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ABSTRACT

Materials are provided for a 14-hour course designed to introduce the automotive mechanic to the basic operations of automotive fuel and exhaust systems incorporated on military vehicles. The four study units cover characteristics of fuels, gasoline fuel system, diesel fuel systems, and exhaust system. Each study unit begins with a general objective. It is divided into numbered work units, each presenting one or more specific objectives. These work units also consist of text material, illustrations, and study questions. Answer keys appear at the end of each study unit. A review lesson, which is a multiple choice exercise, is also provided. Troubleshooting guides for diesel fuel injection systems are included as appendixes. (YLB)

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IN REPLY REFER TO

35.25b
31 July 85

1. ORIGIN

MCI course 35.25b, Automotive Fuel and Exhaust Systems, has been prepared by the Marine Corps Institute.

2. APPLICABILITY

This course is for instructional purposes only.

H. LEE HUGHES
Deputy Director

ACKNOWLEDGMENT

The Marine Corps Institute, Marine Barracks, Washington, D.C. gratefully acknowledges the important contributions provided by the following MCI personnel in developing and publishing this course:

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INFORMATION

FOR

MCI STUDENTS

Welcome to the Marine Corps Institute training program. Your interest in self-improvement and increased professional competence is commendable.

Information is provided below to assist you in completing the course. Please read this guidance before proceeding with your studies.

1. MATERIALS

Check your course materials. You should have all the materials listed in the "Course Introduction." In addition you should have an envelope to mail your review lesson back to MCI for grading unless your review lesson answer sheet is of the self-mailing type. If your answer sheet is the pre-printed type, check to see that your name, rank, and social security number are correct. Check closely, your MCI records are kept on a computer and any discrepancy in the above information may cause your subsequent activity to go unrecorded. You may correct the information directly on the answer sheet. If you did not receive all your materials, notify your training NCO. If you are not attached to a Marine Corps unit, request them through the Hotline (autovon 288-4175 or commercial 202-433-4175).

2. LESSON SUBMISSION

The self-graded exercises contained in your course are not to be returned to MCI. Only the completed review lesson answer sheet should be mailed to MCI. The answer sheet is to be completed and mailed only after you have finished all of the study units in the course booklet. The review lesson has been designed to prepare you for the final examination.

It is important that you provide the required information at the bottom of your review lesson answer sheet if it does not have your name and address printed on it. In courses in which the work is submitted on blank paper or printed forms, identify each sheet in the following manner:

DOE, John J. Sgt 332-11-9999
08.4g, Forward Observation
Review Lesson
Military or office address
(RUC number, if available)

Submit your review lesson on the answer sheet and/or forms provided. Complete all blocks and follow the directions on the answer sheet for mailing. Otherwise, your answer sheet may be delayed or lost. If you have to interrupt your studies for any reason and find that you cannot complete your course in one year, you may request a single six month extension by contacting your training NCO, at least one month prior to your course completion deadline date. If you are not attached to a Marine Corps unit you may make this request by letter. Your commanding officer is notified monthly of your status through the monthly Unit Activity Report. In the event of difficulty, contact your training NCO or MCI immediately.

3. MAIL-TIME DELAY

Presented below are the mail-time delays that you may experience between the mailing of your review lesson and its return to you.

	TURNAROUND MAIL TIME	MCI PROCESSING TIME	TOTAL NUMBER DAYS
EAST COAST	16	5	21
WEST COAST	16	5	21
FPO NEW YORK	18	5	23
FPO SAN FRANCISCO	22	5	27

You may also experience a short delay in receiving your final examination due to administrative screening required at MCI.

4. GRADING SYSTEM

LESSONS			EXAMS	
GRADE	PERCENT	MEANING	GRADE	PERCENT
A	94-100	EXCELLENT	A	94-100
B	86-93	ABOVE AVERAGE	B	86-93
C	78-85	AVERAGE	C	78-85
D	70-77	BELOW AVERAGE	D	65-77
NL	BELOW 70	FAILING	F	BELOW 65

You will receive a percentage grade for your review lesson and for the final examination. A review lesson which receives a score below 70 is given a grade of NL (no lesson). It must be resubmitted and PASSED before you will receive an examination. The grade attained on the final exam is your course grade, unless you fail your first exam. Those who fail their first exam will be sent an alternate exam in which the highest grade possible is 65%. Failure of the alternate will result in failure of the course.

