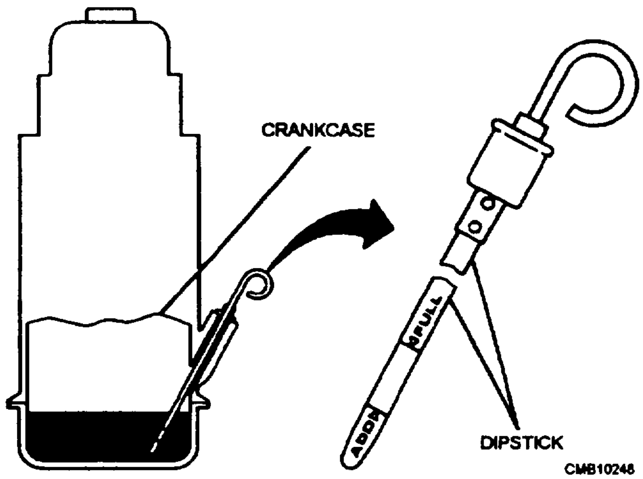


Figure 6-20.—Oil level gauge.

holds a supply of oil for the lubrication system. The oil pan is fitted with a screw-in drain plug for oil changes. Baffles may be used to keep the oil from splashing around in the pan.

The sump is the lowest area in the oil pan where oil collects. As oil drains from the engine, it fills the sump. Then the oil pump can pull oil out of the pan for recirculation.

Oil Level Gauge

The oil level gauge, also known as a dipstick, is usually of the bayonet type (fig. 6-20). It consists of a long rod or blade that extends into the oil pan. It is marked to show the level of oil within the oil pan. Readings are taken by pulling the rod out from its normal place in the crankcase, wiping it clean, replacing it, and again removing and noting the height of the oil on the lower or marked end. This should be done with the engine stopped unless the manufacturer recommends otherwise. It is important that the oil level not drop below the LOW mark or rise above the FULL mark.

Oil Pump

The oil pump is the heart of the lubricating system; it forces oil out of the oil pan, through the oil filter, galleries, and to the engine bearings. Normally, a gear on the engine camshaft drives the oil pump; however, a cogged belt or a direct connection with the end of the camshaft or crankshaft drives the pump in some cases.

There are two basic types of oil pumps—rotary and gear.

The ROTARY pump (fig. 6-21) has an inner rotor with lobes that match similar shaped depressions in the

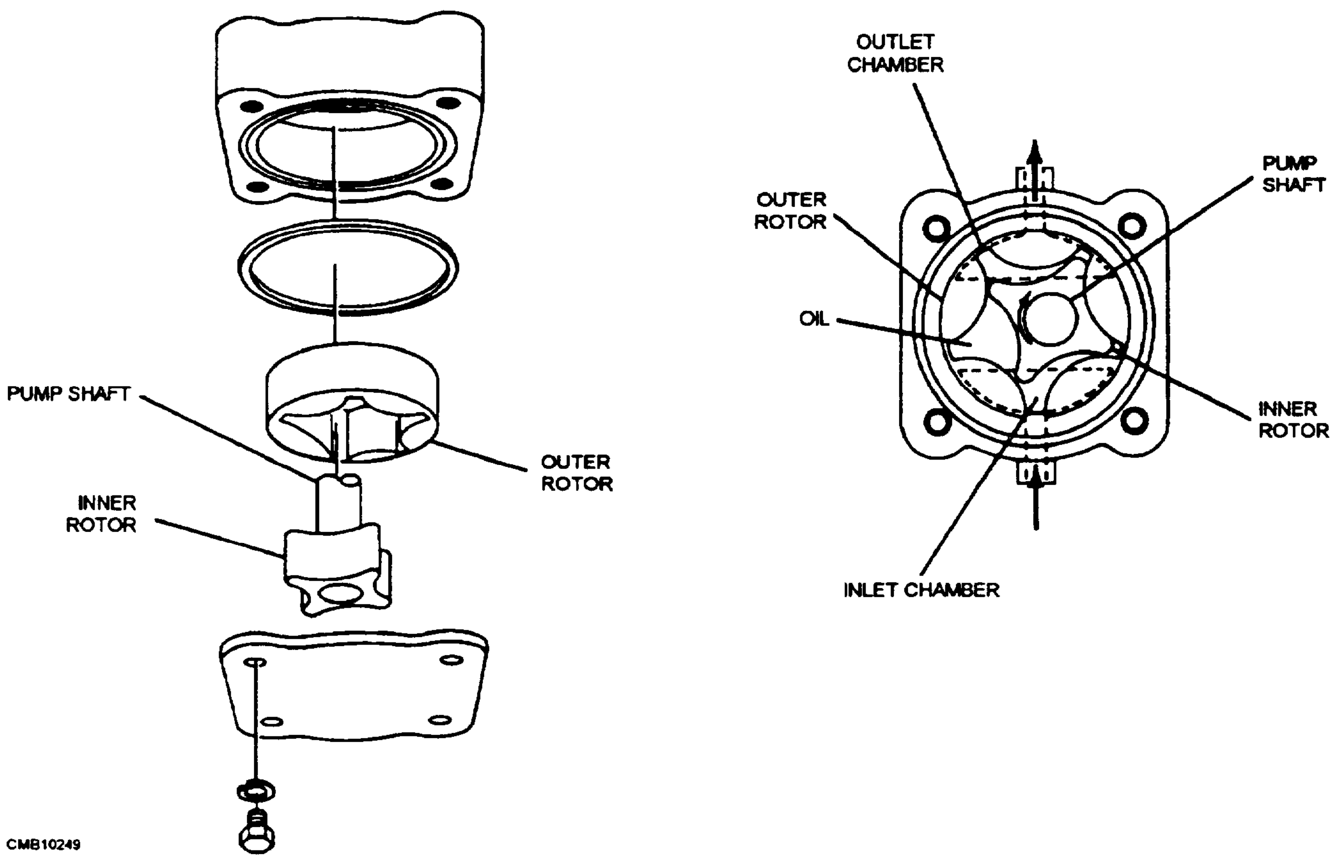


Figure 6-21.—Rotor-type oil pump.

outer rotor. The inner rotor is off center from the outer rotor.

As the oil pump shaft turns, the inner rotor causes the outer rotor to spin. The eccentric action of the two rotors forms pockets that change size. A large pocket is formed on the inlet side of the pump. As the rotors turn, the oil-filled pocket becomes smaller, as it nears the outlet of the pump. This action squeezes the oil and makes it spurt out under pressure. As the pump spins, this action is repeated over and over to produce a relatively smooth flow of oil.

The GEAR pump (fig. 6-22) consists of two pump gears mounted within a close-fitting housing. A shaft, usually turned by the distributor, crankshaft, or accessory shaft, rotates one of the pump gears. The gear turns the other pump gear that is supported on a short shaft inside the pump housing.

Oil on the inlet side of the pump is caught in the gear teeth and carried around the outer wall inside the pump housing. When oil reaches the outlet side of the pump, the gear teeth mesh and seal. Oil caught in each gear tooth is forced into the pocket at the pump outlet and pressure is formed. Oil squirts out of the pump and to the engine bearings.

As a safety factor to assure sufficient oil delivery under extreme operating conditions, the oil pump (gear or rotary) is designed to supply a greater amount of oil than is normally required for adequate lubrication. This requires that an oil pressure relief valve be incorporated in the pump to limit maximum oil pressure.

The pressure relief valve is a spring-loaded bypass valve in the oil pump, engine block, or oil filter housing. The valve consists of a small piston, spring, and cylinder. Under normal pressure conditions, the spring holds the relief valve closed. All the oil from the oil pump flows into the oil galleries and to the bearings.

However, under abnormally high oil pressure conditions (cold, thick oil, for example), the pressure relief valve opens. Oil pressure pushes the small piston back in its cylinder by overcoming spring tension. This allows some oil to bypass the main oil galleries and pour back into the oil pan. Most of the oil still flows to the bearings and a preset pressure is maintained. Some pressure relief valves are adjustable. By turning a bolt or screw or by changing spring shim thickness, the pressure setting can be altered.

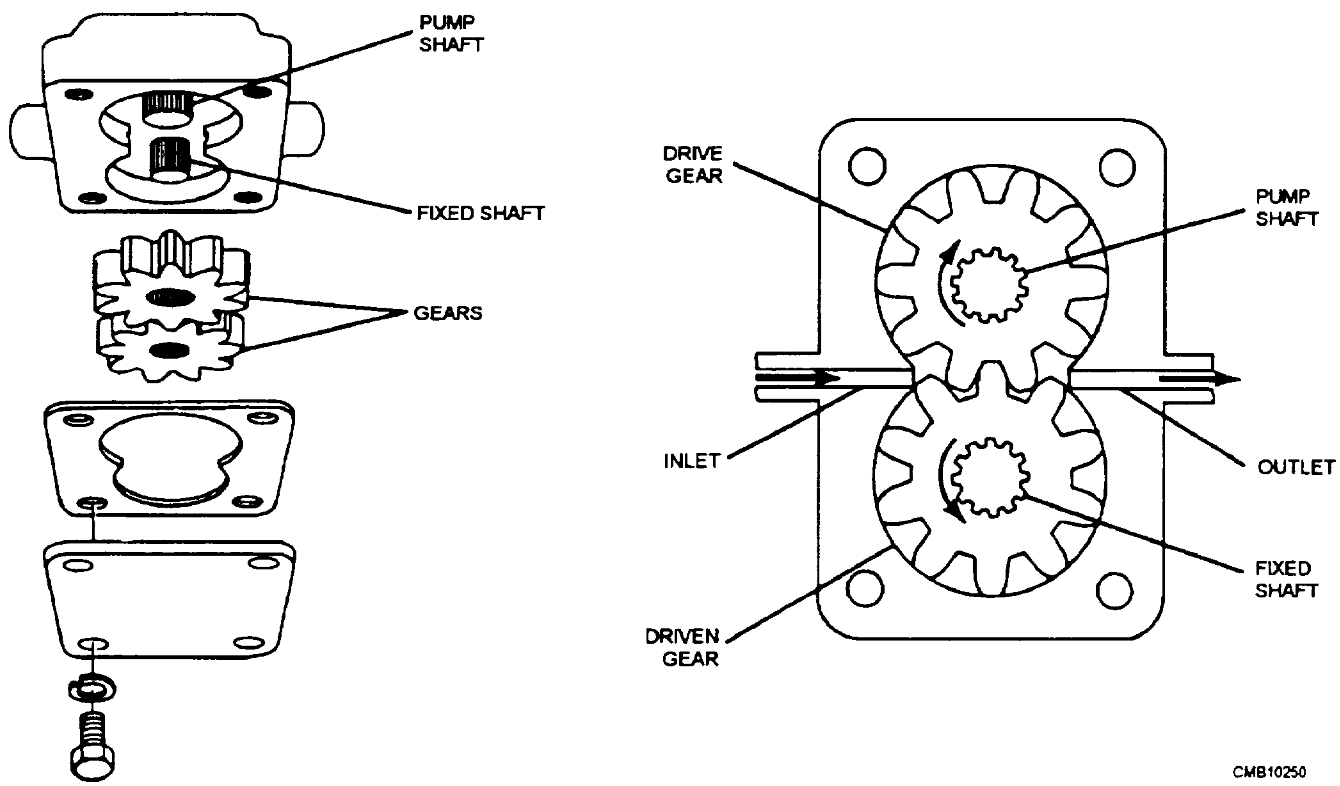


Figure 6-22.—Gear-type oil pump.

Oil Pickup and Strainer

The oil pickup is a tube that extends from the oil pump to the bottom of the oil pan. One end of the pickup tube bolts or screws into the oil pump or to the engine block. The other end holds the strainer.

The strainer has a mesh screen suitable for straining large particles from the oil and yet passes a sufficient quantity of oil to the inlet side of the oil pump. The strainer is located so all oil entering the pump from the oil pan must flow through it. Some assemblies also incorporate a safety valve that opens in the event the strainers become clogged, thus bypassing oil to the pump. Strainer assemblies may be either the floating or the fixed type.

The floating strainer has a sealed air chamber, is hinged to the oil pump inlet, and floats just below the top of the oil. As the oil level changes, the floating intake will rise or fall accordingly. This action allows all oil taken into the pump to come from the surface This design prevents the pump from drawing oil from the bottom of the oil pan where dirt, water, and sludge are likely to collect. The strainer screen is held to the float by a holding clip. The up and down movement of the float is limited by stops.

The fixed strainer (fig. 6-23) is simply an inverted funnel-like device, placed about 1/2 inch to 1 inch from the bottom of the oil pan. This device prevents any sludge or dirt that has accumulated from entering and circulating through the system. The assembly is attached solidly to the oil pump in a fixed position.

Oil Filter

The oil filter removes most of the impurities that have been picked up by the oil, as it circulates through the engine. Designed to be replaced readily, the filter is mounted in an accessible location outside the engine. There are two basic filter element configurations—the cartridge type and spin-on type.

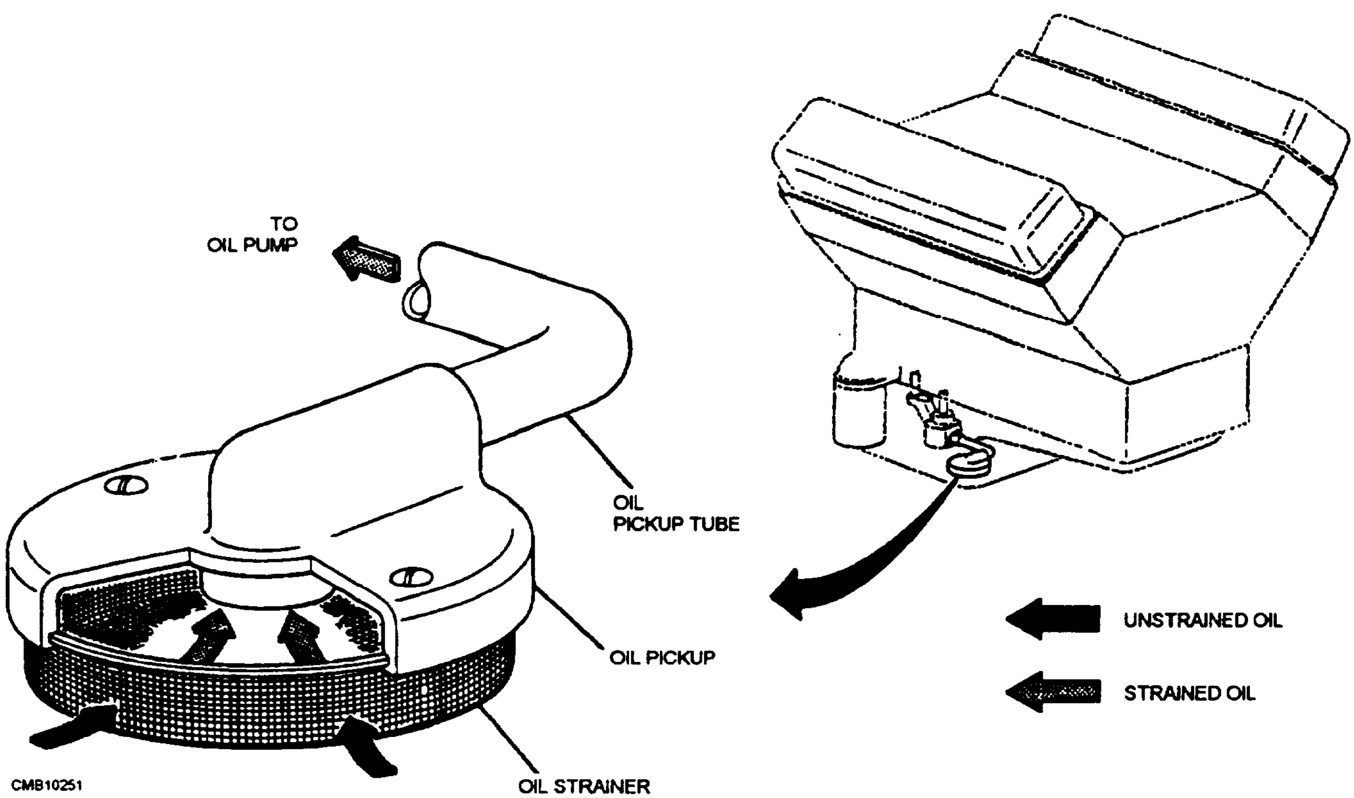


Figure 6-23.—Oil pickup and strainer.

1. The cartridge-type element (fig. 6-24) fits into a permanent metal container. Oil is pumped under pressure into the container where it passes from the outside of the filter element to the center. From here, the oil exits the container. The element is changed easily by removing the cover from the container.
2. The spin-on filter (fig. 6-24) is completely self-contained, consisting of an integral metal container and filter element. Oil is pumped into the container on the outside of the filter element. The oil then passes through the filter medium to the center of the element where it exits the container. This type of filter is screwed onto its base and is removed by spinning it off.

The elements themselves may be either metallic or nonmetallic. Cotton waste or resin-treated paper is the most popular filter mediums. They are held in place by sandwiching them between two perforated metal sheets. Some heavy-duty applications use layers of metal that are thinly spaced apart. Foreign matter is strained out, as the oil passes between the metal layers.

There are two filter configurations. These are the full-flow system and the bypass system. Operations of each system is as follows:

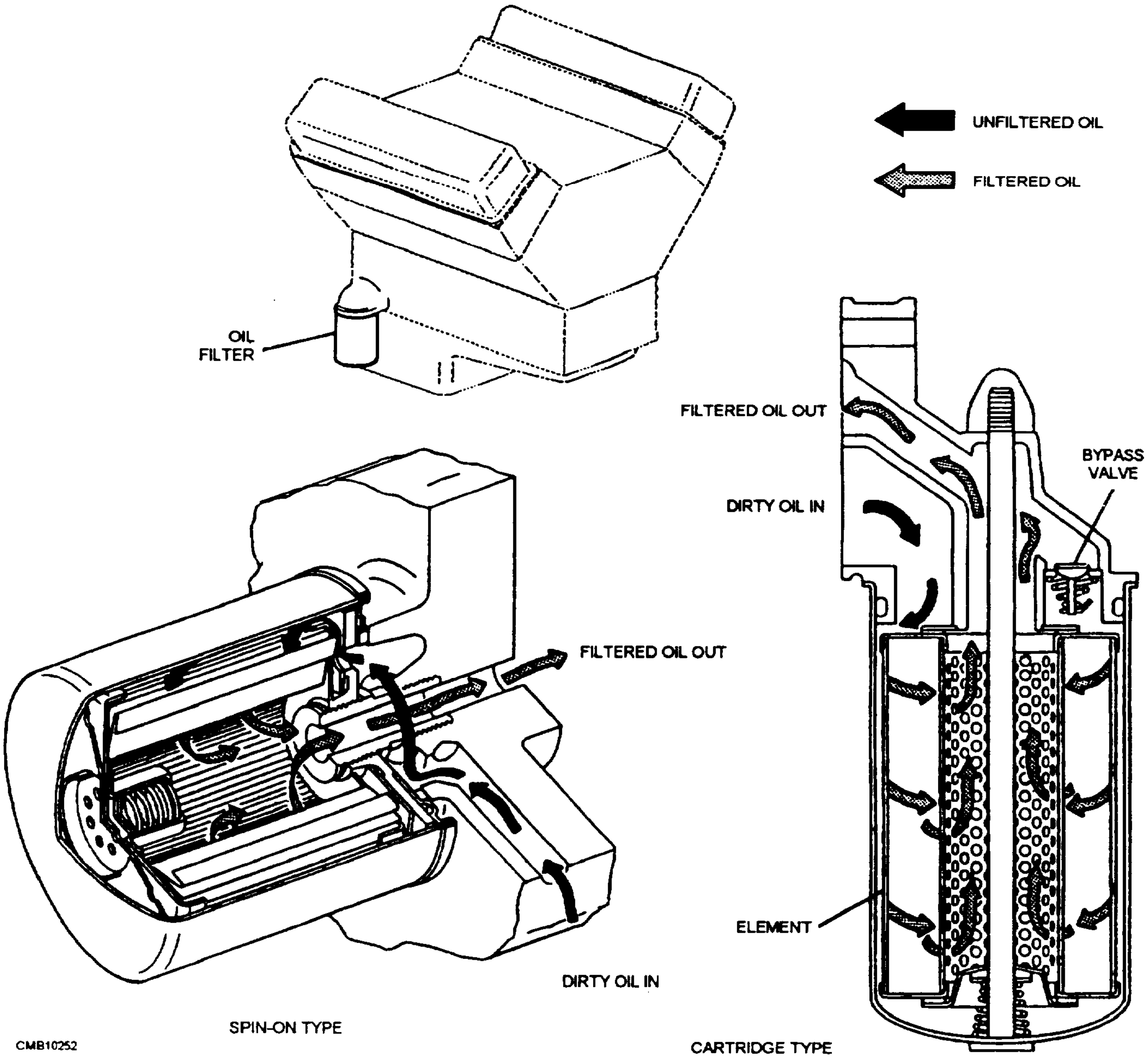


Figure 6-24.—Oil filters.