FINAL EXAMINATION

ACTIVE DUTY PERSONNEL: When you pass your REVIEW LESSON, your examination will be mailed automatically to your commanding officer. The administration of MCI final examinations must be supervised by a commissioned or warrant officer or a staff NCO.

OTHER PERSONNEL: Your examination may be administered and supervised by your supervisor.

6. COMPLETION CERTIFICATE

The completion certificate will be mailed to your commanding officer and your official records will be updated automatically. For non Marines, your completion certificate is mailed to your supervisor.

7. RESERVE RETIREMENT CREDITS

Reserve retirement credits are awarded to inactive duty personnel only. Credits awarded for each course are listed in the "Course Introduction." Credits are only awarded upon successful completion of the course. Reserve retirement credits are not awarded for MCI study performed during drill periods if credits are also awarded for drill attendance.

8. AMERICAN COUNCIL ON EDUCATION (ACE) ACCREDITATION

Many of MCI's MOS courses have been evaluated by ACE and determined to have equivalency credit in either the Vocational Certificate (VC) category or the Baccalaureate/Associate Degree (BA) level.

If you are enrolled in a college or vocational program or plan to enroll and have completed one or more MCI courses, you may be able to receive college or vocational credit for them. All that you need to do is to petition your school to see if they will award you credit for the courses that apply to your program area. You will need your completion certificate, and the Evaluation of Educational Experiences in the Armed Services.

9. DISENROLLMENT

Only your commanding officer can request your disenrollment from an MCI course. However, an automatic disenrollment occurs if the course is not completed (including the final exam) by the time you reach the CCD (course completion deadline) or the ACCD (adjusted course completion deadline) date. This action <u>will</u> adversely affect the unit's completion rate.

10. ASSISTANCE

Consult your training NCO if you have questions concerning course content. Should he/she be unable to assist you, MCI is ready to help you whenever you need it. Please use the Student Course Content Assistance Request Form (ISD-1) attached to the end of your course booklet or call one of the AUTOVON telephone numbers listed below for the appropriate course writer section.

Personnel/Administration/Corrections/Logistics Embarkation/Maintenance Management	288-3259
Communications/Electronics/Aviation/NBC/Intelligence	288-3604
Infantry	288-3611
Engineer/Motor Transport/Utilities	288-2275
Supply/Food Services/Fiscal	288-2295
Tanks/Artillery/Infantry Weapons Repair Assault Amphibian Vehicles	288-2290

For administrative problems use the UAR or call the MCI HOTLINE: 288-4175

For commercial phone lines, use area code 202 and prefix 433 instead of 288.

AUTOMOTIVE FUEL AND EXHAUST SYSTEMS

Course Introduction

AUTOMOTIVE FUEL AND EXHAUST SYSTEMS is designed to introduce the automotive mechanic to the basic operations of automotive fuel and exhaust systems incorporated on military vehicles. Trouble-shooting guides for diesel fuel injection systems are included as appendices so the mechanic may keep a ready reference to trouble-shooting diesel system malfunctions. Maintenance and repair information including removal of components are covered in the technical manual for the respective vehicle and, therefore, are not covered in this course.

ADMINISTRATIVE INFORMATION

ORDER OF STUDIES

Study Unit Number	Study Hours	Subject Matter
1	2	Characteristics of Fuel
2	3	Gasoline Fuel System
3	4	Diesel Fuel Systems
4	1	Exhaust System
	2	REVIEW LESSON
	2	FINAL EXAMINATION
	14	

RESERVE RETIREMENT CREDITS: 5

COLLEGE CREDIT: American Council on Education (ACE) has awarded 35.25b, Automotive Fuel and Exhaust Systems, 2 semester hours in gasoline and diesel fuel systems in lower division Baccalaureate/Associate Degree.

EXAMINATION: Supervised final examination without text or notes with a time limit of 2 hours.

MATERIALS: MCI 35.25b, Automotive Fuel and Exhaust Systems, Review lesson and answer sheet.

RETURN OF MATERIALS: Students who successfully complete this course are permitted to keep the course materials.

Students disenrolled for inactivity or at the request of their commanding officer will return all course materials.

SOURCE MATERIALS

TM 9-8000	Principles of Automotive Vehicles, Jan 56
TM 9-2320-260-20	Truck 5 ton 6 x 6 M809, Jul 72
TM 9-2320-266-20	Truck Cargo 1-1/4 ton 4 x 4 M880, Jan 76
TM 9-2320-272-20-1	Truck Chassis 5 ton 6 x 6 M939, Sept 82
TM 9-2320-272-20-2	Truck Chassis 5 ton 6 x 6 M939, Oct 82
TM 9-2320-272-34-2	Truck Chassis 5 ton 6 x 6 M939 (DS&GS), Oct 82
TM 9-2320-289-20	Truck Cargo 1 1/4 ton 4 x 4 M1008, Apr 83
TM 9-2320-289-34	Truck Cargo 1 1/4 ton 4 x 4 M1008, May 83
TM 9-2815-202-34	Engine, Diesel, Oct 65

HOW TO TAKE THIS COURSE

This course contains 4 study units. Each study unit begins with a general objective that is a statement of what you should learn from the study unit. The study units are divided into numbered work units, each presenting one or more specific objectives. Read the objective(s) and then the work unit text. At the end of the work unit are study questions that you should be able to answer without referring to the text of the work unit. After answering the questions, check your answers against the correct ones listed at the end of the study unit. If you miss any of the questions, you should restudy the text of the work unit until you understand the correct responses. When you have mastered one study unit, move on to the next. After you have completed all study units, complete the review lesson and take it to your training officer or NCO for mailing to MCI. MCI will mail the final examination to your training officer or NCO when you pass the review lesson.

TABLE OF CONTENTS

MARINE CORPS INSTITUTE STUDY GUIDE

Congratulations for enrolling in the Marine Corps Institute's correspondence training program! By enrolling in this program, you have shown a desire to improve the skills you need to enhance your on-the-job performance.

Since 1920, MCI has been helping tens of thousands of hard-charging young Marines, like yourself, achieve educational goals by teaching necessary new skills or reinforcing existing skills. MCI will do every thing possible to help you reach your individual goals, whatever they may be.

Before you begin your course of instruction, you may be asking yourself, "How much will I benefit from a correspondence training program?" The answer to this depends upon you, *"YOUR PROFESSIONAL TRAITS"* (what you bring to the learning situation).

Because you have enrolled in an MCI course, your professional traits are evident and we know that:

YOU ARE PROPERLY MOTIVATED. You made a positive decision to get training on your own. Self-motivation is perhaps the most important force in learning-or achieving—anything. Wanting to learn something badly enough so that you will do what's necessary to learn—*THAT IS MOTIVATION.*

YOU SEEK TO IMPROVE YOURSELF. You enrolled to learn new skills and develop special abilities.

YOU HAVE THE INITIATIVE TO ACT. By acting on your own, you have shown that you are a self-starter, willing to reach out for opportunities.

YOU ACCEPT CHALLENGES. You have self-confidence and believe in your ability to gain training in your areas of interest.

YOU ARE ABLE TO SET PRACTICAL GOALS. You are willing to commit time, effort, and resources toward accomplishing what you set out to do. These professional traits will help you achieve success in your MCI program.

To begin your course of study:

* Look at the course introduction page. Read the COURSE INTRODUCTION to get the "nitty gritty" of what the course is about. Then read the MATERIALS section near the bottom of the page to find out which text(s) and study aids you should have received with the course. If any of the listed materials are missing, see *Information for MCI Students* to find out how to obtain them. If you have everything that is listed, you are ready to begin your MCI course.