1. The full-flow system (fig. 6-25) is the most common. All oil in a full-flow system is circulated through the filter before it reaches the engine. When a full-flow system is used, it is necessary to incorporate a bypass valve in the oil filter to allow the oil to circulate through the system without passing through the element in the event that it becomes clogged. This prevents the oil supply from being cut off to the engine.

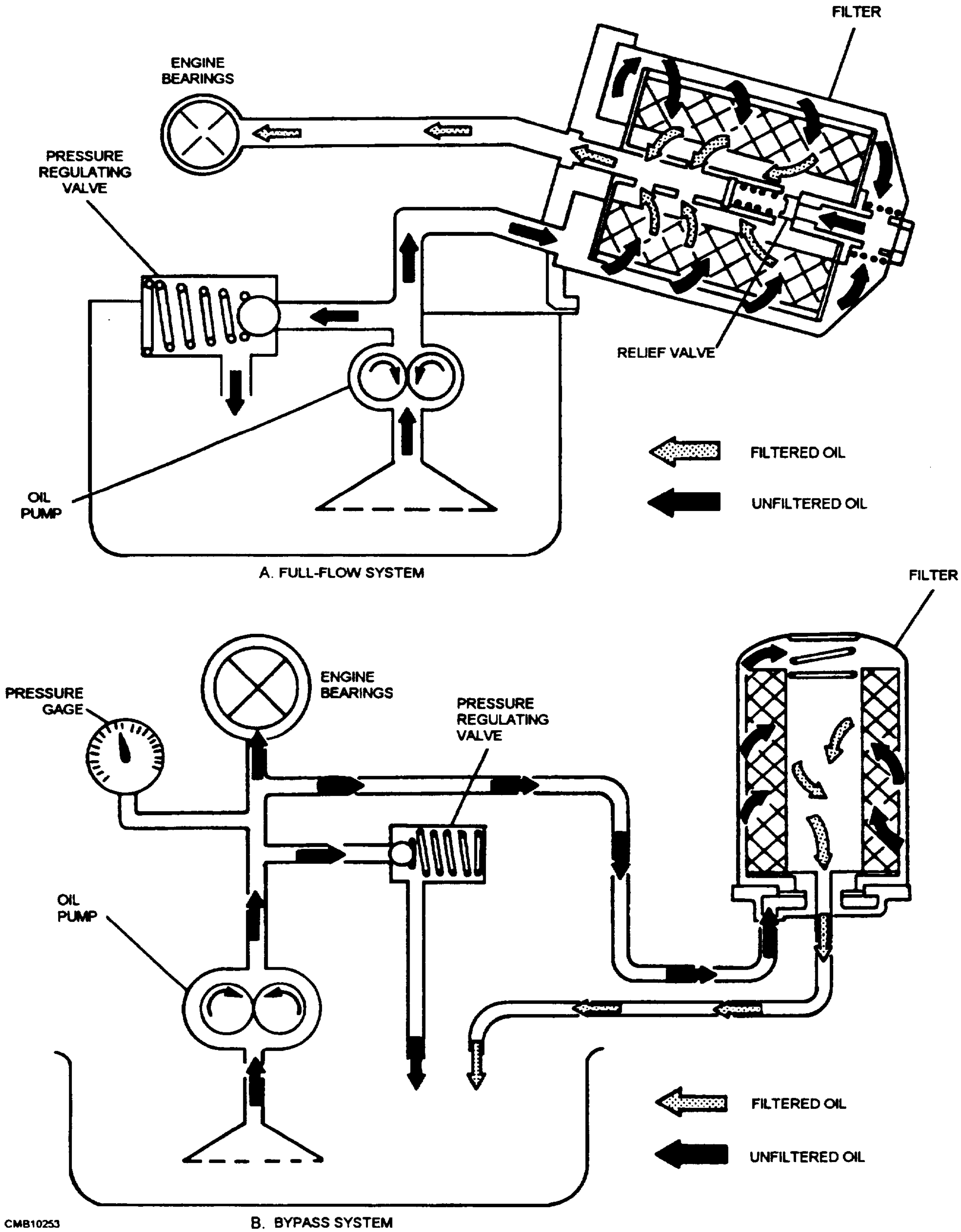


Figure 6-25.—Filter system configurations.

2. The bypass system (fig. 6-25) diverts only a small quantity of oil each time it is circulated and returns it directly to the oil pan after it is filtered. This type of system does not filter the oil before it is sent to the engine. The oil from the main oil gallery enters the filter and flows through the filter element. It then passes into the collector in the center of the filter. The filtered oil then flows out a restricted outlet preventing the loss of pressure. The oil then returns directly to the oil pan.

Oil Galleries

Oil galleries are small passages through the cylinder block and head for lubricating oil. They are cast or machined passages that allow oil to flow to the engine bearing and other moving parts.

The main oil galleries are large passages through the center of the block They feed oil to the crankshaft bearings, camshaft bearings, and lifters. The main oil galleries also feed oil to smaller passages running up to the cylinder heads.

Oil Pressure Warning Light

The oil pressure warning light (fig. 6-26) is used in place of a gauge on many vehicles. The warning light, although not as accurate, is valuable because of its high visibility in the event of a low oil pressure condition. Because the engine can fail or be damaged in less than a minute of operation without oil pressure, the warning light is used as a backup for a gauge to attract instant attention to a malfunction.

The warning light receives battery power through the ignition switch. The circuit to ground is completed through the oil pressure-sending unit that screws into the engine and is exposed to one of the oil galleries. The sending unit consists of a pressure-sensitive diaphragm that operates a set of contact points. The contact points are calibrated to turn on the warning light anytime oil pressure drops below approximately 15 psi in most vehicles.

When oil pressure is low, the spring in the sending unit holds a pair of contacts closed. This action completes the circuit and the indicator light glows. When oil pressure is normal, oil pressure acts on a diaphragm in the sending unit. Diaphragm deflection opens the contact points to break the circuit. This action causes the warning light to go out, informing the operator of good pressure.

Oil Pressure Gauge

The oil pressure gauge is mounted on the instrument panel of a vehicle. Marked off on a dial in pounds per square inch (psi), the gauge indicates how regularly and evenly the oil is being delivered to all vital parts of the engine and warns of any stoppages in this delivery. Pressure gauges may be electrical or mechanical.

In the mechanical type, the gauge on the instrument panel is connected to an oil line tapped into an oil gallery leading from the pump. The pressure of the oil in the system acts on a diaphragm within the gauge, causing the needle to register on the dial.

In the electrical type, oil pressure operates a rheostat connected to the engine that signals electrically

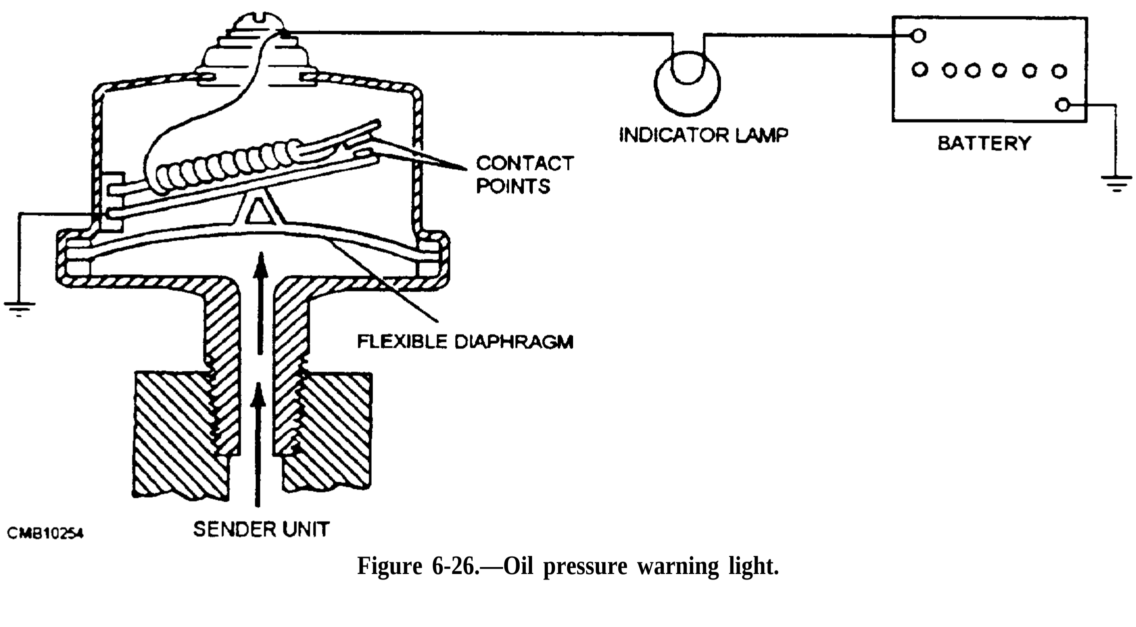


Figure 6-26.—Oil pressure warning light.

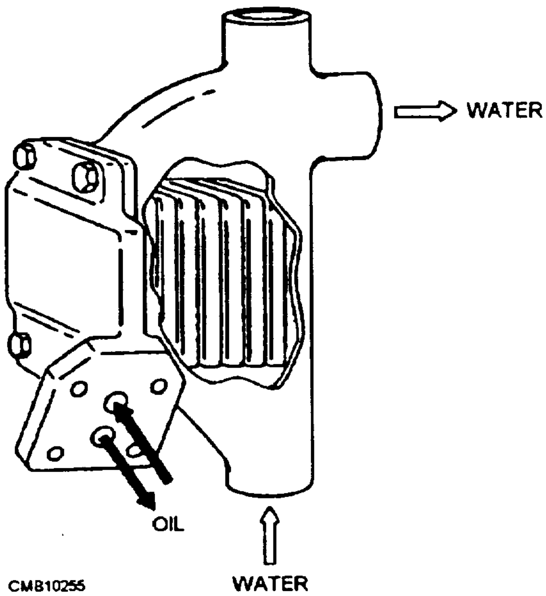


Figure 6-27.—Oil temperature regulator.

to the pressure gauge indicating oil pressure within the system.

Oil Temperature Regulator

The oil temperature regulator (fig. 6-27) must be used in diesel engine lubricating systems, prevents oil temperature from rising too high in hot weather, and assists in raising the temperature during cold starts in winter weather. It provides a more positive means of controlling oil temperature than does cooling by radiation of heat from the oil pan wells.

The regulator uses engine coolant in the cooling system to regulate the temperature of the oil and is made up of a core and housing. The core, through which the oil circulates, is of cellular or bellows construction and is built to expose as much oil as possible to the coolant that circulates through the housing. The regulator is attached to the engine so that the oil will flow through the regulator after passing through the pump. As the oil passes through the regulator, it is either cooled or heated, depending on the temperature of the coolant and then is circulated through the engine.

Some military vehicles use an oil cooler (fig. 6-28) that consists of a radiator through which air is circulated by movement of the vehicle or by a cooling fan. Oil from the engine is circulated through this radiator and back to the sump or supply tank. The radiator acts to cool the oil only in this system. It will not heat oil in a cold engine.

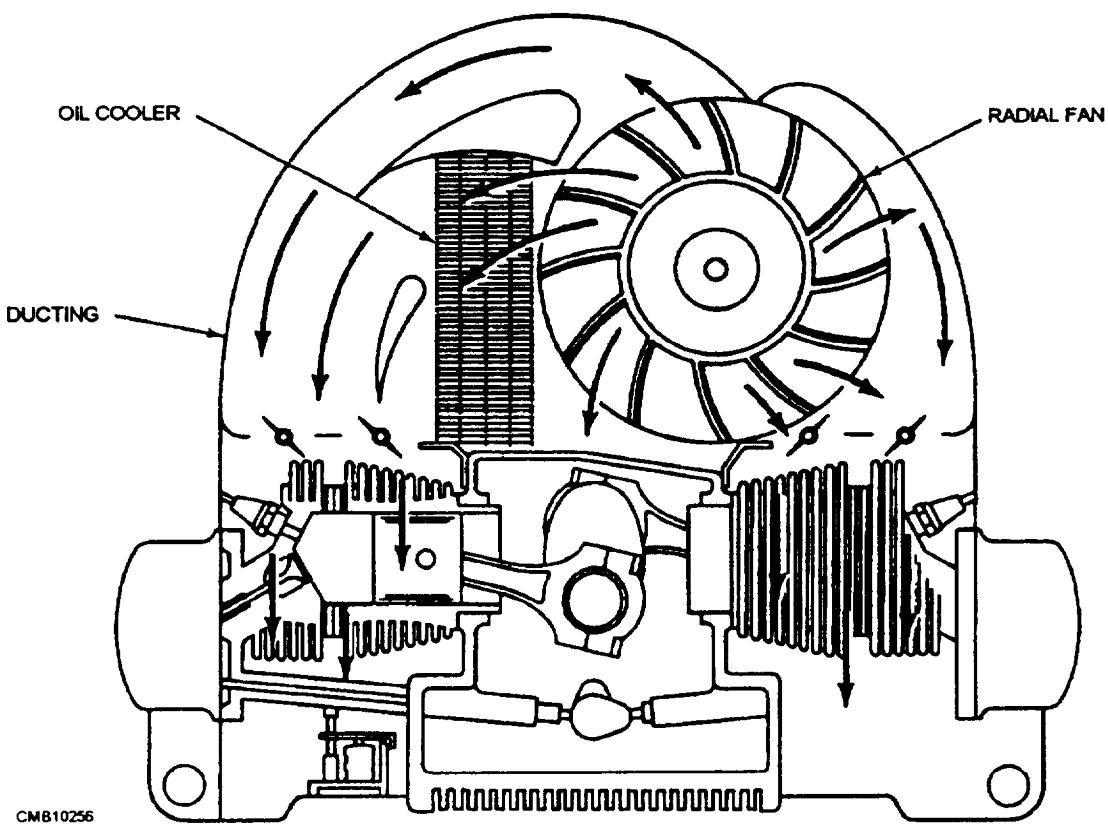


Figure 6-28.—Oil cooler.

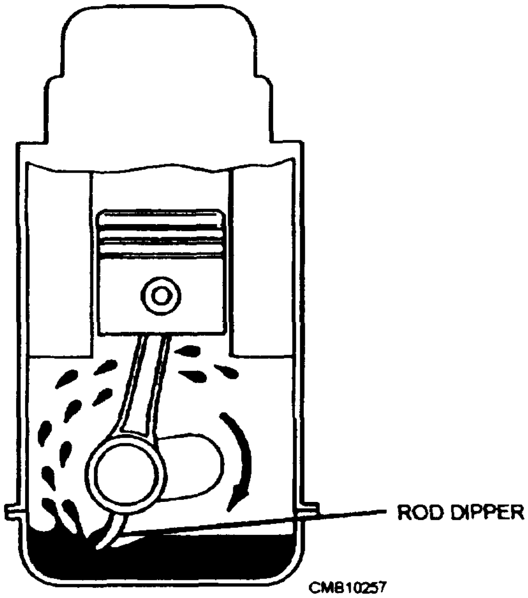


Figure 6-29.—Splash-type lubrication system.

TYPES OF LUBRICATING (OIL) SYSTEMS

Now that you are familiar with the lubricating system components, you are ready to study the different systems that circulate oil through the engine. The systems used to circulate oil are known as splash, combination splash force feed, force feed, and full force-feed.

Splash

The splash system is no longer used in automotive engines. It is widely used in small four-cycle engines for lawn mowers, outboard marine operation, and so on.

In the splash lubricating system (fig. 6-29), oil is splashed up from the oil pan or oil trays in the lower part of the crankcase. The oil is thrown upward as droplets or fine mist and provides adequate lubrication to valve mechanisms, piston pins, cylinder walls, and piston rings.

In the engine, dippers on the connecting-rod bearing caps enter the oil pan with each crankshaft revolution to produce the oil splash. A passage is drilled in each connecting rod from the dipper to the bearing to ensure lubrication.

This system is too uncertain for automotive applications. One reason is that the level of oil in the crankcase will vary greatly the amount of lubrication received by the engine. A high level results in excess lubrication and oil consumption and a slightly low level results in inadequate lubrication and failure of the engine.

Combination Splash and Force Feed

In a combination splash and force feed (fig. 6-30), oil is delivered to some parts by means of splashing and

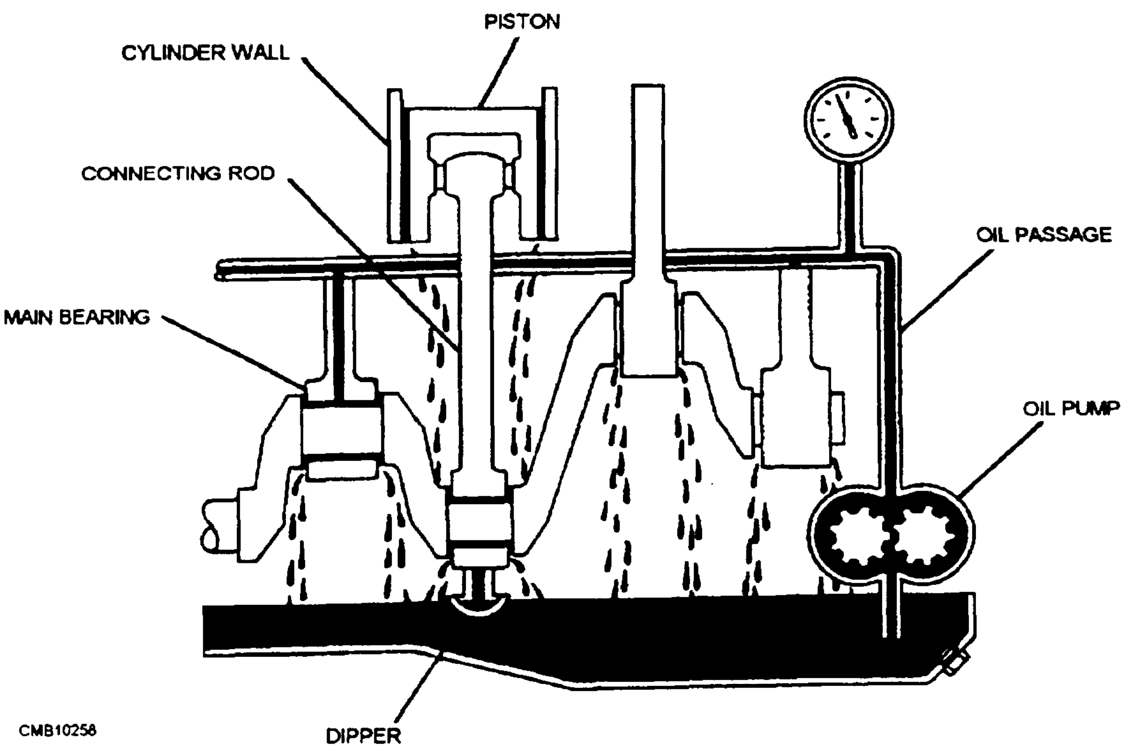


Figure 6-30.—Combination splash and force-feed lubrication system.

other parts through oil passages under pressure from the oil pump.

The oil from the pump enters the oil galleries. From the oil galleries, it flows to the main bearings and camshaft bearings. The main bearings have oil-feed holes or grooves that feed oil into drilled passages in the crankshaft. The oil flows through these passages to the connecting rod bearings. From there, on some engines, it flows through holes drilled in the connecting rods to the piston-pin bearings.

Cylinder walls are lubricated by splashing oil thrown off from the connecting-rod bearings. Some engines use small troughs under each connecting rod that are kept full by small nozzles which deliver oil under pressure from the oil pump. These oil nozzles deliver an increasingly heavy stream as speed increases. At very high speeds these oil streams are powerful enough to strike the dippers directly. This causes a much heavier splash so that adequate lubrication of the pistons and the connecting-rod bearings is provided at higher speeds.

If a combination system is used on an overhead valve engine, the upper valve train is lubricated by pressure from the pump.

Force Feed

A somewhat more complete pressurization of lubrication is achieved in the force-feed lubrication system (fig. 6-31). Oil is forced by the oil pump from the crankcase to the main bearings and the camshaft bearings. Unlike the combination system the connecting-rod bearings are also fed oil under pressure from the pump.

Oil passages are drilled in the crankshaft to lead oil to the connecting-rodbearings. The passages deliver oil from the main bearing journals to the rod bearing journals. In some engines, these opening are holes that line up once for every crankshaft revolution. In other engines, there are annular grooves in the main bearings through which oil can feed constantly into the hole in the crankshaft.

The pressurized oil that lubricates the connecting-rod bearings goes on to lubricate the pistons and walls by squirting out through strategically drilled holes. This lubrication system is used in virtually all engines that are equipped with semifloating piston pins.

Full Force Feed

In a full force-feed lubrication system (fig. 6-32), the main bearings, rod bearings, camshaft bearings, and the complete valve mechanism are lubricated by oil under pressure. In addition, the full force-feed lubrication system provides lubrication under pressure to the pistons and the piston pins. This is accomplished by holes drilled the length of the connecting rod, creating an oil passage from the connecting rod bearing

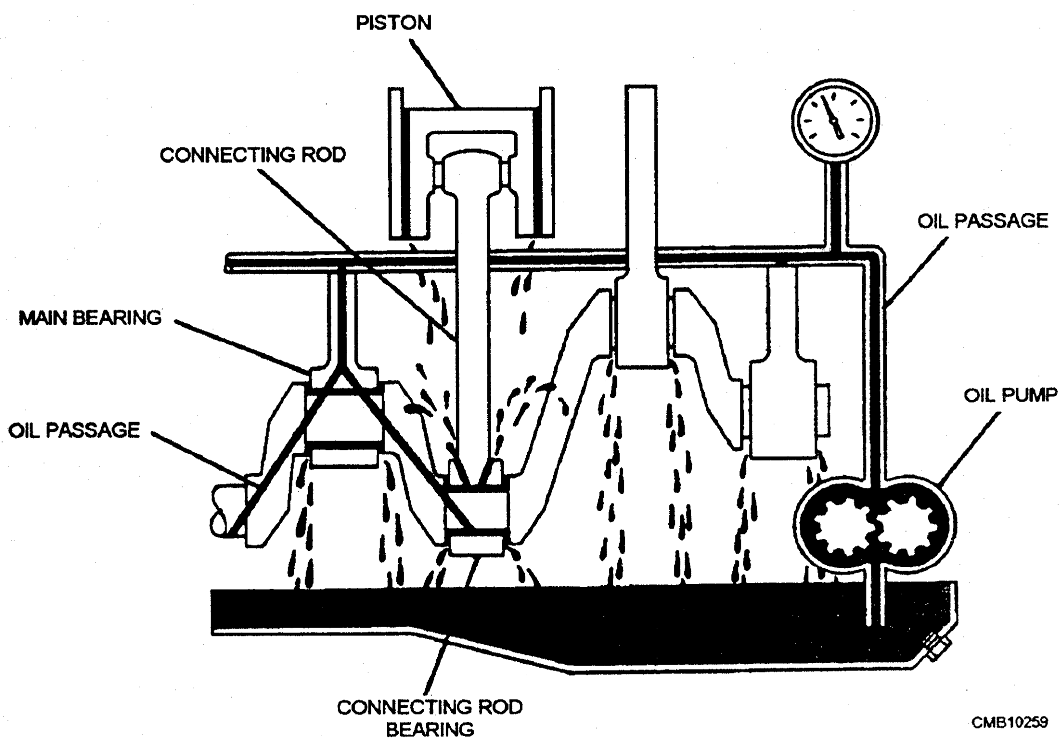


Figure 6-31.—Force-feed lubrication system.

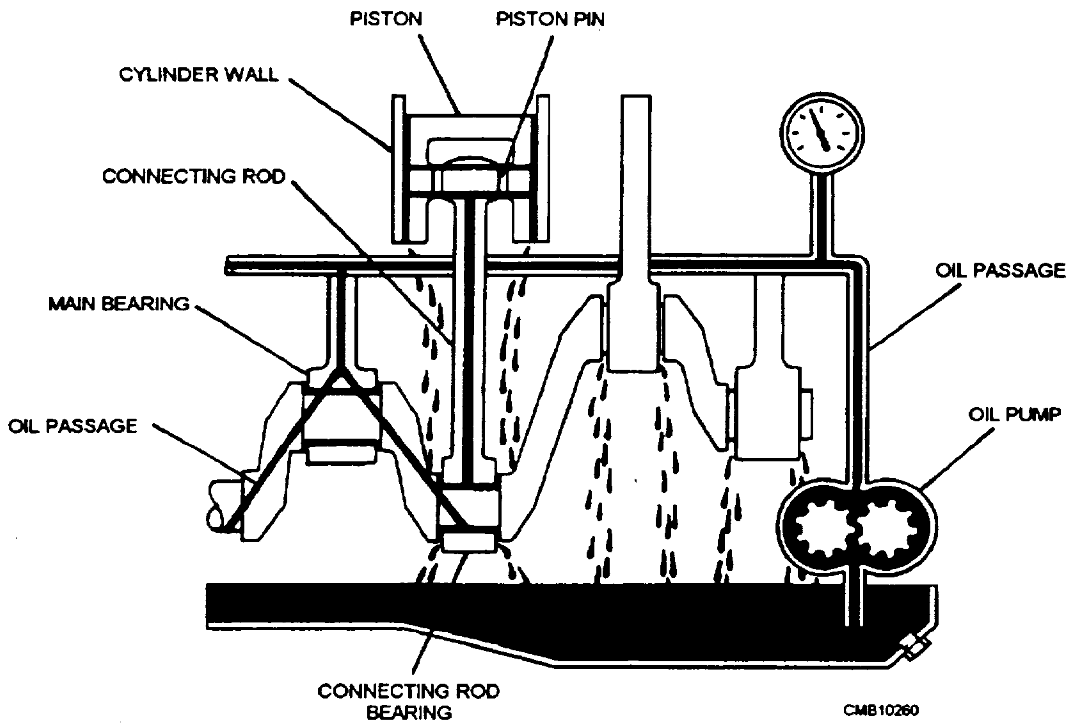


Figure 6-32.—Full force-feed lubrication system.

to the piston pin bearing. This passage not only feeds the piston pin bearings but also provides lubrication for the pistons and cylinder walls. This system is used in virtually all engines that are equipped with full-floating piston pins.

LUBRICATING SYSTEM PROBLEM DIAGNOSIS

To troubleshoot an engine lubricating system, begin by gathering information on the problem. Ask the operator questions. Analyze the symptoms using your understanding of system operation. You should arrive at a logical deduction about the cause of the problem.

The four problems most often occur in the lubrication system are as follows:

1. High oil consumption (oil must be added frequently)
2. Low oil pressure (gauge reads low, indicator light glows, or abnormal engine noises)
3. High oil pressure (gauge reads high, oil filter swelled)
4. Defective indicator or gauge circuit (inaccurate operation or readings)

When diagnosing these troubles, make a visual inspection of the engine for obvious problems. Check for oil leakage, disconnected sending unit wire, low oil level, damaged oil pan, or other troubles that relate to the symptoms.

High Oil Consumption

If the operator must add oil frequently to the engine, this is a symptom of high oil consumption. External oil leakage out of the engine or internal leakage of oil into the combustion chambers causes high oil consumption. A description of each of these problems is as follows:

- External oil leakage—detected as darkened oil wet areas on or around the engine. Oil may also be found in small puddles under the vehicle. Leaking gaskets or seals are usually the source of external engine oil leakage.
- Internal oil leakage—shows up as blue smoke exiting the exhaust system of the vehicle. For example, if the engine piston rings and cylinders are badly worn, oil can enter the combustion chambers and will be burned during combustion

NOTE

Do not confuse black smoke (excess fuel in the cylinder) and white smoke (water leakage into the engine cylinder) with blue smoke caused by engine oil.

Low Oil Pressure

Low oil pressure is indicated when the oil indicator light glows, oil gauge reads low, or when the engine lifters or bearings rattle. The most common causes of low oil pressure are as follows:

1. Low oil level (oil not high enough in pan to cover oil pickup)
2. Worn connecting rod or main bearings (pump cannot provide enough oil volume)
3. Thin or diluted oil (low viscosity or fuel in the oil)
4. Weak or broken pressure relief valve spring (valve opening too easily)
5. Cracked or loose pump pickup tube (air being pulled into the oil pump)
6. Worn oil pump (excess clearance between rotor or gears and housing)
7. Clogged oil pickup screen (reduce amount of oil entering pump)

A low oil level is a common cause of low oil pressure. Always check the oil level first when troubleshooting a low oil pressure problem.

High Oil Pressure

High oil pressure is seldom a problem. When it occurs, the oil pressure gauge will read high. The most frequent causes of high oil pressure are as follows:

1. Pressure relief valve struckopen (not opening at specified pressure)
2. High relief valve spring tension (strong spring or spring has been improperly shimmed)
3. High oil viscosity (excessively thick oil or use of oil additive that increases viscosity)
4. Restricted oil gallery (defective block casting or debris in oil passage)

Indicator or Gauge Problems

A bad oil pressure indicator or gauge may scare the operator into believing there are major problems. The indicator light may stay on or flicker, pointing to a low oil pressure problem. The gauge may read low or high, also indicating a lubrication system problem.

Inspect the indicator or gauge circuit for problems. The wire going to the sending unit may have fallen off. The sending unit wire may also be shorted to ground (light stays on or gauge always reads high).

To check the action of the indicator or gauge, remove the wire from the sending unit. Touch it on a metal part of the engine. This should make the indicator light glow or the oil pressure gauge read maximum. If it does, the sending unit may be defective. If it does not, then the circuit, indicator, or gauge may be faulty.

NOTE

Always check the service manual before testing an indicator or gauge circuit. Some manufacturers recommend a special gauge tester. This is especially important with some computer-controlled systems.

LUBRICATING SYSTEM MAINTENANCE

There are certain lubricating system service jobs that are more or less done automatically when an engine is repaired. For example, the oil pan is removed and cleaned during such engine overhaul jobs as replacing bearing or rings. When the crankshaft is removed, it is usual procedure to clean out the oil passages in the crankshaft. Also, the oil passages in the cylinder block should be cleaned out as part of the overhaul.

As a Construction Mechanic, you will be required to maintain the lubrication system. This maintenance normally consists of changing the oil and filter(s). Occasionally you will be required to perform such maintenance tasks as replacing lines and fittings, servicing or replacing the oil pump and relief valve, and flushing the system. The following discussion provides information that will aid you in carrying out these duties.

Oil and Filter Change

It is extremely important that the oil and filter(s) of the engine are serviced regularly. Lack of oil and filter maintenance will greatly shorten engine service life.

Manufacturers give a maximum number of miles or hours a vehicle can be operated between oil changes. Newer automotive vehicles can be operated 5,000 miles between changes. Older automotive vehicles should have their oil changed about every 3,000 miles. Most construction equipment average between 200 and 250 hours of operation between oil changes. However, depending on the climate and working conditions the miles and hours between oil changes can be greatly reduced. Refer to the service manual for exact intervals.

To change the engine oil, warm the engine to full operating temperature. This will help suspend debris in the oil and make the oil drain more thoroughly. Unscrew the drain plug and allow the oil to flow into a catchment pan Be careful of hot oil; it can cause painful burns.

Usually the filter elements are replaced at the same time the oil is changed. The most common filters are the spin-on filter or replaceable element type oil filter.

- Spin-on, throwaway oil filter—replaced as a complete unit. Unscrew the filter from the base by hand or a filter wrench and throw the filter away. When replacing, wipe the base clean with a cloth and place a small amount of oil or grease on the gasket to ensure a good seal. Screw on a new filter, tightening at least a half a turn after the gasket contacts the base. Do not use a filter wrench because the filter canister could distort and leak.

- Replaceable element oil filter—removed from the filter housing and replaced. Place a pan underneath the filter to catch oil from the filter. Remove the fastening bolt and lift off the cover or filter housing. Remove the gasket from the cover or housing and throw it away. Take out the old element and throw it away. Clean the inside of the filter housing and cover it. Install a new element and insert a new cover or housing gasket (ensure the gasket is completely seated in the recess). Replace the cover or housing and fasten it to the center bolt securely.

After the oil has been completely drained and the drain plug replaced, fill the crankcase to the full mark on the dipstick with the proper grade and weight of oil. Start and idle the engine. Check the oil pressure immediately. Inspect the filter or filter housing for leaks. Stop the engine and check the crankcase oil level and add to the full mark.

Oil Pump Service

Service on oil pumps is limited since they are relatively trouble-free. An oil pump will often still be operating trouble-free when the vehicle is ready for salvage.

A bad oil pump will cause low or no oil pressure and possibly severe engine damage. When inner parts wear, the pump may leak and have a reduced output. The pump shaft can also strip in the pump or distributor, preventing pump operation

To replace the oil pump, it is first necessary to determine its location. Some pumps are located inside the engine oil pan Others are on the front of the engine under a front cover or on the side of the engine. Since removal procedures vary, refer to the manufacturer's service manual for instructions.

Most mechanics install a new or factory rebuilt pump when needed. It is usually too costly to completely rebuild an oil pump in the shop. Before installation, prime (fill) the pump with engine oil. This will assure proper initial operation upon engine starting.

Install the pump in reverse order of removal. Anew gasket should be used and the retaining bolts torqued as specified by the service manual.

Pressure Relief Valve Service

A faulty pressure relief valve can produce oil pressure problems. The valve may be located in the oil pump, filter housing, or engine block.

If symptoms point to the pressure relief valve, it should be disassembled and serviced. Cleaning and adjusting is all that is usually required. Remove the cup or cap, holding the pressure relief valve. Then, slide the spring and piston out of their bore.

Measure the free length of the spring (length of extended spring) and compare it to the specifications. If the spring is too short or long, install a new spring. Some manufacturers recommend checking spring tension.

Use a micrometer and a small hole gauge to check the valve and valve bore wear. Also, check the sides of the valve for scratches or scoring. Replace the parts if any problems are found.

Assemble the pressure relief valve. Make sure that the valve is facing correctly in its bore. Slide the spring into place. Install any shims and the cover plug or cap. Refer to the service manual for details.

The pressure relief valve may be adjusted in one of two ways. One way is by an adjusting screw (having a jam or locknut) which adds or relives pressure on the spring. The other way is by adjusting shims that are added or removed to adjust opening pressure of the relief valve.

Q11. What device is used to determine the viscosity of oil ?

Q12. How is oil that meets SAE low temperature requirements designated?

Q13. Who sets the oil service rating?

Q14. What oil service rating is required for today's automotive gasoline engines?

Q15. What are the two oil filter configurations?

Q16. Name the four types of lubricating systems?

Q17. What type of lubricating system is used on small four-cycle engines?

Q18. What lubricating system is used on engines equipped with full-floating piston pins?

Q19. When servicing the pressure relief valve, you can use what tools to check the valve and valve bore?

APPENDIX 1

GLOSSARY

ACCELERATING PUMP—A device in the carburetor that supplies an additional amount of fuel, temporarily enriching the air-fuel mixture when the throttle is suddenly opened

ACCELERATION—The process of increasing velocity. Average rate of change of increasing velocity, usually in feet per second.

AIR BLEED—An opening into a gasoline passage through which air can pass (or bleed) into the gasoline as it moves through the passage.

AIR CLEANER—A device mounted on the engine through which air must pass before entering the combustion chamber. A filtering device in the air cleaner removes dust and dirt particles from the air.

AIR-COOLED ENGINE—An engine cooled by air circulating between cylinders and around cylinder head.

AIR FILTER—A filter through which air passes, and which removes dust and dirt particles from the air.

AIR-FUEL RATIO—The ratio between the volume of air and the volume of fuel used to establish a combustion mixture.

AIR-INJECTION SYSTEM—A system which injects air into the exhaust manifold or thermal reactor so that the combustion of the carbon monoxide and unburned hydrocarbons in the exhaust gases can be completed.

AIR POLLUTION—Contamination of the air by natural and manufactured pollutants.

AIR PRESSURE—Atmospheric pressure (14.7 pounds per square inch at sea level) or pressure of air produced by pump, by compression in engine cylinder, and so on.

ALLOY—A mixture of two or metals, usually produced to improve characteristics of the base metal.

ANCHORED PISTON PIN—A stationary wrist pin secured to the piston at the bosses that allows the connecting rod to move about the pin.

ATDC —After top dead center.

ANTIFREEZE—A substance added to the liquid-cooled engine to prevent freezing.

ANTIFRICTION BEARING—Type of bearing in which moving parts are in rolling contact; ball, roller, or tapered roller bearing.

ANTIKNOCK—Refers to substances that are added to gasoline to decrease the tendency to knock when the air-fuel mixture is compressed and ignited in the engine cylinder.

ATOMIZATION—The spraying of a liquid through a nozzle so that the liquid is broken into tiny globules or particles.

AUTOMATIC CHOKE—A choke that operates automatically in accordance with certain conditions, usually temperature and intake manifold vacuum.

BABBIT—An antifriction metal lining used as a wearing surface for bearing to reduce the friction between moving components.

BACKFIRING—Pre-explosion of air-fuel mixture so mat explosion passes back around the opened intake valve and flashes back through the intake manifold.

BACK PRESSURE—The resistance of gases to flow through a system.

BAFFLE—A plate or shield to divert the flow of liquid or gas.

BALL-CHECK VALVE—A valve consisting of a ball and seat. Fluid can pass in one direction only; it is checked by the ball seating on the seat.

BBDC—Before bottom dead center.

BDC—Bottom dead center; the position of the piston when it reaches the lower limit of travel in the cylinder.

BEARING—A mechanical component that supports and aligns the location of another rotating or sliding member.

BIMETAL—Referring to the thermostatic bimetal element made up of two different metals with different heat expansion rates; temperature change produces a bending or distorting movement.

BLOCK—*See* CYLINDER BLOCK

BLOW-BY—Leakage of the compressed air-fuel mixture or burned gases from combustion, passing piston and rings, and into the crankcase.

BLOWER—A mechanical device for compressing and delivering air to the engine at higher than atmospheric pressure.

BOILING POINT—The temperature at which a liquid boils.

BOOST PRESSURE—The pressure in the intake manifold while the turbocharger is operating.

BORE—The diameter of a cylinder. Also used to describe the process of enlarging or accurately refinishing an engine cylinder.

BRAKE HORSEPOWER—The power actually delivered by the engine that is available for driving the vehicle.

BTDC—Before top dead center.

BUSHING—A replaceable lining for a hole in which a shaft, rod, or similar part moves.

BUTTERFLY—The choke or throttle valve.

BYPASS—A separate passage that permits a liquid to take a path other than that normally used.

CALIBRATION—(l) Balancing: The setting of the delivery of an injection system or the setting of the rack pointer on a single unit pump in relation to predetermined positions of a quantity control member. (2) Adjustment: Fixing fuel delivery and speed adjustments to specified engine requirements.

CAM-GROUND—A process by which the piston is ground slightly egg-shaped and, when heat becomes round.

CAMSHAFT—The shaft in an engine that has a series of cam lobes for operating the valve mechanism.

CAMSHAFT PUMP—An injection pump containing a camshaft to operate the pumping element or elements.

CARBON—A substance deposited on engine parts by the combustion of fuel. Carbon forms on pistons, rings, valves, and so on, inhibiting their action.

CARBON DIOXIDE—A gas resulting from burning fuel.

CARBON MONOXIDE—A colorless, odorless, tasteless, deadly gas found in engine exhaust, formed by incomplete burning of hydrocarbons.