* Read through the *TABLE OF CONTENTS* of your text(s). Note the various subjects covered in the course and the order in which they are taught. Leaf through the text(s) and look at the illustrations. Read a few work unit exercise questions to get an idea of the types of questions that are asked. If MCI provides other study aids, such as a slide rule or a plotting board, familiarize yourself with them. Now, you are ready to begin work on your MCI course.

* Turn to the first page of study unit 1. On this page you will find the study unit goal. This is a statement of what you should be able to do when you complete the final exam. Each study unit is divided into work units. Each work unit contains one terminal learning objective and several enabling objectives. The terminal learning objective is what you should be able to accomplish when you complete the work unit exercises. The enabling objectives are the steps you need to learn to help you accomplish the terminal learning objective. Read each objective for the work unit and then read the work unit text carefully. Make notes on the ideas you feel are important.

* Without referring to the text, answer the questions in each exercise.

* Check your answers against the correct ones listed at the end of the study unit.

* If you miss any of the questions, restudy the work unit until you understand the correct response.

* Go on to the next work unit, repeating the above steps, until you have completed all the work units in the study unit.

* Follow the same procedure for each study unit of the course. If you have problems with the text or work unit questions that you cannot solve on your own, ask your training NCO for the name of someone who can help you. If they cannot aid you, request assistance from MCI on the Student Course Content Assistance Request included with this course, or refer to your INFORMATION FOR MCI STUDENTS (MCI-R24i-NRL) for the telephone number of the appropriate Course Developing Division at MCI.

* When you have finished all the study units, complete the course review lesson. Try to answer each question without the aid of reference materials. However, if you do not know an answer, look it up. When you have finished the review lesson, take it to your training officer or NCO for mailing to MCI. MCI will grade it and send you a feedback sheet (MCI-R69) with your final examination listing course references for any questions that you missed on the review lesson.

"RECON" Reviews:

To prepare for your final examination you *must* review what you learned in the course. Therefore, why not make reviewing as interesting as possible. The following suggestions will make reviewing not only interesting but also a challenge.

1. Challenge yourself. Reconstruct the learning event *in your mind*. Try to recall and recapture an entire learning sequence, without notes or other references. Can you do it? You just have to "look back" to see if you've left anything out, and *that* will be an interesting read-through (review) for you.

Undoubtedly, you'll find that you were not able to recall everything. But with a little effort you'll be able to recall a great deal of the information.

Also, knowing that you are going to conduct a "reconstruct-review" will change the way you approach your learning session. You will try to learn so that you will be able to "reconstruct the event."

2. Use unused minutes. While waiting at sick bay, riding in a truck or bus, living through field duty, or just waiting to muster—use these minutes to review. Read your notes or a portion of a study unit, recalculate problems, do self-checks a second time; you can do many of these things during "unused" minutes. Just thinking about a sequence of instruction will refresh your memory to help "secure" your learning.

3. Apply what you've learned. Always, it is best to do the thing you've learned. Even if you cannot immediately put the lesson to work, sometimes you can "simulate" the learning situation. For example, make up and solve your own problems. Make up problems that take you through most of the elements of a study unit.

4. Use the "shakedown cruise" technique. Ask a fellow Marine to lend a hand and have him ask you questions about the course. Give him a particular study unit and let him fire away. It can be interesting and challenging.

The point is, reviews are necessary for good learning, but they don't have to be long and tedious. Several short reviews can be very beneficial.

Semper Fi

STUDY UNIT 1

CHARACTERISTICS OF FUELS

STUDY UNIT OBJECTIVE: WITHOUT THE AID OF REFERENCES, YOU WILL IDENTIFY THE FUELS USED IN INTERNAL COMBUSTION ENGINES; THE VOLATILITY OF FUEL; THE STAGES OF NORMAL FUEL COMBUSTION; THE CAUSES AND EFFECTS OF ABNORMAL COMBUSTION; WHY ADDITIVES ARE USED IN GASOLINE; AND THE PURPOSE OF USING UNLEADED GASOLINE. YOU WILL ALSO IDENTIFY THE REQUIREMENTS OF DIESEL FUEL.

Work Unit 1-1. CHARACTERISTICS OF GASOLINE

LIST THE THREE TYPES OF FUEL USED IN INTERNAL COMBUSTION ENGINES.