CARBURETION—The action that takes place in the carburetor: converting liquid fuel to vapor and mixing it with air to form a combustible mixture.

CARBURETOR—The device in a gasoline fuel system that mixes air and fuel and delivers the combustible mixture to the intake manifold.

CATALYTIC CONVERTER—A device used on the exhaust system of gasoline engines to reduce harmful emissions.

CETANE—Ignition quality of diesel fuel. A high-cetane fuel ignites more easily (at lower temperature) than a low-cetane fuel.

CFM—Cubic feet per minute.

CHOKE—A device in the carburetor that chokes off, or reduces, the flow of air into the intake manifold; producing a partial vacuum in the intake manifold and a consequent richer air-fuel mixture.

CID—Cubic inch displacement.

CLOSED CRANKCASE VENTILATING SYSTEM—A system in which the crankcase vapors are discharged into the engine intake system and pass through the engine cylinders rather than being discharged into the air.

CLOSED NOZZLE—A nozzle incorporating either a poppet valve or a needle valve, loaded in order to open at some predetermined pressure.

COMBUSTION—The rapid burning of the air-fuel mixture in the cylinder.

COMBUSTION CHAMBER—The space at the top of the cylinder and in the head where combustion of the air-fuel mixture takes place.

COMPRESSION—The act of pressing into a smaller space or reducing in size or volume by pressure.

COMPRESSION RATIO—The ratio between the volume in the cylinder with the piston at bottom dead center and with the piston at top dead center.

COMPRESSION RINGS—The upper rings on a piston; the rings designed to hold the compression in the cylinder and prevent blow-by.

COMPRESSION STROKE—The piston stroke from bottom dead center during which both valves are closed and the gases in the cylinder are compressed.

CONCENTRIC—Having a common center, as circles or spheres, one within the other.

CONNECTING ROD—Linkage between the crankshaft and piston, usually attached to the piston by a piston pin and to the crank journal on the crankshaft by a split bearing and bearing cap.

CONTROL PINON—A collar engaging the plunger and having a segment of gear teeth, integral or attached, which mesh with the control rack.

CONTROL RACK—A toothed rod inside mechanical injection pumps that rotates the pump plunger to control the quantity of fuel injected.

COOLANT—The liquid that circulates in an engine cooling system that reduces heat generated by the engine.

COOLING FAN—The fan in the engine cooling system that provides a forced circulation of air through the radiator or around the engine cylinders so that cooling is affected.

COOLING PINS—The thin metal projections on the air-cooled engine cylinder and head that greatly increases the heat-radiating surfaces and helps provide cooling of engine cylinder.

COOLING SYSTEM—A system that reduces heat generated by the engine and thereby prevents engine overheating, including liquid-cooled engines, engine water jackets, radiator, and water pump.

CRANKCASE—The lower part of the engine that serves as a housing for the crankshaft.

CRANKSHAFT—The main rotating member or shaft of the engine that converts rotary motion into reciprocating motion.

CYCLE—A series of events with a start and finish during which a definite train of events takes place.

CYLINDER—A hollow tube that contains the actions of combustion gases and the piston in an internal combustion engine.

CYLINDER BLOCK—The part of the engine to which and in which other engine parts and accessories are attached or assembled.

CYLINDER HEAD—The part of the engine that encloses the cylinder bores; contains water jackets (on liquid-cooled engines) and valves (on I-head engines).

CYLINDER SLEEVE—A pipe-shaped removable insert used as the cylinder wall on some engines.

DASHPOT—A device that controls the rate at which the throttle valve closes.

DEAD CENTER—Either of the two positions when the crank and connecting rod are in a straight line at the end of the stroke.

DELIVERY VALVE—A spring loaded valve which opens at some predetermined pressure to permit fuel flow from the injector plunger and bushing spray tip.

DETERGENT—A chemical sometimes added to the engine oil, designed to help keep the internal parts of the engine clean by preventing the accumulation of deposits.

DETONATION—In the engine, excessively rapid burning of the compressed charge which results in engine knock.

DIESEL ENGINE—An engine using the diesel cycle of operation; air alone is compressed and diesel fuel is injected before the end of the compression stroke. Heat of the compression produces ignition.

DIESEL FUEL—A light oil sprayed into the cylinders of a diesel engine near the end of the compression stroke.

DIESELING—A condition in which a spark-ignition engine continues to run after the ignition is off; caused by carbon deposits or hot spots in the combustion chamber glowing sufficiently to furnish heat for combustion.

DIPSTICK—*See* OIL-LEVEL GAUGE.

DISPERSANT—A chemical added to oil to prevent dirt and impurities from clinging together in lumps that could clog the engine lubrication system.

DISTRIBUTOR PUMP—An injection pump where each metered delivery is directed to the appropriate engine cylinder by a distributing device.

DOHC—Double overhead camshaft.

DRIBBLE—Insufficiently atomized fuel issuing from the nozzle at or immediately following the end of main injection.

DRIVABILITY—The general operation of a vehicle, usually rated from good to poor; based on characteristics of concern to the average driver, such as smoothness of idle, even acceleration, ease of starting, quick warm-up, and not overheating.

ECCENTRIC—Off center.

EMISSION CONTROL—Any device or modification added to or designed into a motor vehicle for the purpose of reducing air-polluting emissions.

ENERGY—The ability or capacity to do work.

ENGINE—A machine that converts heat energy into mechanical energy.

ETHYLENE GLYCOL—A solution added to antifreeze to help prevent freezing.

EVAPORATIVE CONTROL SYSTEM—A system that prevents the escape of fuel vapors from the fuel tank or air cleaner while the engine is off. The vapors are stored in a charcoal canister or in the engine crankcase until the engine is started.

EXHAUST EMISSIONS—Pollutants emitted into the atmosphere through any opening downstream of the exhaust ports of an engine.

EXHAUST-GAS ANALYZER—A device for sensing the amounts of air pollutants in the exhaust gas of a motor vehicle.

EXHAUST-GAS RECIRCULATION (EGR) SYSTEM—An NO_x control system that recycles a small part of the inert exhaust gas back through the intake manifold to lower the combustion temperature.

EXHAUST MANIFOLD—The part of the engine that provides a series of passages through which burned gases from the engine cylinders may flow to the muffler.

EXHAUST PIPE—The pipe connecting the exhaust manifold to the next component in the exhaust system.

EXHAUST STROKE—When the exhaust gases from the cylinder are removed via the exhaust valves.

EXHAUST SYSTEM—The system that collects the exhaust gases and discharges them into the air. Consists of the exhaust manifold, exhaust pipe, muffler, tail pipe, and catalytic converter (if required).

EXHAUST VALVE—The valve that opens to allow the burned gases to escape from the cylinder during the exhaust stroke.

EXPANSION TANK—A tank connected by a hose to the filler neck of an automobile radiator; the tank provides room for heated coolant to expand and to give off any air that may be trapped in the coolant.

F-HEAD—A type of engine with the valves arranged to form an F; one valve is in the head, the other in the cylinder block.

FAN—The bladed device in back of the radiator that rotates to draw cooling air through the radiator or around the engine cylinders.

FAN BELT—A belt (or belts), driven by the crankshaft, whose primary purpose is to drive the engine fan and water pump.

FIRING ORDER—The order in which the engine cylinders deliver their power strokes.

FLOAT BOWL—In the carburetor, the reservoir from which gasoline feeds into the passing air.

FLOAT LEVEL—The float position at which the needle valve closes the fuel inlet to the carburetor to prevent further delivery of fuel.

FORCE—The action of one body on another tending to change the state of motion of the body acted upon. Force is usually expressed in pounds.

FOUR-STROKE CYCLE ENGINE—An engine that requires four piston strokes (intake, compression, power, exhaust) to make a complete cycle of events in the engine cylinder.

FRICTION—The resistance to motion between two bodies in contact with each other.

FRICTION BEARING—A bearing having no moving parts. The shaft that rotates simply rubs against or rides on a thin film of oil between the bearing and shaft.

FUEL—The substance that is burned to produce heat and create motion of the piston on the power stroke of the engine.

FUEL FILTER—A device located in the fuel system that removes dirt and other contaminates from the fuel passing through.

FUEL GAUGE—The gauge that indicates to the operator the height of the fuel level in the tank.

FUEL INJECTION—A fuel delivery system that sprays fuel either directly into the cylinders or into the intake manifold just ahead of the cylinders.

FUEL INJECTION TUBING—The tube connecting the injection pump to the nozzle holder assembly.

FUEL INJECTOR—A device in a diesel engine fuel system for injecting fuel into the cylinder.

FUEL LINE—The pipe or tube through which fuel travels from the tank to other components within the fuel system.

FUEL PUMP—The electrical or mechanical device in the fuel system which forces fuel from the fuel tank to the carburetor or fuel injection system.

FUEL PUMPHOUSING—The main casing into or to which are assembled all the components of the injection pump, and may accommodate the camshaft in the case of camshaft pumps; or the camshaft or driveshaft in the case of distributor type pumps.

FUEL TANK—The metal tank that serves as a storage place for fuel.

FULL-FLOATING PISTON—A piston pin free to turn in the piston boss of the connecting rod eye.

FULL THROTTLE—Wide-open throttle position with accelerator pressed all the way down to the floorboard

GASOLINE—A liquid blend of hydrocarbons, obtained from crude oil; used as the fuel in most automotive engines.

GASOLINE ENGINE—An engine having its piston driven by the explosions of a mixture of air and gasoline vapor ignited by an electric spark

GASTIGHT—Constructed or arranged so that gas will not enter or escape an enclosed space under specified conditions.

GEAR TRAIN—A drive mechanism consisting of a group of gear that mesh together to operate an engine and its accessories.

GLOW PLUG—A small electric heater installed in the precombustion chamber of diesel engine to preheat the chamber for easier starting in cold weather.

GOVERNOR—A device that controls, or governs, another device, usually on the basis of speed or load.

HEAT-CONTROL VALVE—In the engine, a thermostatically operated valve in the exhaust manifold; diverts heat to the intake manifold to warm it before the engine reaches normal operating temperature.

HONE—A tool/process for enlarging cylinders or cylinder lines to precise tolerances; also used for controlling finishes.

HORSEPOWER—A measure of a definite amount of power; 550 foot-pound per second.

HYDRAULIC GOVERNOR—A mechanical governor having a hydraulic servo-booster to increase output force.

HYDRAULIC HEAD ASSEMBLY—The assembly containing the pumping, metering, and distributing elements (and may include the delivery valve) for distributor-type pumps.

HYDRAULIC VALVE TAPPET—A valve tappet that, by means of hydraulic pressure, maintains zero valve clearance so that valve noise is reduced.

HYDROCARBON (HC)—A compound containing only carbon and hydrogen atoms, usually derived from fossil fuels such as petroleum, natural gas, and coal; an agent in the formation of photochemical smog. Gasoline is a blend of liquid hydrocarbons refined from crude oil.

HYDROGEN (H)—A colorless, odorless, highly flammable gas whose combustion produces water; the simplest and lightest element.

HYDROMETER—A device to determine the specific gravity (roughly the heaviness) of a liquid. This determination indicates the freezing point of the coolant in the cooling system.

I-HEAD—A type of engine with the valves located in the cylinder head.

INDICATED HORSEPOWER—A measurement of engine power based on power actually developed in the engine cylinders.

IDLE-MIXTURE SCREW—The adjustment screw (on some carburetors) that can be turned in or out to lean or enrich the idle mixture.

IDLE SPEED—The speed, or rpm, at which the engine runs when the accelerator pedal is fully released and there is no load on the engine.

IGNITION-COMPRESSION—When the heat generated by compression in an internal combustion engine ignites the fuel (as in a diesel engine).

IGNITION-SPARK—When the mixture of air and fuel in an internal combustion engine is ignited by an electric spark (as in a gasoline engine).

IGNITION TIMING—Refers to the timing of the spark at the spark plug as related to the piston in the engine cylinder.

INJECTION/IGNITION—When the piston nears the top of its stroke, fuel admitted under pressure is sprayed into the cylinder. The fuel ignites due to the heat in the cylinder.

INJECTION PUMP—The device which meters the fuel and delivers it under pressure to the nozzle and holder assembly.

INJECTION PUMP ASSEMBLY—A complete assembly consisting of the fuel pump proper, together with additional units such as governor, fuel supply pump, and additional optional devices, when these are assembled with the injection pump to form a unit.

INJECTION TIMING—The matching of the pump timing mark, or the injector timing mechanism, to some index mark on an engine component, such that injection will occur at the proper time with reference to the engine cycle.

INJECTOR—The mechanism, including nozzle, that injects fuel into the engine combustion chamber on diesel engines.

IN-LINE ENGINE—An engine in which the cylinders are arranged in one straight line.

IN-LINE PUMP—An injection pump with two or more pumping elements arranged in line, each pumping element serving one engine cylinder only.

INTAKE MANIFOLD—That component of the engine that provides a series of passages to allow the air-fuel mixture to flow to the engine cylinders.

INTAKE STROKE—The piston stroke from top dead center to bottom dead center during which the intake valve is open and the cylinder receives a charge of air-fuel mixture.

INTAKE VALVE—The valve in the engine that is opened during the intake stroke to permit the entrance of the air-fuel mixture into the cylinder.

INTERNAL COMBUSTION ENGINE—An engine in which the fuel is burned inside the engine, as opposed to an external combustion engine where the fuel is burned outside the engine, such as a steam engine.

JOURNAL—Serves as the point of support and the center of rotation for the shaft. That part of the shaft that is prepared to accept a bearing (connecting rod, main bearing).

KNOCK—A heavy metallic engine sound that varies with engine speed; usually caused by a loose or worn bearing; name also used for detonation, pinging, and spark knock. See DETONATION.

L-HEAD—A type of engine with the valves located in the cylinder block.

LAP—To work two surfaces together with abrasive until a very close fit is produced; to polish.

LASH—The clearance or play between adjacent movable mechanical parts. See VALVE LASH.

LEAN MIXTURE—A air-fuel mixture that has a high proportion of air and a low proportion of fuel.

LUBRICATION SYSTEM—The system in the engine that supplies the engine with lubricating oil to prevent contact between any two moving metal surfaces.

MANIFOLD—A device with several inlet or outlet passageways through which a gas or liquid is gathered or distributed. See INTAKE MANIFOLD and EXHAUST MANIFOLD.

MECHANICAL EFFICIENCY—In an engine, the ratio between brake horsepower and indicated horsepower.

MECHANICAL GOVERNOR—A speed sensitive device of the centrifugal type, which controls the injection pump delivery sole by mechanical means.

MICROMETER—A measuring device that measures accurately such dimensions as shaft or bore diameter or thickness of an object.

MICROPROCESSOR—The small, on-board solid-state electronic device that acts as the central processing unit. Sensors provide input information which the microprocessor uses to determine the desired response (in any) as an output signal.

MUFFLER—In the exhaust system, a device through which the exhaust gases must pass and which reduces the exhaust noise.

MULTIPLE-POINT INJECTION—A gasoline fuel injection system in which only air enters the intake manifold. As the air approaches the intake valve, an injection valve opens in the intake port, spraying fuel into the airstream. Also called port injection.

MULTIPLE-VISCOSITY OIL—An engine oil that has a low viscosity when cold (for easier starting) and a higher viscosity when hot (to provide adequate engine lubrication).

NEEDLE VALVE—A small, tapered, needle-pointed valve that can move into or out of a seat to close or open the passage through it. Used to control the fuel level in the carburetor float bowl.

NITROGEN (N)—A colorless, tasteless, odorless gas that constitutes 78 percent of the atmosphere by volume and is a part of all living substances.

NITROGEN OXIDES (NO_x)—Any chemical compound of nitrogen and oxygen; a basic air pollutant. Automotive exhaust emissions levels of nitrogen oxides are limited by law.

NOZZLE—The opening or jet, through which fuel or air passes as it's discharged. Also, the assembly of parts employed to atomize and deliver fuel to the engine.

NOZZLE AND HOLDER ASSEMBLY—The complete apparatus which injects the pressurized fuel into the combustion chamber.

NOZZLE TIP—The extreme end of the nozzle body containing the spray holes.

OCTANE RATING—A measure of the antiknock properties of gasoline. The higher the octane rating, the more resistant the gasoline is to spark knock or detonation.

OIL—A liquid lubricant, usually made from crude oil and used for lubrication between moving parts.

OIL CLEARANCE—The space between the bearing and the shaft rotating within it.

OIL CONTROL RINGS—The lower ring or rings on a piston; designed to prevent excessive amounts of oil from working up into the combustion chamber.

OIL COOLER—A small radiator that lowers the temperature of oil flowing through it.

OIL FILTER—A filter that removes impurities from the engine oil passing through it.

OIL GALLERY—A pipe or drilled passageway in the engine used to transport oil from one area to another.

OIL-LEVEL GAUGE—The dipstick that is removed and inspected to check the level of the oil in the crankcase of an engine.

OIL PAN—The lower part of the crankcase in which a reservoir of oil is maintained.

OIL-PRESSURE INDICATOR—A gauge that indicates (to the operator) the oil pressure in the lubricating system, or a light that comes on if the oil pressure drops too low.

OIL PUMP—A device that forces oil from the oil pan to the moving parts of an engine.

OIL SLINGER—A device mounted to a revolving shaft such that any oil passing that point will be thrown outward where it will return to the point of origin.

OVERHEAD CAMSHAFT—A camshaft located in the cylinder head where the cam lobes are in direct contact with the rocker arms.

OXYGEN—A colorless, tasteless, odorless, gaseous element that makes up about 21 percent of the air. Capable of combining rapidly with all elements except the inert gases in the oxidation process called burning.

PARTICLE—A very small piece of metal, dirt, or other impurity which may be contained in the air, fuel, or lubricating oil used in an engine.

PASSAGE—A small hole or gallery in an assembly or casting through which air, coolant, fuel, or oil flows.

PCV VALVE—The valve that controls the flow of crankcase vapors in accordance with ventilation requirements for different speeds and loads.

PETROLEUM—The crude oil from which gasoline, lubricating oil, and other such products are refined.

PHOTOCHEMICAL SMOG—Smog caused by hydrocarbons and nitrogen oxides reacting photochemically in the atmosphere. The reactions take place under low wind velocity, bright sunlight, and an inversion layer in which the air mass is trapped Can cause eye and lung irritation

PING—Engine spark knock or detonation that occurs usually during acceleration. Caused by excessive advance of ignition timing or low-octane fuel.

PISTON—A cylindrical plug that slides up and down in the cylinder and is joined to the connecting rod.

PISTON BOSS—The reinforced area around the piston-pin bore.

PISTON CROWN—The top or head of the piston.

PISTON DISPLACEMENT—The volume of air moved or displaced by the piston as the piston moves from BDC to TDC.

PISTON HEAD—The portion of the piston above the top ring.

PISTON LANDS—The spaces in the piston between the ring grooves.

PISTON PIN-A cylindrical pin that passes through the piston bore and joins the connecting rod to the piston.

PISTON RING—A split ring (expansion type) placed in a groove of the piston to seal the space between the piston and the cylinder wall.

PISTON-RING END GAP—The clearance between the ends of the piston ring.

PISTON-RING GROOVE—The grooves cut in the piston into which the piston rings are fitted.

PISTON-RING SIDE CLEARANCE—The clearance between the side of the ring and the ring lands.

PISTON SKIRT—The portion of the piston that is below the piston bore.

PISTON STROKE—The distance that a piston moves between its limits of travel.

POLLUTANT—Any substance that adds to the pollution of the atmosphere. In a vehicle, any such substance in the exhaust gas from the engine or escaping from the fuel tank or air cleaner.

POSITIVE CRANKCASE VENTILATION (PCV)—A crankcase ventilation system; uses intake manifold vacuum to return the crankcase vapors and blow-by gases to the intake manifold to be burned, thereby preventing their escape into the atmosphere.

POWER—The rate of doing work or the rate for expanding energy. The unit for mechanical power is horsepower.

PRONY BRAKE—A device using a friction brake to measure horsepower.

PRECISION INSERT BEARING—A precision type of bearing consisting of an upper and lower shell.

PRECOMBUSTION CHAMBER—In some engines, a separate small combustion chamber where combustion begins.

PREIGNITION—Ignition of the air-fuel mixture in the combustion chamber by some unwanted means, before the ignition spark occurs at the spark plug.