IDENTIFY VOLATILITY OF FUELS.

LIST THE THREE STAGES OF NORMAL COMBUSTION.

STATE THE TWO TYPES OF ABNORMAL COMBUSTION IN THE INTERNAL COMBUSTION ENGINE.

LIST THE CAUSES AND EFFECTS OF DETONATION.

LIST THE CAUSES AND EFFECTS OF PRE-IGNITION.

STATE THE PURPOSE OF ADDING TETRAETHYL LEAD TO GASOLINE.

STATE THE PURPOSE OF USING UNLEADED GASOLINE IN THE INTERNAL COMBUSTION ENGINE.

The internal combustion engine must use energy (fuel) to obtain power. In the Motor Transport Field, this power would be used to move automotive vehicles to transport personnel and cargo. The types and characteristics of fuel and how the fuel is delivered in the proper ratio to the combustion chamber are explained in this course. In this study unit, gasoline and diesel fuel characteristics will be discussed.

There are three types of fuels used in the internal combustion engine--natural gas, liquified petroleum gas, and fossil fuel. Natural gas is a combustible gas formed naturally in the earth where petroleum (crude oil) is produced. Liquified petroleum gas (LPG) is a byproduct of refining crude oil. These fuels have been used in the internal combustion engine with success; however, they will not be discussed in this course as these types of fuel are not used in military engines.

Gasoline and diesel, as used in automotive engines, are made by refining crude oil (a fossil fuel). In this work unit gasoline will be discussed.

Gasoline, a colorless liquid obtained by the refining process of crude oil, is a mixture of hydrocarbons. Each hydrocarbon has its own boiling point (volatility). This volatility (fig 1-1) or vaporizing ability affects the ease of starting your vehicle, the length of warm-up period, and the engine's performance during normal operation. Therefore, the volatility of gasoline should be high for easy starting of your vehicle in cold weather. However, when the engine warms up, the highly volatile fuel vaporizes in the fuel line (vapor lock) which causes fuel starvation to the engine (no fuel to the cylinders). For engine warm-up, a fuel with not as high volatility is required. This means that the fuel must have a percentage of highly volatile hydrocarbons along with not so volatile hydrocarbons to allow the engine to operate in all temperatures (cold start to operating temperature). You must remember that liquid gasoline will not burn, only the vapor is ignited in the combustion chamber. Atomization and vaporization will be further discussed in study unit 2.

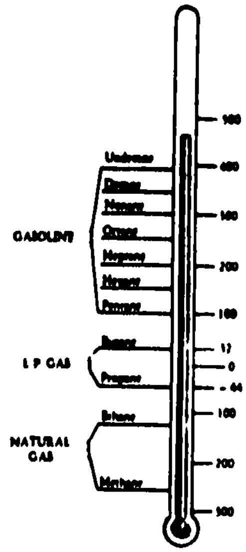


Fig 1-1. Range of volatility of hydrocarbons.

Other characteristics of gasoline which affect engine operation are impurities, its oxidation, its anti-knock quality, and the octane rating. Crude oil contains many impurities (sulfur, water, etc.) of which most are removed by modern refining procedures and are not a problem. Hydrocarbons in gasoline tend to oxidize into a sticky gum when exposed to air which results in clogged passages in the carburetor, stuck valves, and excessive deposits in the combustion chamber. Chemical compounds are added to the gasoline at the refinery to control oxidation.