PRESSURE—The amount of force distributed over each unit of area. Pressure is expressed in pounds per square inch (psi), inches of mercury, and other units.

PRESSURE CAP—A radiator cap with valves which causes the cooling system to operate under pressure at a higher and more efficient temperature.

PRESSURIZE—To apply more than atmospheric pressure to a gas or liquid.

PSI—Pound per square inch; usually to indicate pressure of a liquid or gas.

PUSHRODS—A special rod used to transit the motion of the cam and the lifter to the rocker on the cylinder head.

RADIAL ENGINE—An engine with each cylinder located on a radius of a circle and with all cylinders disposed around a common crankshaft.

RADIATOR—In the cooling system, the device that removes heat from coolant passing through it; receives hot coolant from the engine and sends the coolant back to the engine at a lower temperature.

RADIATOR CAP—The cap placed on the radiator filler neck.

RATIO—The value obtained by dividing one number by another, indicating their relative proportions.

RECIPROCATING—Moving back and forth; as a piston reciprocating in a cylinder.

RELIEF VALVE—A valve that opens when a preset pressure is reached. This relieves or prevents excessive pressure.

REVOLUTION—A term to describe a 360° circular motion of the crankshaft.

RICH MIXTURE—An air-fuel mixture that has a low proportion of air and a high proportion of fuel.

ROCKER ARM—A device that rocks or pivots on the rocker arm shaft as the cam rotates, causing the valve to open.

ROCK POSITION—The piston and connecting rod position (top or bottom dead center) at which the crank can rock or rotate a few degrees without appreciable movement of the piston.

ROD CAP—The lower part of a connecting rod that can be taken off by removing bolts or nuts so the rod can be detached from the crankshaft.

SAE—Society of Automotive Engineers.

SCAVENGING-A cleaning or blowing out action in reference to exhaust gases.

SEMIFLOATING PISTON PIN—A piston pin in which the ends of the pin are free to move in the piston bearings of the bosses.

SHROUD—A hood placed around an engine fan to improve air flow.

SLEEVE METERING—A system of metering fuel delivery by incorporating a movable sleeve with which port opening and/or port closing is controlled.

SMOG—A term coined from the words "smoke" and "fog." First applied to the foglike layer that hangs in the air under certain atmospheric conditions; generally used to describe any condition of dirty air and/or fumes or smoke.

SOHC—Single overhead camshaft.

SPILL VALVE—A valve used to end injection at a controllable point on the pumping stroke by allowing fuel to escape from the pumping chamber.

SPRING RETAINER—The piece of metal that holds the valve spring in place, and is itself locked in place by the valve spring retainer locks.

STATIONARY PARTS—The main parts of an engine that do not move, but provide support

STROKE—The movement, or the distance of the movement, in either direction, of the piston travel in an engine.

SUPERCHARGER—In the intake system of the engine, a pump that pressurizes the incoming air or air-fuel mixture. This increases the amount of fuel that can be burned, increasing engine power. If the supercharger is driven by the engine exhaust gas, it is called a turbocharger.

SUPPLY PUMP—A pump for transferring the fuel from the tank and delivering it to the injection pump.

TANK SENDING UNIT—A device in the fuel tank that provides indication of fuel level for instrument panel gauge.

TDC (TOP DEAD CENTER)—The position of a reciprocating piston at its uppermost point of travel.

TEMPERATURE INDICATOR—A gauge that indicates to the operator the temperature of the engine coolant, or a light that comes on if the coolant gets too hot.

THERMAL EFFICIENCY—The ratio between the power output and the energy in the fuel burned to produce the output.

THERMOSTAT—A device for automatic regulation of temperature; usually contains a temperature-sensitive element that expands or contracts to open and close off the flow of air, a gas, or a liquid.

THERMOSTATIC SWITCH—A switch that is turned on or off by temperature change.

THRUST—A force tending to push a body out of alignment, A force exerted endwise through a member upon another member.

THRUST BEARING—Bearing that limits the axial (longitudinal) movement of the shaft.

TIMING DEVICE—A device responsive to engine speed and/or load to control the timed relationship between injection cycle and engine cycle.

TORQUE—A force that produces a turning or twisting effort; measured in pound-feet.

TORQUE CONTROL—A device which modifies the maximum amount of fuel injected into the engine cylinders at speeds below rated speed to obtain the desired torque output.

TURBOCHARGER—An exhaust driven compressor that forces air into the engine.

TWO-STROKE CYCLE ENGINE—An internal combustion engine requiring but two piston strokes to complete the cycle of events that produce power.

UNIT FUEL INJECTOR—An assembly which receives fuel under supply pressure and is then actuated by an engine mechanism to meter and inject the charge of fuel to the combustion chamber at high pressure and at the proper time.

UNIT PUMP—An injection pump containing no actuating mechanism to operate the pumping element or elements.

VALVE—A mechanism that can be opened or closed to control or stop the flow of a liquid, gas, or vapor from one space to another.

VALVE-ACTUATING MECHANISM—A group of parts that work together to receive power from the drive mechanism (camshaft) and transmit that power to the engine valves.

VALVE GUIDE—A hollow shaft pressed into the cylinder head to keep the valve in proper alignment.

VALVE LASH—Clearance between the top of the valve stem and the valve-lifting mechanism.

VALVE LIFT—The distance a valve moves from the fully closed to the fully open position

VALVE OVERLAP—The period of crankshaft rotation during which both the intake and exhaust valves are open. It is measured in degrees.

VALVE REFACING MACHINE—A special machine used to resurface the face and extend the life of a valve.

VALVE RETAINER—A device designed to lock the valve-spring retainer to the valve stem.

VALVE ROTATOR—A mechanical device locked to the end of the valve stem (used in place of a valve spring retainer) that forces the valve to rotate about 5° with each rocker arm action.

VALVE SEAT—The surface, normally curved, against which the valve disk's operating face comes to rest to provide a seal against leakage of liquid, gas, or vapor.

VALVE SEAT INSERT—A metal ring inserted into the valve seat, made of special metal that can withstand engine operating temperatures.

VALVE SPRING—The compression-type spring that closes the valve when the valve-operating cam assumes a closed-valve position.

VAPORIZATION—A change of state from liquid to vapor gas, by evaporation or boiling; a general term including both evaporation and boiling.

VAPOR LOCK—A condition in the fuel system in which gasoline vaporizes in the fuel line or fuel pump; bubbles of gasoline vapor restrict or prevent fuel delivery to the carburetor.

VARIABLE SPEED FAN—An engine fan that will not exceed a predetermined speed or will rotate only as fast as required to prevent engine overheating.

VENTURI—In the carburetor, a narrowed passageway or restriction that increases the velocity of air moving through it, produces the vacuum responsible for the discharge of fuel from the fuel nozzle.

VIBRATION—An unceasing back and forth movement over the same path; often with reference to the rapid succession of motions of parts of an elastic body.

VIBRATION DAMPER—A weighted device that is attached to the engine crankshaft at the end opposite its power output. Its purpose is to absorb engine vibration.

VISCOSITY—The resistance to flow exhibited by a liquid. A thick oil has a greater viscosity than a thin oil.

VOLATILITY—A measure of the ease with which a liquid vaporizes. Volatility has a direct relationship to the flammability of a fuel.

VOLUME—The amount of air in the combustion space of an engine cylinder.

VOLUMETRIC EFFICIENCY—The ratio between the amount of air-fuel mixture that actually enters an engine cylinder and the amount that could enter under ideal conditions.

V-TYPE ENGINE—An engine with two banks of cylinders set at an angle to each other in the shape of a V.

WASTE GATE—A control device on a turbocharger to limit boost pressure, thereby preventing engine and turbocharger damage.

WATER JACKETS—The spaces between the inner and outer shells of the cylinder block and head through which coolant circulates.

WATER PUMP—In the cooling system, the device that circulates coolant between the engine water jackets and the radiator.

WORK—The result of a force acting against opposition to produce motion. It is measure in terms of the product of the force and the distance it acts.

APPENDIX II

ANSWER KEY

CHAPTER 1 - TECHNICAL ADMINISTRATION

MAINTENANCE ADMINISTRATION

Q1. maintenance supervisor

Q2. 40 working days

Q3. P-300

Q4. one

Q5. indirect labor

MAINTENANCE SUPPORT

Q6. H level

Q7. 1250-2

Q8. 24 hours

Q9. PM groups

Q10. maintenance supervisor

CHAPTER 2 - PRINCIPLES OF AN INTERNAL COMBUSTION ENGINE

INTERNAL COMBUSTION ENGINE

Q1. rotary motion

Q2. fuel, air, ignition

Q3. four (cylinder, piston, connecting rod, and crankshaft)

Q4. scavenging

CLASSIFICATION OF ENGINES

Q6. fuel, lubrication, electrical, cooling, and exhaust systems

Q7. horizontal opposed

Q8. 180°

Q9. I-head

Q10. F-head

ENGINE MEASUREMENTS AND PERFORMANCE

Q11. one foot

Q12. prony brake

Q13. friction

Q14. mechanical efficiency

Q15. liters

CHAPTER 3 - CONSTRUCTION OF AN INTERNAL COMBUSTION ENGINE

ENGINE CONSTRUCTION

Q1. cylinder sleeves or liners

Q2. wet- and dry-type

Q3. cup and disk

Q4. crankcase

Q5. scavenging

Q6. manifold heat control valve

Q7. synthetic rubber and wick

Q8. head, skirt, ring grooves, and lands

Q9. anchored, semi-floating, full-floating

Q1O. provide a seal between piston and cylinder wall, contains lubricating oil, and provides a solid bridge to conduct heat from piston to cylinder wall

Q11. crankshaft

Q12. camshaft, followers, pushrods, and rocker arms

Q13. mushroom, semi-tulip, and tulip

Q14. stellite

Q15. umbrella and O ring

ENGINE ADJUSTMENTS AND TEST

Q16. spring squareness, spring free height, and spring tension

Q17. normal operating temperature

Q18. piston rings and cylinders may be worn and leaking pressure

Q19. incorrect timing

Q20. leaking intake valves

CHAPTER 4 - GASOLINE FUEL SYSTEMS

GASOLINE FUEL SYSTEM

Q1. antiknock

Q2. octane rating

Q3. fuel neck restrictor

Q4. wet- and dry-type

PRINCIPLES OF CARBURETION

Q5. float, idle, off-idle, acceleration, high speed, full power, choke

Q6. float

Q7. throttle return dashpot

Q8. manifold pressure sensor (MAP)

GASOLINE FUEL INJECTION

Q9. timed injection

Q10. crankshaft postion sensor

Q11. throttle positioner

EXHAUST AND EMISSIONS CONTROL SYSTEMS

Q12. hydrocarbons, carbon monoxide, and oxides of nitrogen

Q13. platinum and palladium

Q14. monolithic

Q15. coolant temperature switch

CHAPTER 5 - DIESEL FUEL SYSTEMS

DIESEL FUEL SYSTEM

Q1. 2D

Q2. pour point

Q3. cleaniness

Q4. spherical

Q5. ischronous

Q6. electronic governor

Q7. hydraulic power piston

Q8. six

Q9. 2 to 2 1/2 inches

METHODS OF INJECTION

Q10. meter, inject, time, atomize, and create pressure

Q11. 9 gallons per minute

Q12. front end of the engine camshaft

Q13. low side of the injection pump housing

Q14. drive shaft, distributor rotor, transfer pump

Q15. maximum outward travel of the plungers

Q16. spring-loaded ballcheck return fitting

Q17. 65 to 75 psi

Q18. unit type

Q19. one

Q20. AFC device

Q21. PT pump is not timed to the engine

Q22. oil temperature sensor

Q23. 140 psi

Q24. control valve

Q25. multifuel

Q26. fuel density compensator

SUPERCHARGERS AND TURBOCHARGERS

Q27. intercooler

Q28. sealing rings

COLD **WEATHER STARTING AIDS**

Q29. manifold flame heater

Q30. extreme emergencies

DIESEL FUEL SYSTEM MAINTENANCE

Q31. daily

Q32. clean work area

GENERAL TROUBLESHOOTING

Q33. 3 to 5 minutes

Q34. blue

Q35. push down and hold the injector follower with a large screwdriver

CHAPTER 6 - COOLING AND LUBRICATING SYSTEM

COOLING SYSTEMS

Q1. air-cooled

Q2. radiator

Q3. downflow and crossflow

Q4. bottom of the cap

Q5. thermostatic

Q6. thermostat

Q7. 50/50

Q8. fast, reversing, and chemical

Q9. hydrometer and refractometer

Q10. hand-operated air pump

LUBRICATING SYSTEM

Q11. viscometer

Q12. by the letter W (10W30)

Q13. American Petroleum Institue (API)

Q14. SG

Q15. full-flow and bypass

Q16. splash, combination splash and force-feed, force-feed, and full force-feed

Q17. splash

Q18. full forced-feed

Q19. micrometer and small hole gauge

APPENDIX III

REFERENCES USED TO DEVELOP THIS TRAMAN

NOTE: The following references were current at the time this TRAMAN was published, but you should be sure you have the current editions.

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P

Assignment Questions

Information: The text pages that you are to study are provided at the beginning of the assignment questions.

ASSIGNMENT 1

Textbook Assignment: "Technical Administration" and "Principles of an Internal Combustion Engine," chapters 1 and 2, pages 1-1 through 2-22.

1-1. Guidelines for the maintenance of equipment assigned to the Naval Construction Force are contained in what NAVFAC publication?

1. P-280
2. P-300
3. P-315
4. P-458

1-2. The equipment maintenance branch is normally under the overall supervision of a person having what rank?

1. An EQCM
2. A CMCS
3. A GS-12
4. A CMC

1-3. The overall responsibility for ensuring proper maintenance and repair of all automotive, construction, and materials-handling equipment assigned to an NMCB belongs to what person?

1. The light shop supervisor
2. The heavy shop supervisor
3. The support shop supervisor
4. The maintenance supervisor

1-4. What person is responsible for ensuring that the equipment repair order is complete with times, initials, materials list, and required requisitions?

1. The cost control supervisor
2. The preventive maintenance clerk
3. The shop supervisor
4. The inspector

1-5. What person should report any unscheduled repairs to a piece of CESE to the shop supervisor?

1. The crew leader
2. The inspector
3. The preventive maintenance clerk
4. The maintenance supervisor

1-6. Under normal conditions, an inspector inspects an item of equipment brought into the maintenance shop a total of how many times?

1. One
2. Two
3. Three
4. Four

1-7. What person is responsible for maintaining the deadline file and deadline status board?

1. The cost control supervisor
2. The technical librarian
3. The direct turnover clerk
4. The preventive maintenance clerk

1-8. Which of the following equipment services are included in organizational maintenance?

1. Lubrication and minor adjustments
2. Component rebuilding and major repairs
3. Major overhaul and restoration
4. All of the above

1-9. What is the primary objective of preventive maintenance?

1. Ensure early detection of deficiencies
2. Ensure that the equipment is clean and serviceable
3. Maximize equipment availability and minimize repair cost
4. Perform minor adjustment and services

1-10. What type of maintenance is performed on equipment requiring major overhaul or comprehensive restoration?

1. Operational
2. Organizational
3. Intermediate
4. Depot

1-11. Which of the following maintenance personnel can authorize changes to the PM schedule?

1. Maintenance supervisor
2. Shop supervisor
3. Cost control clerk
4. Inspector

1-12. NCF equipment is scheduled for preventive maintenance at what standard time intervals?

1. Once every 20 calendar days
2. Once every 20 working days
3. Once every 40 calendar days
4. Once every 40 working days

1-13. After the PM system is established and operating, what person should review its effectiveness?

1. Shop supervisor
2. Cost control supervisor
3. Maintenance supervisor
4. Brigade equipment office

1-14. When a prestart check is being performed, the operator should use what form?

1. NACFAC 9-11240/13
2. NAVFAC 11200.1
3. NAVFAC 9-11240/2
4. NAVFAC 11200.12B

1-15. How many times a day is an operator required to inspect an assigned item of CESE?

1. One
2. Two
3. Three
4. Four

1-16. What type of PM is used as an annual safety inspection?

1. 01
2. 02
3. 03
4. 12

1-17. What person may authorize controlled parts interchange on deadline equipment?

1. Brigade equipment office
2. Alfa company commander
3. Maintenance supervisor
4. Shop supervisor

1-18. Which of the following is NOT a reason deadlined vehicles should be inspected on a regular basis?

1. To detect any cannibalization
2. To ensure adequate preservation
3. To prevent deterioration
4. To maximize use of personnel

1-19. What type of ERO is used to estimate damage and have any required repairs performed?

1. 12
2. 07
3. 06
4. 03

1-20. Which of the following information is NOT recorded on the PM record card?

1. Type of PM performed
2. Oil and filter change
3. Cumulative mileage/hours
4. Engine manufacturer

1-21. When repairs are completed, the copy of the ERO filed in the equipment history jacket is what color?

1. White
2. Blue
3. Yellow
4. Green

1-22. Which of the following types of labor is considered direct labor?

1. Material support
2. Project travel
3. Site surveying
4. Safety training

1-23. Completed time cards are forwarded to what department?

1. Administration
2. Operations
3. Safety
4. Supply

1-24. In an NMCB, what person is responsible for general supply, ship's service, material control, and delivery?

1. s-2
2. s-3
3. s-4
4. s-7

1-25. When an NMCB deploys, the initial supply of repair parts should support operations for how many days?

1. 60
2. 90
3. 120
4. 180

1-26. What level of repair parts support is assigned to a CBU?

1. D
2. G
3. H
4. O

1-27. What is the lowest level of repair parts support?

1. O
2. H
3. G
4. D

1-28. Repair parts for use on one make and model of equipment are known as parts

1. peculiar
2. specific
3. consumable
4. common

1-29. To determine the APL(s) pertaining to a particular vehicle, which part of the COSAL should you refer to?

1. I
2. II
3. III
4. IV

1-30. Which part of the COSAL provides a cross reference between part numbers and stock numbers?

1. I
2. II
3. III
4. IV

1-31. What criterion is used to determine how many technical manuals are provided to a unit for each type of vehicle assigned?

1. Vehicle population
2. Location of the maintenance facilities
3. Size of the maintenance facilities
4. None, each unit receives two copies

1-32. Manuals in excess of COSAL quantities must be returned to M3 stock at what location?

1. SPCC Mechanicsburg, Pennsylvania
2. CBC Gulfport, Mississippi
3. CBC Port Hueneme, California
4. CBC Davisville, Rhode Island

1-33. Which of the following forms should you use when requesting repair parts from the supply department?

1. NAVSUP 1949
2. NAVSUP 1342
3. NAVSUP 1250
4. NAVSUP 1099

1-34. When filling out a supply requisition form, you use the communication symbol for zero for what reason?

1. Because zero is not used in the NSN system
2. To allow computer scanning of the requisition
3. It is required by supply
4. To distinguish it from the letter "O"

1-35. What digits in a national stock number (NSN) identify the country where the part was cataloged?

1. lst, 2nd, 3rd, and 4th
2. 5th and 6th
3. 7th, 8th, and 9th
4. 10th, 11th, 12th, and 13th

1-36. Priority "A" (NORS) requisition should be ordered by supply within how many hours?

1. 1 2
2. 2 4
3. 3 6
4. 4 8

1-37. After the requisition number is entered on a NAVSUP 1250, supply returns what copy to the DTO clerk?

1. White
2. Green
3. Pink
4. Yellow

1-38. In what manner are the repair parts summary sheets tiled by the DTO clerk?

1. By NSN number
2. By Julian date
3. By PM group
4. By equipment codes

1-39. An internal combustion engine is a machine that

1. uses heat to create mechanical energy
2. converts heat energy to mechanical energy
3. converts mechanical energy to heat energy
4. use mechanical energy to create heat

1-40. What action forces the piston downward during the operation of a gasoline engine?

1. Compression of the air-fuel mixture
2. Intake of the air-fuel mixture
3. Expansion of the heated gases
4. Exhaust of waste gases

1-41. Reciprocating motion is changed to rotary motion in the combustion engine by means of a

1. piston pin and a connecting rod
2. flywheel and a crankshaft
3. cylinder and a piston
4. crankshaft and a connecting rod

1-42. What are the basic parts of a one-cylinder engine?