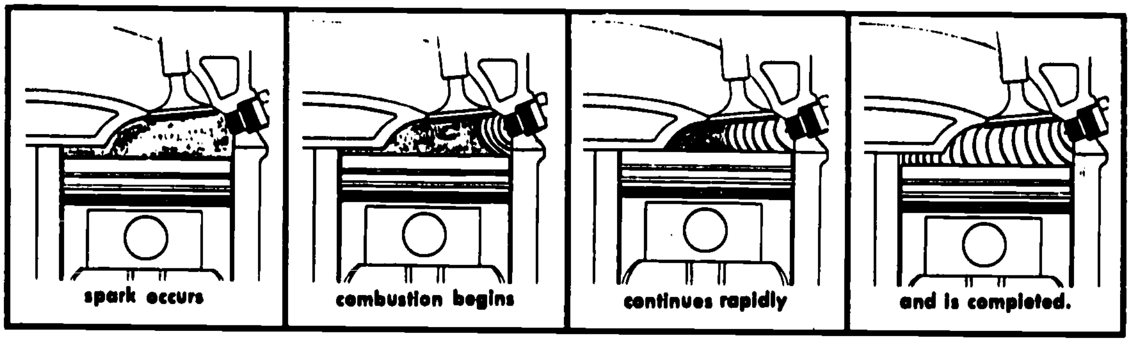
One of the most important qualities of gasoline is the ability to burn without causing a knocking. The addition of tetraethyl lead to the gasoline reduces this tendency. In order to understand what is meant by "anti-knock" let us discuss the combustion process.

NORMAL COMBUSTION (fig 1-2)

The process of normal combustion has three stages: formation, hatching out, and propagation. When the spark occurs in the combustion chamber, the fuel-air mixture is ignited which forms a nucleus of flame. As the flame (nucleus) enlarges, fingers of flame are sent out, causing a slight rise in temperature and pressure in chamber. This hatching out of the nucleus starts the propagation phase of combustion where effective burning of the fuel-air mixture occurs. The flame front burns rapidly, causing great heat and a rapid rise in pressure. The increased pressure causes the piston to move downward.

During normal combustion, burning of the fuel-air mixture is progressive, increasing gradually during the formation and hatching out phases and then continuing rapidly during the propagation phase. In normal combustion, pressure and temperature rise progressively rather than in a violent manner (explosively). This abnormal combustion (explosion) is commonly called detonation.

14



Note: Fuel-air mixture does not burn all at once. Flame front moves in a rapid but controlled manner throughout the combustion chamber.

Fig 1-2. Normal combustion.

ABNORMAL COMBUSTION

Detonation (fig 1-3) occurs when the fuel-air mixture explodes rather than burns at an even rate. This creates an audible knock or pinging sound. As the nucleus of the flame spreads across the combustion chamber, the remaining unburned fuel-air mixture is ignited spontaneously. As the two flame fronts collide, extreme pressure erupts instantaneously, causing an audible sound. In extreme cases of detonation, pistons may shatter and cylinders may burst or cylinder heads may crack. This condition may also create overheating, broken spark plugs, high fuel consumption, and loss of power. There are several probable causes of detonation which include fuel of too low an octane rating, lean fuel-air mixture, lugging the engine, ignition timing over advanced, and excessive carbon accumulation in the combustion chamber.

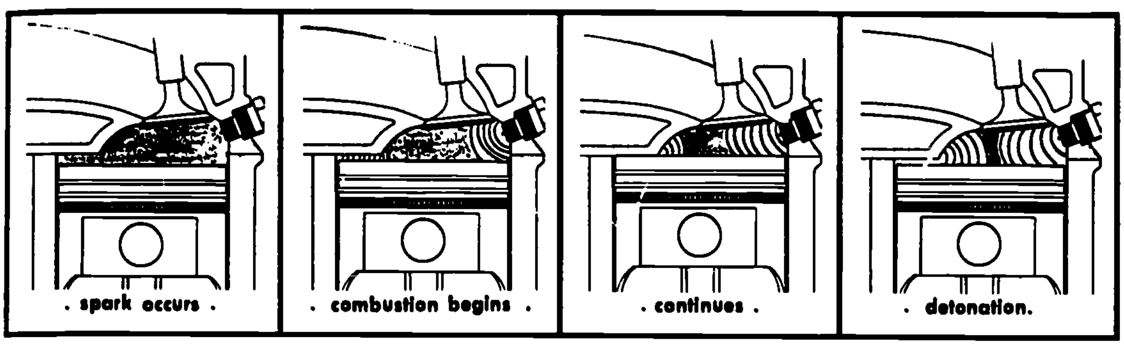


Fig 1-3. Detonation.