1. Cylinder, camshaft, valves, piston, piston pin, connecting rod, and crankshaft
2. Cylinder, valves, piston, piston pin, connecting rod, and crankshaft
3. Cylinder, piston, piston pin, connecting rod, and crankshaft
4. Cylinder, piston, connecting rod, and crankshaft

1-43. What is the ratio of crankshaft revolutions to piston strokes in a one-cylinder engine?

1. 1 to 1
2. 2 to 1
3. 1 to 2
4. 4 to 2

1-44. Which of the following actions occurs during the second stroke in the sequence of strokes in a four-stroke cycle engine?

1. The air-fuel mixture is compressed
2. The piston moves downward
3. The waste gases are exhausted
4. The air-fuel mixture is ignited

1-45. At what point in the cycle of a four-stroke cycle engine does ignition occur?

1. At the end of the compression stroke
2. At the beginning of the intake
3. During the power stroke
4. At the beginning of the compression stroke

1-46. During which stroke in the operating cycle of a four-stroke cycle engine is the greatest force exerted on the piston?

1. Intake
2. Compression
3. Power
4. Exhaust

1-47. In what order do the strokes of a four-stroke cycle engine occur during operation?

1. Compression, power, exhaust, intake
2. Compression, power, intake, exhaust
3. Intake compression, power, exhaust
4. Intake, compression, exhaust, power

1-48. A two-stroke cycle engine operating at the same speed as a four-stroke cycle engine has a power advantage of approximately what percentage’?

1. 30 to 40
2. 50 to 60
3. 60 to 70
4. 70 to 80

1-49. Which of the following reasons accounts for the failure of a two-stroke cycle engine to produce twice the power of a four-stroke cycle engine’!

1. Power is used to drive the blower
2. Burned gases not completely cleared from the cylinder
3. Smaller amount of air is admitted
4. Each of the above

1-50. In a two-stroke cycle engine, one cycle equals one crankshaft revolution and what number of piston strokes?

1. One
2. Two
3. Three
4. Four

1-51. How are engines most commonly classified?

1. The kind of fuel they use
2. Their cooling system
3. Their valve arrangements
4. The number of cylinders

1-52. In a four-stroke cycle, six-cylinder engine, the throws of the crankshaft are set at what number of degrees apart?

1. 180°
2. 120°
3. 90°
4. 45°

1-53. The flywheel of an engine affects the operation of the engine by

1. smoothing out power impulses
2. keeping the engine from stalling
3. preventing crankshaft vibration
4. increasing piston life

1-54. What type of cylinder arrangement has all cylinders cast in a straight line above the crankshaft’?

1. V-type
2. Horizontal opposed
3. In-line
4. Radial

1-55. The firing order is not marked on an engine and a manufacturer's manual is not available. In this case, you use what method to determine the firing order of the engine?

1. Crank the engine by hand while observing the order in which the exhaust valves open
2. Crank the engine by hand while observing the timing mark on the crankshaft
3. Crank the engine with the starter and observe the rotor in the distributor
4. Crank the engine by hand and observe the order in which the intake valves open

1-56. What type of valve arrangement has the intake valves located in the head and the exhaust valves located in the engine block?

1. F-head
2. T-head
3. I-head
4. L-head

1-57. What type of valve arrangement has the intake and exhaust valves located on opposite sides of the cylinder in the block, each requiring their own camshaft?

1. F-head
2. T-head
3. L-head
4. I-head

1-58. What are the definitions of torque, energy, and power-in that order?

1. Turning force, ability to do work, rate of doing work
2. Turning force, rate of doing work, ability to do work
3. Rate of doing work, turning force, ability to do work
4. Rate of doing work, ability to do work, turning force

1-59. What device can provide a quick report on engine conditions by measuring output at various speeds and loads?

1. Prony brake
2. Engine dynamometer
3. Engine analyzer
4. Chassis dynamometer

1-60. The power needed to overcome engine friction is known as

1. inertia
2. engine torque
3. frictional horsepower
4. frictional inertia

1-61. The relationship between the amount of air-fuel mixture that enters an engine cylinder and the amount that could enter is known as what type of efficiency?

1. Mechanical
2. Volumetric
3. Thermal
4. Operational

1-62. Volumetric efficiency of an engine can be increased by which of the following actions?

1. Controlling engine operating temperature
2. Heating the intake mixture
3. Reducing friction loss between moving parts
4. Modifying intake passages

1-63. What is the meaning of the cylinder designation 3 1/4 by 3 1/2 inches?

1. Piston stroke is 3 1/4 inches and cylinder bore is 3 1/2 inches
2. Cylinder diameter is 3 1/4 inches and piston stroke is 3 1/2 inches
3. Cylinder bore is 3 1/4 inches and piston diameter is 3 1/2 inches
4. Piston stroke is 3 1/4 inches and cylinder bore is 3 1/2 inches

1-64. The compression ratio of an engine is determined by

1. subtracting the cylinder volume at TDC from the cylinder volume at BDC
2. dividing the cylinder volume at TDC by the cylinder volume at BDC
3. multiplying the cylinder volume at TDC by the length of the piston stroke
4. dividing the cylinder volume at BDC by the cylinder volume at TDC

1-65. Increasing the compression ratio of an engine provides

1. more power
2. high engine speed
3. higher fuel consumption
4. less cylinder wear

1-66. The period in a four-stroke cycle engine when the intake valves open before the exhaust valves close is known as the

1. opening point
2. closing point
3. valve overlap
4. duration

1-67. Ignition timing should be adjusted so the spark occurs when the piston does which of the following?

1. Nears the end of the compression stroke
2. Starts down on the power stroke
3. Completes the intake stroke
4. Completes the compression stroke

1-68. As engine speed increases, power loss is avoided by altering ignition timing., This is accomplished by what component?

1. High speed compensator
2. Vacuum advance
3. Spark advance
4. Mechanical compensator

ASSIGNMENT 2

Textbook Assignment: "Construction of an Internal Combustion Engine," chapter 3, pages 3-1 through 3-48.

2-1. Gasoline and diesel engines are alike in what respect?

1. Both belong to the same engine family
2. Both have the same basic internal components
3. Both have the same number of cylinders
4. Their internal parts are interchangeable

2-2. What is the function of the stationary parts of an engine?

1. Add power to the engine
2. Keep the engine firmly attached to its supporting base
3. Furnish a framework on which to attach or enclose moveable parts
4. Regulate crankshaft speed

2-3. Which of the following parts provides a basic frame for the liquid-cooled engine used in automotive and construction equipment?

1. Engine base
2. Cylinder head
3. Cylinder block
4. Crankcase

2-4. Aluminum cylinder blocks are cheaper to produce than cast iron cylinder blocks.

1. True
2. False

2-5. An engine block with newly bored cylinders may not vary in diameter by more than

1. 0.0005 in.
2. 0.0050 in.
3. 0.0500 in.
4. 0.5000 in.

2-6. The cylinders of an air-cooled engine are separate from the crankcase and made of what material?

1. Cast iron
2. Nickel
3. Molybdenum
4. Forged steel

2-7. The purpose of the fins surrounding the cylinders of an air-cooled engine is to provide

1. means for strengthening the cylinder walls
2. a large surface area for heat dissipation
3. mounting plates for the cylinder head
4. a uniform diameter the entire length of the cylinder

2-8. What is the function of the cylinder liners in an engine?

1. To prevent scoring and cracking of the engine block
2. To increase cylinder wear limitations
3. To reduce the frequency of engine overhauls
4. To provide a wearing surface other than the engine block

2-9. What is the purpose of the interconnecting passages in the cylinder head and block?

1. To allow access for the removal of casting material
2. To provide a path for the coolant to circulate
3. To prevent cracks in the casting as they cool
4. To provide a path for the lubrication oil to circulate

2-10. What part of the air-cooled engine provides the mounting surface for the cylinders and oil pump?

1. Crankcase
2. Cylinder block
3. Cylinder head
4. Core hole

2-11. On an air-cooled engine, the cylinder heads are made of aluminum to resist corrosion.

1. True
2. False

2-12. The stationary part of an internal combustion engine that carries waste gases of combustion from the cylinders is called the

1. intake manifold
2. exhaust manifold
3. carburetor
4. water pump

2-13. The intake manifold of a gasoline engine is designed to provide the fuel with a short and direct path between the carburetor or fuel injection system and the cylinder. This design reduces the possibility of the air-fuel mixture condensing in the intake manifold.

1. True
2. F a l s e

2-14. What valve controls the amount of exhaust diverted into the intake manifold heat passage in an exhaust-heated intake manifold?

1. Manifold heat control
2. Exhaust control
3. Butterfly
4. Bimetal control

2-15. A gasket is placed between the cylinder head and engine block to

1. prevent gas and water leaks
2. provide even heat distribution
3. maintain clearance between the cylinder head and engine block
4. prevent excessive temperatures within the cylinder head

2-16. From what material are the gaskets for intake and exhaust manifolds usually constructed?

1. Pressed paper
2. Pressed cork
3. Soft metal
4. Asbestos

2-17. Of what type of material are oil pan gaskets usually made?

1. Oil-resistant paper
2. Pressed cork
3. Soft metal
4. Asbestos

2-18. In modem engines, fluid losses through clearances between moving parts and stationary parts are prevented by the use of

1. plastic strips
2. packing glands
3. leather wicks
4. oil seals

2-19. In an engine, heat energy is changed to mechanical energy by the pressure of combustion acting on the

1. connecting rods
2. camshaft
3. crankshaft
4. pistons

2-20. The downward motion of the piston in the cylinder is converted to rotary motion by the action of the

1. gear tram
2. camshaft
3. connecting rod and crankshaft
4. valves

2-21. What design feature is the principal difference between a diesel engine piston and a gasoline engine piston?

1. Diesel engine pistons weigh less than gasoline pistons
2. Diesel engine pistons are made of cast iron while gasoline engine pistons are made of aluminum
3. Diesel engine pistons are usually fitted with more piston rings than gasoline engine pistons
4. Diesel engine piston use oversized lands and piston pins

2-22. What feature is built into pistons to control expansion?

1. A larger crown
2. A slot is cut up the side of the skirt
3. A bronze brace is cast into them
4. Oversized lands

2-23. What are the two types of piston skirts?

1. Partial trunk and full-skirted
2. Full trunk and semiskirted
3. Semi-trunk and full-skirted
4. Full trunk and partial skirted

2-24. The piston pin (wrist pin) attaches the piston to what component?

1. The crankshaft
2. The camshaft
3. The connecting rod
4. The balance shaft

2-25. In addition to sealing off the combustion chamber and distributing lubricating oil, piston rings serve to

1. transfer heat from the pistons to the cylinder walls
2. absorb the shock of the power stroke
3. prevent heat expansion of the piston
4. provide an air bleed during the intake stroke

2-26. The additional groove cut into a piston just above the top ring groove is known as a

1. piston land
2. heat dam
3. oil control groove
4. ring gap

2-27. The split in the piston ring is necessary for installing the ring on the piston and for expansion from heating. This split is known as a

1. ring gap
2. ring joint
3. heat dam
4. staggering gap

2-28. Piston rings are staggered during assembly to

1. allow even heat dissipation
2. prevent cylinder blow-by
3. cause even cylinder wear
4. allow the use of expanders

2-29. Piston rings are coated with what material to minimize scuffing?

1. Graphite
2. Engine oil
3. Silicone
4. Carbide

2-30. During engine operation, thrust from the piston is transmitted to the crankshaft by what component?

1. The balance shaft
2. The camshaft
3. The connecting rod
4. The flywheel

2-31. What type of bearing is used in the piston end of the connecting rod?

1. Roller
2. Ball
3. Bushing
4. Sleeve

2-32. Precision connecting rod bearings are held in position against the crankshaft by

1. projection on the bearing shells
2. bolts that hold the connecting rods together
3. slip fittings on the connecting rod
4. projections on the connecting rod and cap

2-33. The crankshaft of a military engine is normally constructed of what material?

1. Aluminum
2. Cast steel
3. Forged steel
4. Cast iron

2-34. On an in-line six-cylinder engine, the crankshaft throws are set apart by how many degrees?

1. 180°
2. 120°
3. 90°
4. 60°

2-35. What is the function of the counterweights on a crankshaft?

1. To balance the weight of the connecting rod and piston
2. To transmit power from the crankshaft to the camshaft
3. To reduce shock from the power strokes
4. To provide momentum for crankshaft rotation during the compression stroke

2-36. The purpose of thrust faces found on some main bearings is to

1. prevent crankshaft vibration
2. maintain connecting rod alignment
3. eliminate crankshaft end play
4. ensure proper bearing lubrication

2-37. What type of vibration occurs when the crankshaft twists because of the power stroke?

1. Vibration due to deflection
2. Vibration due to imbalance
3. Torsional vibration
4. Thrust vibration

2-38. What part of an engine is likely to fail when subjected to uncontrolled torsional vibrations?

1. Camshaft
2. Piston
3. Connecting rod
4. Crankshaft

2-39. In addition to reducing engine speed fluctuations, the flywheel often serves as a

1. power takeoff for the camshaft and a pressure surface for the clutch
2. pressure surface for the clutch and starting system gear
3. starting system gear and a power takeoff for the fuel pump
4. power takeoff for the fuel pump and a timing reference for the ignition system

2-40. Which of the following components does not help to make up the valve-actuating mechanism?

1. Camshaft and camshaft followers
2. Pushrods
3. Rocker arms
4. Crankshaft

2-41. What is the function of the camshaft?

1. To hold the valves in place
2. To force gases from the combustion chamber
3. To operate the valve mechanism
4. To rotate the valves

2-42. On what type of engine head is the camshaft usually located directly above the crankshaft?

1. V
2. L
3. I
4. F

2-43. The camshaft of a two-stroke cycle engine will rotate at what speed when the crankshaft speed is 1,000 rpm?

1. 250 rpm
2. 500 rpm
3. 1,000 rpm
4. 2,000 rpm

2-44. The camshaft may have external gears or cams that operate the fuel injectors, lubrication pump, and fuel pump.

1. True
2. False

2-45. What type of mechanical follower (tappet) is used in heavy-duty applications?

1. Roller
2. Mushroom
3. Flathead
4. Adjusting

2-46. How is zero clearance maintained by the hydraulic type tappet shown in figure 3-48 in the text?

1. By vacuum pressure
2. By oil pressure
3. By cam lobe action
4. By spring action

2-47. Poppet-type valves are not designed in which of the following shapes?

1. Mushroom
2. Tulip
3. Semitulip
4. Semimushroom

2-48. Because the exhaust valves of an engine can experience temperatures in excess of 1300°F, the valve IS normally made of what type of alloy?

1. Nickel chromium
2. Nickel sodium
3. Silichrome
4. Silichrome chromium

2-49. In vehicles that use unleaded -fuel. the wear of the valve face and seat IS accelerated. What type of valve is used to decrease wear and prolong the life of the valve?

1. Stellite
2. Mushroom
3. Poppet
4. Sodium-filled

2-50. An accumulation of carbon on valve seats will result in what problem?

1. Increased valve life
2. Cooler operating temperatures
3. Positive valve seating
4. Improper valve closure

2-51. Valve seat inserts used in aluminum engines are made of what material to withstand the extreme heat produced'?

1. Steel
2. Bronze
3. Copper
4. Zinc

2-52. The close clearance between the valve guide and the valve stem is important for which of the following reasons?

1. Allows lubricating oil into the combustion chamber
2. Permits exhaust gases into the crankcase
3. Permits exhaust gases into the combustion chamber
4. Keeps the valve face in alignment with the valve seat

2-53. Valve float is caused by which of the following conditions?

1. Low spring tension
2. Excessive spring tension
3. Weak valve retainer
4. Weak valve rotator

2-54. Valve reconditioning does not include which of the following?

1. Grinding valves and valve seats
2. Adjusting valve tappet clearance
3. Timing the valves
4. Sanding the rings

2-55. What part of the engine must be removed before the valves are accessible'?

1. Cylinder head
2. Exhaust manifold
3. Intake manifold
4. Valve-operating mechanism

2-56. During reassembly of an engine, replacing the valves in their original guides will ensure

1. excessive wear of the valve and guide
2. less wear of the valve and guide
3. failure of the valve to seat properly
4. noisy valve operation

2-57. The difference between valve seat angle and valve face angle is known as interference angle.

1. True
2. False

2-58. One procedure for checking valve guide wear involves the use of what instrument(s)?

1. A thickness gauge only
2. A hole gauge and micrometer
3. A depth gauge and micrometer
4. A valve guide gauge only

2-59. What procedure is used to compensate for valve guide wear?

1. Reaming
2. Boring
3. Knurling
4. Honing

2-60. Once the valve guides are serviced and the valve seats are ground, the concentricity of the two are checked using what measuring instrument?

1. Hole gauge
2. Valve seat dial indicator
3. Micrometer
4. Bore gauge

2-61. When replacing pressed-in valve seats, you should chill the new inserts in dry ice for 15 minutes.

1. True
2. False

2-62. When the valve seat does not touch the valve face properly, the seat must be reground at different angles. This procedure is known as

1. narrowing a valve
2. lapping a valve
3. squaring a valve
4. bluing a valve

2-63. Which of the following checks does not have to be made on valve springs before reassembling them?

1. Squareness
2. Free height
3. Tension
4. Tensile strength

2-64. Which of the following actions is a step in the procedure for installing the directly driven timing gears on an engine?

1. Position the gears so that the single marked tooth of one gear is between the two marked teeth of the other gear
2. Rotate the two gears until their marked teeth can be aligned with a straightedge
3. Install the timing chain after positioning the crankshaft and camshaft gears
4. Match the idler gear teeth with those on the camshaft and crankshaft

2-65. Oil moving across the face of a bearing does not accomplish which of the following functions?

1. Cools the bearing
2. Lubricates the bearing
3. Removes dirt from the bearing
4. Heats the bearing

2-66. The back of the typical bearing half is made of what bearing?

1. Cast iron
2. Bronze
3. Steel
4. Copper

2-67. Which of the following metal alloys is not plated on the back of a typical bearing halt?

1. Babbitt
2. Aluminum
3. Copper
4. Bronze

2-68. What test is the most often used to determine the mechanical condition of an engine?

1. Vacuum gauge
2. Compression
3. Cylinder leakage
4. Computer control

2-69. When a compression test is performed on a gasoline engine, the compression reading from the highest to the lowest cylinder should not vary over 15 to 20 psi.

1. True
2. False

2-70. When a vacuum test is performed above 1,000 feet, the average reading will lose approximately what amount of inches of vacuum per 1,000 feet?

1. 1 in.
2. 2 in.
3. 3 in.
4. 4 in.

2-71. When a vacuum test is being performed, the gauge drops to 15 inches and remains there. This reading indicates the existence of what problem?

1. Improper idling adjustment
2. Compression leak between the cylinder walls and the piston rings
3. Electrodes set to close on the spark plugs
4. Compression leak between the cylinder head and the engine block

2-72. When performing a cylinder leakage test, you must ensure the piston is at what position'?

1. BDC
2. TDC
3. ATDC
4. BBDC

2-73. When a cylinder leakage test is performed, a leaking head gasket is indicated by which of the following conditions?

1. Bubbles in the coolant at the radiator
2. Excessive hissing of air at the oil tiller tube
3. Loud hissing of air at the carburetor
4. Coolant observed coming out the exhaust pipe

ASSIGNMENT 3

Textbook Assignment: "Gasoline Fuel Systems," chapter 4, pages 4-1 through 4-48.

3-1. What type of additives are used in leaded gasoline to slow down ignition?

1. Antiping
2. Antiknock
3. Anticombustion
4. Antioxidants

3-2. Which of the following properties is NOT a property of gasoline?

1. Volatility
2. Antiknock quality
3. Cetane number
4. Octane rating

3-3. The measurement of the ability of a fuel to resist knock or ping is known as

1. air-fuel ratio
2. cetane number
3. volatility
4. octane rating

3-4. A mixture of 9 parts of air and 1 part of gasoline is richer than one consisting of 18 parts of air and 1 part of gasoline.

1. True
2. False

3-5. Which of the following air-fuel ratios is considered to be perfect for a gasoline engine?