Pre-ignition (fig 1-4) results when the fuel-air mixture is ignited before the regular spark occurs. Pre-ignition may result in a pinging sound if the regular spark occurs shortly after the spontaneous ignition. However, a lack of noise is just as common. If premature combustion is completed prior to the regular spark, no noise is heard. Pre-ignition and detonation are closely linked and it is difficult to distinguish between them. Pre-ignition can lead to detonation. The causes of pre-ignition are: excessive carbon deposits in the chamber; high valve temperature; hot spots due to cooling system defects; hot spark plugs; sharp edges in the combustion chamber, and detonation.

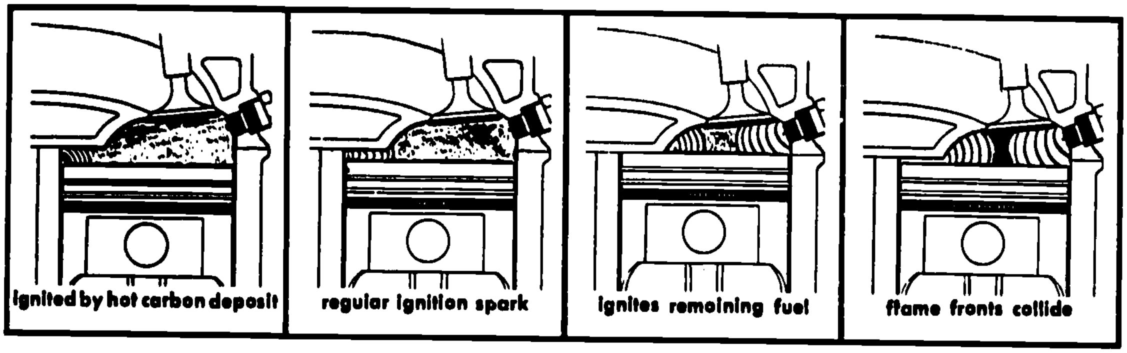


Fig 1-4. Pre-ignition or igniting of fuel-air mixture prior to regular spark ignition.

Detonation can be alleviated somewhat by using a gasoline of a higher octane rating. This rating is the ability of a fuel to resist detonation. Octane rating is figured by comparison with a control fuel (iso-octane and heptane). For instance, a fuel with an octane rating of 90 means that the anti-knock qualities of the fuel are the same as those of a test fuel of 90 percent iso-octane and 10 percent heptane. Of course, the tendency of a fuel to detonate varies with the operating conditions, the shape of the combustion chamber, and, most importantly, the compression ratio.

The octane number of a fuel has nothing to do with the starting quality, volatility, power, or any other characteristics. Performance cannot be improved by using an octane of higher number than that which is satisfactory in that particular engine.

Additives, which are compounds added to fuel, can decrease detonation, increase the octane rating, absorb moisture, reduce deposits in the combustion chamber, or lubricate valve stems and rings.

- Tetraethyl lead is a compound added to gasoline which decreases detonation tendencies.
- Alcohol can be used as a fuel for internal combustion engines or mixed with gasoline (gasohol). The purpose of adding alcohol to gasoline is to absorb moisture which accumulates in the fuel system as water will not pass through filters. However, when the water is absorbed by alcohol, the moisture laden alcohol will pass through to the combustion chamber. The alcohol is burned thus ridding the fuel system of the corrosive tendency of the water.
- Benzol, a volatile hydrocarbon, has a high octane value. It is used, occasionally, to increase the octane value of gasoline.

During combustion of gasoline, the temperature in the combustion chamber can be as high as 5500 degrees F. Therefore, the boiling range of fuel must be at a point to give good results under all temperature conditions (cold start to operating temperature). A lower boiling point of fuel gives more satisfactory results. The boiling range and heat value (power) of fuel are adjusted by the refinery. Fuels that cannot vaporize and burn (fuel is burned in vaporized state) will accumulate and form deposits in the engine. This is noticeable when the engine is started (cold). In cold starts, the engine requires a rich mixture, and black smoke will normally be emitted from the exhaust. This black smoke is the unburned (raw) fuel. As the engine warms up, a leaner mixture is required and the black smoke will stop, normally. If the smoke does not stop after warm-up to operating temperature, the reason for the rich mixture must be determined. A sticking choke valve is normally the cause of this condition.