1. 8:1
2. 10:1
3. 15:1
4. 20: 1

3-6. An air-fuel mixture that is too lean will cause which of the following conditions?

1. Increased power
2. Increased fuel consumption
3. Poor engine performance
4. Decreased exhaust emissions

3-7. Which of the following is NOT a condition of abnormal combustion?

1. Detonation
2. Pre-ignition
3. Dieseling
4. Spark ping

3-8. Which of the following factors can cause dieseling in a gasoline engine?

1. Low octane fuel
2. Low heat range spark plugs
3. Incorrect timing
4. Hot exhaust valve

3-9. What device is used in the filler neck of a gasoline fuel tank to prevent the accidental use of leaded fuel?

1 A fuel valve
2. A restrictor
3. A vacuum valve
4. A fuel Nozzle

3-10. What is the function of the baffles in a fuel tank?

1. To reinforce the bottom of the fuel tank
2. To reinforce the sides of the fuel tank
3. To prevent the fuel from sloshing and splashing
4. To prevent the escape of fuel and fuel vapors from the tank

3-11. Fuel filters are NOT made of which of the following materials?

1. Sintered brass
2. Ceramic
3. Treated paper
4. Metal screen

3-12. What is the function of the fuel pump?

1. To measure the amount of fuel that enters the carburetor or fuel injectors
2. To deliver the fuel from the tank to the engine under pressure
3. To pump fuel from the carburetor to the intake manifold
4. To pump fuel from the carburetor through the fuel filter into the manifold

3-13. What are the two types of fuel pumps used in a gasoline fuel system?

1. Electric and pneumatic
2. Electromechanical and hydraulic
3. Mechanical and electromechanical
4. Mechanical and electrical

3-14. What type of fuel pump delivers fuel continuously?

1. Autopulse
2. Positive displacement
3. Nonpositive displacement
4. Diaphragm

3-15. When a vacuum test is being performed on a fuel pump, what reading indicates a good fuel pump?

1. 3 to 5 in/hg
2. 5 to 7 in/hg
3. 7 to 10 in/hg
4. 10 to 15 in/hg

3-16. Fuel lines are normally made of what material?

1. Single-wall steel tubing
2. Double-wall steel tubing
3. Single-wall copper tubing
4. Double-wall copper tubing

3-17. What part of the carburetor controls air flow through the air horn?

1. Main discharge tube
2. Carburetor body
3. Venturi
4. Throttle valve

3-18. The function of the venturi in a carburetor is to

1. lower the atmospheric pressure in the float bowl to force fuel through
2. reduce the rate of vaporization by lowering the pressure of the air entering the carburetor
3. spray the fuel in the air by increasing the speed of the air entering the carburetor
4. produce sufficient suction to pull fuel out of the main discharge tube

3-19. The fuel supply in the carburetor bowl is controlled by the

1. float
2. choke
3. throttle
4. fuel pump

3-20. What component of the float system regulates the amount of fuel passing through the fuel inlet of a carburetor?

1. Needle valve
2. Carburetor float
3. Bowl vent
4. Vacuum pump

3-21. At speeds below 800 rpm or 20 mph, the air-fuel mixture of the engine is controlled by what carburetor system?

1. Off-idle
2. Idle
3. Acceleration
4. Choke

3-22. When adjusting the idle on a carburetor, the idle mixture screw is turned out to increase the size of the idle port. This action increases the fuel mixture at idle.

1. True
2. False

3-23. When the acceleration pump is opened, what component controls the length of time that the stream of fuel will last?

1. Pump check ball
2. Pump check weight
3. Duration spring
4. Throttle linkage

3-24. What system provides the leanest and most fuel efficient air-fuel ratio?

1. Idle
2. Off-idle
3. Full power
4. High speed

3-25. Which of the following carburetor components is designed to increase engine power and also maintains reasonable economy?

1. Power jet
2. Metering jet
3. Vacuum jet
4. Mechanical jet

3-26. A choke alters the air-fuel mixture that enters the manifold of a cold gasoline engine during starting by admitting

1. less air
2. more air
3. less fuel and more air
4. more fuel and more air

3-27. What type of automatic choke mounts the thermostatic spring in the top of the exhaust manifold?

1. Exhaust manifold
2. Heated well-type
3. Engine coolant
4. Electrical

3-28. What device cracks open the choke plate as soon as the engine starts, thus preventing the engine from flooding?

1. Fast idle cam
2. Choke linkage
3. Fast idle solenoid
4. Vacuum choke unloader

3-29. On a carburetor, what device keeps the throttle from closing too quickly when the accelerator pedal is suddenly released?

1. Fast idle solenoid
2. Throttle return dashpot
3. Antistall solenoid
4. Throttle decelerator dashpot

3-30. Under high engine temperatures, what device prevents the engine from stalling or idling rough by admitting extra air into the engine to increase idle speed?

1. Temperature compensator
2. Temperature idle cam
3. Hot idle compensator
4. Venturi vent compensator

3-31. In a computerized carburetor, what sensor allows the computer to enrich the fuel mixture during cold engine operations?

1. Manifold pressure
2. Oxygen
3. Mixture control
4. Temperature

3-32. The manifold pressure sensor (MAP) measures exhaust manifold pressure and engine load.

1. True
2. False

3-33. In a computerized carburetor, what device alters the air-fuel mixture?

1. Throttle control solenoid
2. Idle speed solenoid
3. Mixture control solenoid
4. Oxygen pressure solenoid

3-34. In a carburetor system, which of the following conditions does NOT result in excessive fuel consumption?

1. High float level
2. Sticking metering rod
3. Too lean an idling mixture
4. Sticking accelerator pump

3-35. Which of the following carburetor conditions can be attributed to a poorly operating accelerator pump?

1. Sluggish engine
2. Poor idling
3. Slow engine warm-up
4. Smoky black exhaust

3-36. The engine runs but misses. This malfunction is most likely caused by which of the following conditions?

1. Very lean air-fuel mixture
2. Clogged fuel line
3. Incorrectly adjusted choke
4. Vacuum leak at the intake manifold

3-37. Which of the following conditions is a good indication that the float level is too high?

1. High speed nozzle is dripping
2. Engine speeds up slightly
3. Discharges a squirt of fuel into the air horn
4. Engine runs rough at idle

3-38. When you are making a quick check of the main metering system, after placing a piece of stiff cardboard over the air horn, engine speed should

1. speed up slightly
2. stay the same
3. slow down slightly
4. speed up then slow down

3-39. Which of the following attributes is NOT an advantage of a gasoline injection system over a carburetor type system?

1. Improved atomization
2. Better fuel distribution
3. Richer fuel mixture
4. Lower emissions

3-40. In a gasoline indirect injection system, fuel is sprayed into the

1. precombustion chamber
2. cylinder
3. combustion chamber
4. intake manifold

3-41. Of the gasoline fuel injection systems, what system is the most precise and also the most complex?

1. Hydraulic-timed injection
2. Throttle body fuel injection
3. Timed fuel injection
4. Continuous fuel injection

3-42. In a mechanical-timed injection system, the throttle valve regulates engine speed and power output by regulating the

1. intake pressure
2. manifold vacuum
3. exhaust pressure
4. metering pump vacuum

3-43. Which of the following is NOT a subsystem of an electronic-timed fuel injection system?

1. Fuel delivery system
2. Air induction system
3. Computer control system
4. Fuel metering system

3-44. In an electronic fuel injection system, what sensor measures the amount of outside air entering the engine?

1. Air flow
2. Inlet air temperature
3. Manifold pressure
4. Oxygen

3-45. In an electronic fuel injection system, the fuel pressure regulator diverts the excess fuel to which of the following locations?

1. Back to the fuel tank
2. Inlet side of the fuel filter
3. Inlet side of the fuel pump
4. Back to the inlet side of the fuel line

3-46. In a continuous fuel injection system, the cold start injector is activated by electric current from what sensor?

1. Air inlet temperature
2. Air flow
3. Manifold pressure
4. Thermal

3-47. What component of a throttle body injection system contains the fuel pressure regulator?

1. Throttle air horn
2. Throttle body housing
3. Throttle positioner
4. Throttle fuel mixture valve

3-48. What component actuates the throttle positioner to open and close the throttle plates?

1. Electric current
2. Hydraulic pressure
3. Computer
4. Pressure regulator

3-49. Of the following chemical compounds, which one is NOT a major pollutant?

1. Carbon dioxide
2. Carbon monoxide
3. Hydrocarbons
4. Oxides of nitrogen

3-50. In areas with heavy vehicular traffic, hydrocarbons in heavy concentrations produce a gray fog. This fog is known as photochemical smog.

1. True
2. False

3-51. Exhaust manifolds are made from what type of material?

1. Aluminum
2. Steel
3. Cast iron
4. Iron alloy

3-52. The manifold heat control valve deflects exhaust gases toward a hot spot in the exhaust manifold until the engine reaches operating temperature.

1. True
2. False

3-53. What device is used to reduce the acoustic pressure of exhaust gases and discharge the gases into the atmosphere?

1. Resonator
2. Catalytic converter
3. Muffler
4. Exhaust manifold

3-54. The catalytic converter changes carbon monoxide and hydrocarbons into carbon dioxide and

1. hydrogen
2. oxygen
3. methane
4. water

3-55. What two materials inside a catalytic converter act as a catalyst?

1. Silver and bronze
2. Bronze and platinum
3. Silver and palladium
4. Platinum and palladium

3-56. In an air injection system, what device is used to prevent air from entering the exhaust system during deceleration?

1. Air distribution manifold
2. Air check valve
3. Air pump
4. Diverter valve

3-57. What device keeps exhaust gases from entering the air injection system?

1. Air check valve
2. Diverter valve
3. Air distribution manifold
4. Air pump

3-58. The open type positive crankcase ventilation system has a sealed breather that is connected to the air filter by a hose.

1. True
2. False

3-59. To control the formation of oxides of nitrogen, the exhaust gas recirculation system recirculates a portion of the exhaust gases back through the

1. intake manifold
2. exhaust manifold
3. muffler
4. catalytic converter

3-60. At idle, engine vacuum is blocked off so it cannot act on the EGR valve. How is this accomplished?

1. By a closed diverter valve
2. By a closed vacuum diaphragm
3. By a closed throttle plate
4. By a closed heat control valve

3-61. The fuel dome provides what amount of air space for fuel heating and volume increase?

1. 5 percent
2. 10 percent
3. 15 percent
4. 20 percent

3-62. What device is used to prevent fuel from entering the fuel tank vent line in the event of a accident in which the vehicle turns over?

1. Purge valve
2. Fuel tank valve
3. Roll-over valve
4. Spillage valve

3-63. The charcoal canister does not store fuel vapors when the engine is running.

1. True
2. False

3-64. What component connects the charcoal canister to the engine intake manifold and is used to clean out stored fuel vapors from the charcoal canister?

1. Purge line
2. Carburetor vent line
3. Fuel tank vent line
4. Liquid-vapor separator

3-65. When the engine is turned off, heat produces excess vapors. These vapors are carried to the charcoal canister through the

1. liquid-vapor separator
2. fuel tank vent line
3. carburetor vent line
4. purge line

ASSIGNMENT 4

Textbook Assignment: "Diesel Fuel Systems," chapter 5, pages 5-1 through 5-54.

4-1. What factor makes it possible to ignite the air-fuel mixture of a diesel engine without the use of a spark plug as required in a gasoline engine?

1. The ignition temperature of diesel fuel is low
2. The compression ratio of the diesel engine is low
3. The compression temperature of the diesel engine is high
4. The speed of the diesel engine's moving parts is high

4-2. What action controls the speed of a diesel engine?

1. Regulation of the amount of fuel delivered to the engine's cylinders
2. Alteration of the compression pressure within the engine's cylinders
3. Regulation of the volume of air entering the cylinders
4. Limitation of the capacity of the fuel injection system

4-3. Which of the following characteristics is one advantage of the diesel engine over the gasoline engine?

1. Low production cost
2. Suitability for vehicles transporting small loads
3. Smoothness of operation
4. High ratio of power output to fuel consumed

4-4. Which of the following items is NOT considered a disadvantage of the diesel engine as compared to the gasoline engine?

1. High cost of manufacture
2. Heavier construction required to withstand high compression pressures
3. Difficulty in starting
4. Less of a fire hazard

4-5. What agency is responsible for grading diesel fuel?

1. Society of Automotive Engineers
2. American Petroleum Institute
3. American Society for Testing And Materials
4. Society of Automotive Petroleum

4-6. What grade of diesel fuel is used in truck fleets because of its greater heat value?

1. 1D
2. 2D
3. 3D
4. 4D

4-7. Which of the following factors must be considered when selecting a fuel oil?

1. Engine size and design
2. Fuel cost and availability
3. Atmospheric conditions
4. Speed and load range

4-8. The measure of the volatility of a diesel fuel is known as

1. cetane number
2. octane number
3. distillation number
4. stability number

4-9. If the cetane number of a diesel fuel is too low, which of the following conditions can result?

1. Pre-ignition
2. Difficulty in starting
3. Puffs of blue smoke during start-up
4. Detonation

4-10. Current diesel fuels have a cetane rating that ranges between

1. 20 and 25
2. 30 and 35
3. 40 and 45
4. 50 and 55

4-11. Low volatile fuels tend to provide better fuel economy and produce

1. more crankcase dilution
2. higher exhaust temperature
3. less exhaust smoke
4. less lubrication

4-12. Which of the following properties has a direct bearing on the life expectancy of the engine and its components?

1. Sulfur content
2. Viscosity
3. Volitilty
4. Cleanliness and stability

4-13. Which of the following combustion chamber designs is the simplest form?

1. Precombustion
2. Spherical
3. Turbulence
4. Open

4-14. Which of the following combustion chamber designs requires the highest fuel injection pressure?

1. Open
2. Precombustion
3. Turbulence
4. Spherical

4-15. When precombustion chambers are used on a diesel engine, which of the following factors cause the greatest amount of fuel atomization?

1. Rapid air movement within the cylinders
2. High fuel injection pressure
3. Dispersion of fuel from the multi-orifice fuel injectors
4. Turbulence within the precombustion chamber

4-16. Which of the following combustion chamber designs is principally used in the multifuel engine?

1. Turbulence
2. Spherical
3. Open
4. Precombustion

4-17. Which of the following components is designed to prevent an engine from overspeeding and allow the engine to meet changing load conditions?

1. Fuel pump
2. Carburetor
3. Throttle valve
4. Governor

4-18. At what location is the governor connected on a diesel engine?

1. Next to the fuel pump
2. Between the throttle and the fuel injector
3. Between the fuel pump and the fuel filter
4. Between the fuel filter and throttle

4-19. Which of the following terms is used to describe the change in speed required before the governor makes a corrective movement of the throttle?

1. State of balance
2. Isochronous
3. Deadband
4. Response time

4-20. What type of governor prevents an engine from exceeding a specified maximum speed?

1. Limiting-speed
2. Constant-speed
3. Variable-speed
4. Load-control

4-21. What type of governor maintains any specified engine speed between idle and maximum speed?

1. Load-limiting
2. Load-control
3. Pressure-regulating
4. Variable-speed

4-22. Which of the following governors provides a regular or stable engine speed, regardless of load conditions?

1. Variable-speed
2. Constant-speed
3. Load-control
4. Pressure-regulating

4-23. What part of a spring-loaded mechanical governor does the manual throttle directly adjust?

1. Linkage between flyballs and injectors
2. Spring tension
3. Position of flyballs
4. Centrifugal-force generator

4-24. The tension of the spring in the mechanical flyweight governor has a tendency to

1. stabilize the amount of fuel delivered to the cylinders
2. reduce the amount of fuel delivered to the cylinders
3. increase the amount of fuel delivered to the cylinders
4. increase and reduce the amount of fuel delivered to the cylinders

4-25. For engine speed to stabilize, what condition must exist within the governor?

1. Centrifugal force must overcome spring tension
2. Spring tension must overcome centrifugal force
3. Centrifugal force and spring tension must balance fuel supply pressure
4. Centrifugal force and spring tension must be equalized

4-26. Which of the following is NOT an advantage of a mechanical governor?

1. Inexpensive to manufacture
2. Very simple, few parts
3. Large deadbands
4. Not required to maintain the same speed, regardless of load

4-27. The hydraulic governor is inherently unstable. To maintain stability, hydraulic governors employ

1. speed droop
2. deadbands
3. sensitivity
4. isochronous

4-28. In an electronic governor, at what location is the magnetic pickup sensor installed?

1. Next to a drive shaft gear
2. Between the crankshaft and electronic control module
3. Between the flyweights and springs
4. Next to the idle speed control

4-29. Sediment or water is prevented from entering the fuel system because the inlet fuel line is approximately 2 inches from the bottom of the tank.

1. True
2. False

4-30. The secondary fuel filter should be capable of removing dirt particles of what size?

1. Between 5 to 7 microns
2. Between 7 to 9 microns
3. Between 10 to 12 microns
4. Between 13 to 15 microns

4-31. Why is it necessary to have a supply pump to transfer fuel from the tank to the injection pump of a diesel engine?

1. Because the injection pump will not create sufficient suction
2. Because the fuel filters pass fuel only under pressure
3. Because the injection pump will deliver excessive fuel to the engine
4. Because use of the injection pump alone will cause the fuel system to become airbound

4-32. Which of following types of supply pumps are used on a diesel engine?

1. Electric
2. Wobble-plate
3. Rotary
4. Gear

4-33. What are the five functions of a diesel fuel system?

1. Measure, introduce, timed, atomization, and create force
2. Meter, inject, time, atomize, and create pressure
3. Measurable, insert, timing, atomiferous, and catalyze
4. Metered, introjection, timer, atomism, and catalysis

4-34. The rate at which fuel is injected also determines the rate of

1. combustion
2. speed
3. timing
4. distribution

4-35. What type of injection system is used on Caterpillar diesel engines?

1. Unit injection
2. Pump and nozzle
3. Distributor
4. Pressure time

4-36. What action varies the metering of fuel in a Caterpillar injection system?

1. An increase and decrease in the nozzle orifices
2. Controlled cam and spring action
3. Turning of the plungers in the barrels
4. Turning of the rack and pinion

4-37. Which of the following features was NOT a design consideration in the Caterpillar sleeve metering fuel system?

1. Fewer moving parts
2. A hydraulic assist governor
3. Fuel lubricates all internal parts
4. Transfer pump, governor, and injection pump all in one unit

4-38. With the engine operating at full load, the transfer pump fills the injection pump housing with fuel at approximately

1. 10 to 15 psi
2. 20 to 25 psi
3. 30 to 35 psi
4. 40 to 45 psi

4-39. At approximately what rate does the constant bleed valve return fuel back to the fuel tank?

1. 2 gallons per hour
2. 5 gallons per hour
3. 9 gallons per hour
4. 12 gallons per hour

4-40. What type of governor is used on the sleeve metering fuel system?

1. Mechanical
2. Hydraulic
3. Electronic
4. Hydromechanical

4-41. The automatic timing advance on a sleeve metering fuel system is at what location?

1. On the rear of the engine camshaft
2. On the rear of the engine crankshaft
3. On the front of the engine camshaft
4. On the front of the engine crankshaft

4-42. On a 3406 Caterpillar engine using a scroll metering system, what is the opening pressure of the injection nozzle?

1. Between 1200 and 2350 psi
2. Between 1750 and 2500 psi
3. Between 2000 and 2800 psi
4. Between 2400 and 3100 psi

4-43. What type of governor is used in a scroll metering fuel system?

1. Hydromechanical
2. Mechanical
3. Hydraulic
4. Electronic

4-44. What type of seal is used to prevent engine oil from entering the DB2 fuel pump?

1. Two cone seals
2. Two lip seals
3. Two O rings
4. Two Quad-X rings

4-45. In a DB2 fuel pump, the hydraulic head has a number of charging and discharging ports. This design feature is based on the

1. maximum speed of the engine
2. volume requirements of the engine
3. pressure requirements of the engine
4. number of engine cylinders

4-46. What type of transfer pump is used in the DB2 fuel pump?

1. Positive displacement vane type
2. Positive displacement rotary type
3. Positive displacement electric type
4. Positive displacement piston type

4-47. What action limits the maximum amount of fuel that can be injected by the DB2 fuel pump?

1. The outward travel of the plungers
2. The roller shoes contacting the leaf spring
3. The opening of the charging ports
4. The movement of the cam lobes

4-48. What component in a DB2 fuel pump serves as a cushion between the governor weight retainer and the weight retainer hub?

1. Flexible governor drive
2. Governor pillow
3. Governor torque drive
4. Flexible torque drive

4-49. Which of the following factors does NOT affect the torque of a DB2 fuel pump?

1. The metering valve opening area
2. The time allowed for fuel charging
3. The transfer pump pressure curve
4. The reduced fuel flow to the pumping plungers

4-50. What component controls the amount of fuel delivered at full-load governor speed?

1. Flexible governor drive
2. Torque screw
3. Metering valve
4. Pumping plungers

4-51. What component maintains fuel pressure within the governor housing on a DB2 fuel pump?

1. Spring-loaded poppet valve
2. Spring-loaded ball-check valve
3. Constant bleed valve
4. Delivery valve

4-52. When repairing a fuel pump on a Detroit diesel, you should NOT use any type of gasket material.

1. True
2. False

4-53. A hole of what diameter is indicated when the restricted fitting on a Detroit diesel engine is stamped R60?

1. 0.0006
2. 0.006
3. 0.060
4. 0.60

4-54. By what means are the injector control racks actuated on the Detroit diesel engine?

1. Camshaft lobes
2. A lever on the injector control tube
3. Fuel pressure
4. Rocker arms and camshaft lobes

4-55. Which of the following conditions must exist on a Detroit unit injector before it can inject fuel?

1. The lower port must be open and the upper port closed
2. The lower port must be closed and the upper port open
3. The lower and upper ports must be closed
4. The lower and upper ports must be open

4-56. When properly timing an unit injector, the injector follower height is adjusted by using which of the following tools?

1. Timing pin gauge
2. Timing light
3. Timing depth gauge
4. Timing height caliper

4-57. Unit injectors are equalized by adjusting the

1. length of stroke of the injector plunger
2. diameter of the injector valve orifices
3. control rack levers
4. amount of centrifugal force exerted on the governor flyweights

4-58. When troubleshooting a Detroit diesel engine, one cylinder has a lower temperature than the others. To supply this cylinder with more fuel, you must make what adjustment to the control rack?

1. Tighten the inner screw after loosening the outer screw
2. Tighten the outer screw after loosening the inner screw
3. Loosen the inner screw but maintain the setting of the outer screw
4. Loosen the outer screw but maintain the setting of the inner screw

4-59. Which of the following governors are NOT used on Detroit diesel engines?

1. Limiting speed mechanical
2. Woodward PSG hydraulic
3. Dual-range limiting speed mechanical
4. Variable high-speed hydraulic

4-60. Engines requiring a minimum and maximum automatic speed control and a manually intermediate speed control are equipped with what type of governor?

1. Woodward electric
2. Hydraulic
3. Limiting speed mechanical
4. Variable speed mechanical

4-61. The PTG-AFC fuel pump meters fuel to the injectors.

1. True
2. False

4-62. The PTG-AFC fuel pump is NOT timed to the engine.

1. True
2. False

4-63. In the PTG-AFC fuel pump, the AFC plunger position is determined

1. by the amount of turbocharger boost pressure in the exhaust manifold
2. by the amount of turbocharger boost pressure in the intake manifold
3. by the amount of supercharger boost pressure in the intake manifold
4. by the amount of supercharger boost pressure in the exhaust manifold

4-64. After replacing the injectors in a Cummins PT fuel system, they are readjusted after the engine has been warmed up. What should the engine oil temperature read after the warm-up?

1. Between 120° and 140°
2. Between 110° and 130°
3. Between 140° and 160°
4. Between 160° and 180°

4-65. When overhauling a set of PT fuel injectors, you must keep them together because they are matched sets.

1. True
2. False

4-66. What sensor in the Cummins Celect system is used by the electronic control module to determine the basic operating altitude of a vehicle?

1. Engine position
2. Intake manifold temperature
3. Ambient air pressure
4. Vehicle speed

4-67. How much pressure is the fuel pump in the Celect fuel system designed to deliver to the fuel manifold?

1. 110 psi
2. 120 psi
3. 130 psi
4. 140 psi

4-68. What type of pump is the American Bosch Model PSB?

1. Variable-stroke, distributing plunger, and sleeve-control
2. Constant-stroke, distributing plunger, and sleeve-control
3. Variable-stroke, distributing plunger, and rack-control
4. Constant-stroke, distributing plunger, and rack-control

4-69. What is the function of the fuel density compensator?

1. Varies the viscosity of the fuel injected into the engine
2. Varies injection pressure of the fuel
3. Varies the quantity of fuel injected into the engine
4. Varies fuel pressure entering the fuel pump

4-70. Which of the following is NOT a type of supercharger?

1. Diaphragm
2. Centrifugal
3. Rotor
4. Vane

4-71. A turbocharger is driven by the exhaust.

1. True
2. False

4-72. What type of cold weather starting devices uses a spark plug to ignite fuel vapors to heat the air before it enters the combustion chamber?

1. Glow plugs
2. Manifold flame heater
3. Ether
4. Fuel/spark control heater

4-73. Which of the following conditions does NOT cause an abnormal amount of black smoke to come from a diesel engine?

1. Improper grade of diesel fuel
2. Low cetane diesel fuel
3. Faulty automatic timing advance unit
4. Incorrect valve adjustment clearances

4-74. Blue smoke coming from the exhaust indicates the existence of what condition?

1. High exhaust back pressure
2. Water leaking into the combustion chamber
3. Low cylinder compression from worn rings
4. Oil entering the combustion chamber

4-75. How is a quick injector misfire check performed on a Detroit diesel?

1. Loosen the injector fuel lines
2. Loosen the fuel pump lines
3. Press down on the injector follower
4. Press down on the injector plunger

ASSIGNMENT 5

Textbook Assignment: "Cooling and Lubricating Systems," chapter 6, pages 6-1 through 6-37.

5-1. What percentage of engine heat is dissipated through the cooling, lubricating, and fuel systems?

1. Between 10% to 15%
2. Between 20% to 25%
3. Between 30% to 35%
4. Between 40% to 45%

5-2. The temperature of a cylinder wall should NOT be allowed to exceed 500°F because

1. the combustion limit of the lubricating oil may be exceeded
2. no radiator coolants will withstand higher temperatures
3. excess exhaust gases build up faster than they can be expelled
4. lubricating oil films will breakdown with a loss of lubricating properties

5-3. Which of the following functions is NOT a function of the cooling system?

1. Decrease thermal efficiency
2. Remove excess heat from the engine
3. Maintain a constant engine operating temperature
4. Provide a means for heater operation

5-4. In an air-cooled engine, cooling efficiency is NOT dependent on which of the following factors?

1. Heat conductivity of the metal used
2. Volume of air flowing over the heated surfaces
3. Difference in temperature between metal surfaces and the air
4. Decrease in the amount of metal exposed to the cooling air

5-5. Why are cylinders on an air-cooled engine mounted independently?

1. To reduce engine weight
2. To expose more surface area to the cooling air
3. To eliminate the need for cooling system maintenance
4. To provide easy access to the crankcase

5-6. Which of the following components is required on ail air-cooled engines?

1. Baffles
2. Thermostats
3. Fans or blowers
4. Fins

5-7. To avoid problems, what component of an air-cooled system requires frequent checking?

1. Baffles
2. Fins
3. Fan
4. Shroud

5-8. When inspecting an air-cooled engine, you notice a crack in one of the cooling fins extending into the combustion area. What action is required?

1. Replace the engine
2. Replace the cylinder barrel
3. Weld the cooling fin
4. Nothing, this will not affect the cooling

5-9. Coolant in a liquid-cooled system flows directly from the water pump to the

1. bottom of the radiator
2. water jackets and passages
3. cylinder head
4. top of the radiator

5-10. What action is created during the downward flow of the coolant through the radiator?

1. Thermosiphon
2. Thermoexpansion
3. Thermoflow
4. Thermocooling

5-11. The efficiency of a liquid-cooling system is NOT affected by which of following factors?

1. Size of the water passages in the engine
2. Capacity of the water pump
3. Size of the radiator
4. Size of the cooling fins

5-12. Radiator fins contribute to cooling system efficiency because

1. they hold the tubes in a position that allows maximum contact with the air flow
2. they increase heat dissipation by enlarging the surface area exposed to air flow
3. they increase heat dissipation by enlarging the surface area exposed to the coolant
4. they direct the flow of air to the hottest areas of the radiator

5-13. In a vehicle that has air conditioning, the radiator has what number of fins per inch?

1. Five
2. Six
3. Seven
4. Eight

5-14. The lower radiator hose connects the radiator to the

1. thermostat housing
2. engine block water passages
3. cylinder head water passages
4. water pump inlet

5-15. What is the purpose of the hose spring used in the lower radiator hose?

1. To prevent the hose from collapsing
2. To protect the system against damage
3. To allow the hose to be shaped to clear moving parts
4. To allow the hose to withstand engine vibration

5-16. Which of the following is NOT a function of the radiator pressure cap?

1. Seals the top of the radiator filler neck to prevent leakage
2. Pressurizes the system to raise the boiling point of the coolant
3. In a open system, it allows coolant to flow into and from the coolant reservoir
4. Relieves excess pressure to protect the system against damage

5-17. A radiator is equipped with a 12-pound pressure cap. What effect does this cap have on the boiling point of the coolant?

1. Raises it by 36°
2. Lowers it by 26°
3. Raises it by 16°
4. Lowers it by 6°

5-18. One of the spring-loaded valves in a pressure cap controls pressure in the cooling system, whereas the purpose of the other is to

1. prevent the loss of coolant
2. seal the overflow pipe
3. control the flow of coolant in the radiator
4. prevent vacuum from building up in the radiator when it cools

5-19. You should be careful in removing the cap from a hot, pressurized radiator to avoid

1. rapid engine cooling
2. excessive coolant loss
3. being burned by the hot coolant
4. causing major damage to the cooling system

5-20. What part of the water pump provides a mounting place for the fan and belt?

1. Hub
2. Housing
3. Shaft
4. Impeller

5-21. When the gasket is replaced on a water pump and gasket paper of the proper thickness is not available, which of the following materials may be used?

1. Cork
2. RTV sealer
3. Asbestos
4. Rubber

5-22. A bent fan blade will NOT cause which of the following conditions?

1. Worn fan belt
2. Vibration
3. Excessive wear of the water pump shaft
4. Noise

5-23. When an electric fan is used, the fan switch closes to operate the fan when coolant temperature reaches approximately what temperature?

1. 170°F
2. 190'F
3. 210°F
4. 230°F

5-24. Some liquid-cooling systems use a shroud in conjunction with the fan to

1. reduce fan speed at high engine speeds
2. direct air from the fan to engine surfaces
3. increase the amount of air drawn by the fan through the radiator
4. improve the flow of air through the radiator at high speeds

5-25. The water jackets of an engine consists of only those passages within the cylinder block.

1. True
2. False

5-26. A coolant distribution tube is used in cooling systems of an L-head engine in order to

1. disperse hot coolant that enters the top tank of the radiator
2. distribute the coolant equally between the cylinder block and the cylinder head
3. direct the coolant to the cylinder head only
4. direct the coolant to the hottest parts of the cylinders

5-27. A ferrule type coolant director is used in the cooling system of I-head engines. The director directs a jet of coolant towards the

1. exhaust valve guides
2. exhaust valve seats
3. exhaust ports
4. exhaust manifold heat valve

5-28. What type of thermostat is used in a modem pressurized cooling system'?

1. Pellet
2. Bypass
3. Bellows
4. Butterfly

5-29. A thermostat rated at 190°F will fully open at what temperature'?

1. 190°F
2. 200°F
3. 210°F
4. 220°F

5-30. Some stationary engines and large trucks have shutters placed in front of the radiators to

1. restrict the flow of air through the radiator
2. prevent foreign matter from damaging the radiator core
3. eliminate the need for a cooling fan
4. provide slower warm-up and operating temperatures

5-31. Radiator shutters used on large trucks are opened by what type of pressure?

1. Water
2. Spring
3. Hydraulic
4. Air

5-32. What is the function of the expansion tanks in a closed cooling system?

1. To increase the cooling capacity of the system
2. To eliminate the need for a pressure cap
3. To prevent system coolant loss
4. To increase the amount of air bubbles for cooling

5-33. A temperature warning light warns of an overheating condition about

1. 5° to 10° below coolant boiling point
2. 5° to 10° above coolant boiling point
3 10° to 15° below coolant boiling point
4. 10° to 15° above coolant boiling point

5-34. For ideal cooling and winter protection, what mixture of antifreeze and water is recommended?

1. 50/50
2. 60/40
3. 70/30
4. 80/20

5-35. A coolant mixture containing 60% antifreeze provides adequate protection against freezing to a maximum temperature of

1. -20°F
2. -34°F
3. -50°F
4. -62°F

5-36. What is the recommended interval at which the cooling system should be drained and flushed?

1. 2 years
2. 3 years
3. 5 years
4. As recommended by the manufacture

5-37. What is the most common method of flushing?

1. Reverse flushing
2. Fast flushing
3. Chemical flushing
4. Fast-reverse flushing

5-38. In preparation for reverse flushing an engine block, you should take which of the following actions?

1. Remove the radiator cap
2. Disconnect the upper and lower radiator hose from the engine
3. Disconnect the upper and lower radiator hose from the radiator
4. Open the drain cock on the bottom of the radiator

5-39. Of the following devices, which one is used to check antifreeze strength?

1. Antifreeze refractometer
2. Antifreeze dynamometer
3. Antifreeze economizer
4. Antifreeze quantum indicator

5-40. Of the following tests, which one is NOT a cooling system test?

1. Cooling system pressure
2. Combustion leak
3. Water pump capacity
4. Thermostat

5-41. When a pressure tester is being used to test a radiator cap, what is the minimum length of time that the pressure should be held to indicate that the cap is operational?

1. 1 minute
2. 2 minutes
3. 3 minutes
4. 4 minutes

5-42. A combustion leak test should be performed on the cooling system when there is an indication of a blown head gasket.

1. True
2. False

5-43. When a combustion leak is detected in the cooling system, the fluid in the block test will change color from blue to

1. green
2. orange
3. yellow
4. purple

5-44. You are checking the cooling system and find a thermostat that fails to operate correctly. What should you do with the thermostat?

1. Repair it
2. Replace it
3. Adjust it
4. Clean it

5-45. A 180°F thermostat should be opened completely at 180°F.

1. True
2. False

5-46. When a thermostatic fan clutch is checked for proper operation, the fan should engage when cold and slip as the engine warms up the clutch.

1. True
2. False

5-47. When an electric fan is checked for proper operation, what should the resistance reading be when the engine is cold?

1. Zero
2. Ten
3. Twenty
4. Infinite

5-48. A water pump fails to circulate an adequate volume of coolant. What is the most probable cause of this malfunction?

1. Eroded impeller blades
2. A loose fan belt
3. Worn pump housing
4. Faulty water pump bearings

5-49. A radiator hose is suspected of being faulty but does not feel mushy. The hose must be removed for inspection if it is

1. preformed
2. molded
3. spring stiffened
4. tension hardened

5-50. Correct fan belt tension can be determined by measuring the

1. distance between the belt pulleys
2. width of the belt
3. deflection of the belt between pulleys
4. distance between pulleys and subtracting the width of the belt

5-51. In most applications, you can remove the fan belt after loosening which of the following bolts?

1. Air conditioner mounting
2. Power steering mounting
3. Fan belt tensioner
4. Alternator mounting

5-52. After shutting down an engine that has run for some time, you can check the radiator to see if it is partially clogged by

1. taking the temperature of the coolant in the lower radiator outlet
2. taking the temperature of the coolant in the upper radiator tank
3. feeling the upper and lower radiator hoses with your hand
4. feeling the top and bottom of the radiator core with your hand

5-53. Why is a very small leak easier to detect in a cooling system containing an antifreeze solution?

1. Antifreeze leaves a residue
2. More antifreeze leaks through than water
3. Antifreeze does not evaporate as fast as water
4. Antifreeze is colored

5-54. Which of the following is NOT a function of the engine lubrication system?

1. Reduces friction between moving parts
2. Transfers heat
3. Cleans the inside of the engine by removing contaminants
4. Assures maximum wear on moving parts

5-55. Oil service ratings are determined by what agency?

1. The Society of Automotive Engineers
2. The Society of Petroleum Engineers
3. The American Petroleum Institute
4. The American Automotive Institute

5-56. What oil service rating meets warranty requirements for modem gasoline engines?

1. SG
2. SF
3. SE
4. SD

5-57. Which of the following is an operating principle of the rotary oil pump?

1. The inner rotor is centrally located in the outer rotor
2. The inner rotor causes the outer rotor to spin
3. The outer rotor causes the inner rotor to spin
4. A small pocket is formed on the inlet side of the pump

5-58. Which of the following actions is an operating principle of a gear type oil pump?

1. Both gears are independently driven by shafts
2. Both gears turn in the same direction
3. Pumping action forces oil to pass between the gear teeth
4. The pump is driven by the crankshaft or distributor

5-59. Why is a relief valve placed in the lubrication system of an engine?

1. To regulate pressure delivered by the oil pump
2. To prevent damaging the internal parts of the oil pump
3. To provide an adequate supply of oil to the suction side of the oil pump
4. To prevent overlubrication of the engine bearings

5-60. In an engine lubrication system, where is the oil strainer located?

1. In the oil return line to the crankcase
2. At the inlet of the oil pump pickup tube
3. In the discharge line from the oil pump
4. At the inlet side of the oil galleries

5-61. Oil strainers sometimes contain a safety valve for the purpose of

1. allowing oil to bypass a clogged screen
2. limiting the amount of oil entering the oil pump
3. controlling pump discharge pressure
4. controlling the oil level in the oil pan

5-62. Dirt, water, and sludge can NOT pass through an oil strainer with the oil because of which of the following reasons?

1. All oil is collected from the surface of the oil in the oil pan
2. The mesh of the screen will allow only the lubricating oil to pass
3. The strainers are located above the bottom of the oil pan
4. The strainers are designed to allow oil pumps to pick up oil based on their viscosity

5-63. Of the following factors, which is an advantage of using a full flow oil filter in a lubricating system?

1. All oil is circulated through the filter before it reaches the engine
2. The filter does not need to be changed as often as other filters
3. The filter never permits any unfiltered oil to reach the moving parts of the engine
4. The filter diverts a small amount of oil and returns it to the oil pan

5-64. The sending unit for an oil pressure warning light is calibrated to come on when oil pressure drops below what level?

1. 10 psi
2. 15 psi
3. 20 psi
4. 25 psi

5-65. In a mechanical type oil pressure gauge, the oil line is tapped at what location?

1. At the base of the oil filter
2. At the oil gallery leading from the oil pump
3. At the oil gallery leading from the side of the engine
4. At the oil filter housing unit

5-66. In an overhead valve engine using a combination splash and force-feed system, the upper valve train is lubricated by

1. the splash method
2. a combination of both the splash and force-feed methods
3. pressure from the oil pump
4. dippers on the connecting rods

5-67. An operator reports that a vehicle is using a lot of oil; however, there is no sign of external leakage. What color smoke is a sign of internal oil leakage?

1. Gray
2. Black
3. White
4. Blue

5-68. Which of the following conditions is NOT a cause of low oil pressure?

1. Worn main bearings
2. Worn oil pump
3. Restricted oil gallery
4. Weak or broken pressure relief valve spring

5-69. Which of the following conditions is indicated by a high oil pressure reading?

1. Worn engine bearings
2. Overheated engine
3. Blocked oil passage
4. Cracked oil pickup tube

5-70. In changing engine oil, you should drain the oil from the vehicle

1. when the engine is warm
2. while the engine is cold
3. anytime
4. whenever the vehicle is deadlined

5-71. When replacing a spin-on filter, you should turn the filter how far after contact is made with the base?

1. One-fourth him
2. One-third turn
3. One-half turn
4. Full turn

5-72. Before installing a new oil pump, you should fill the pumping chamber with oil

1. to eliminate air pockets that could restrict oil flow
2. to reduce the chances that the pump shaft will bind
3. to prevent rotor damage when the engine is started
4. to ensure proper operation when the engine is started