In recent years, there has been concern about atmospheric emissions created by the internal combustion engine. Automotive engineers have devised several methods of reducing exhaust emissions (hydrocarbons). One method uses a higher combustion temperature for more efficient burning of the fuel and unleaded fuel. The use of unleaded fuel reduces the amount of hydrocarbons and carbon monoxide emitted by the engine and must use a catalytic converter in the exhaust system to collect heat and hydrocarbons. A more detailed description of the exhaust system will be discussed in study unit 4. Other emission control devices utilize the engine vacuum system in various ways. Since tactical military vehicles use diesel fuel, the different methods of emission control will not be discussed in this text.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. List the three types of fuel used in internal combustion engines.

   a. ______________________________

   b. ______________________________

   c. ______________________________

2. Identify the volatility of fuels.

   a. Ability to flow
   b. Heat valve
   c. Boiling point or vaporizing ability
   d. Oxidation

3. List the three stages of normal combustion.

   a. ______________________________

   b. ______________________________

   c. ______________________________

4. State the two types of abnormal combustion in the internal combustion engine.

   a. ______________________________

   b. ______________________________

5. List the causes of detonation.

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

   e. ______________________________

6. List the effects of detonation.

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

   e. ______________________________

   f. ______________________________

   g. ______________________________

7. List the causes of pre-ignition.

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

   e. ______________________________

   f. ______________________________

8. List the effects of pre-ignition.

   a. ______________________________

   b. ______________________________

9. State the purpose of adding tetraethyl lead to gasoline.

   ____

   ____

10. State the purpose of using unleaded gasoline in the internal combustion engine.

   ____

Work Unit 1-2. REQUIREMENTS OF DIESEL FUEL

LIST THREE MAJOR REQUIREMENTS OF DIESEL FUEL.

STATE THE REASONS FOR GOOD IGNITION QUALITY.

STATE HOW THE IGNITION QUALITY OF A DIESEL FUEL IS IDENTIFIED.

STATE WHY VISCOSITY IS CONSIDERED IN DIESEL FUEL.

NAME TWO IMPURITIES WHICH ARE FILTERED OUT OF DIESEL FUEL BEFORE IT IS INJECTED INTO THE COMBUSTION CHAMBER.

IDENTIFY HOW THE CETANE RATING OF DIESEL FUEL IS DETERMINED.

NAME THE ELEMENT IN DIESEL FUEL THAT SIGNIFICANTLY INFLUENCES THE AMOUNT OF CARBON AND DEPOSIT FORMATION (WHICH SHOULD BE KEPT AS LOW AS POSSIBLE).

LIST THE THREE GRADES OF DIESEL FUEL USED IN MILITARY VEHICLES AND SPECIFY THE TEMPERATURE RANGE OF EACH.

Compression ignition engines will run on a variety of fuels; however, some grades of fuel will perform more satisfactorily in these engines than others. Factors which should be considered in the selection of fuel are efficiency, reliability, and maintenance costs. The cost of the fuel has no bearing on the above factors.

Diesel fuel supplies all the energy for the engine and, at the same time, lubricates and cools the precision parts of the fuel system (pump and injectors). These functions, in turn, produce three characteristics of diesel fuel: its ignition quality, viscosity, and cleanliness.

The ignition quality, expressed as cetane rating, insures spontaneous combustion and complete burning of the fuel. The time delay between the injection of fuel into the combustion chamber and ignition by the hot air is expressed as a cetane rating number. This is usually between 30 and 60. Measurement of the ignition quality is done by comparing the operation of an unknown fuel in an engine with the operation of a known reference fuel in the same engine. The reference fuel is a mixture of alpha-methyl-naphthalene and cetane. The cetane rating number indicates the percentage of cetane in the reference fuel which matches the ignition qualities of the fuel being tested.

When fluids get cold, they will get thick and flow slowly. Likewise, when the liquids are warm, they flow freely. The resistance to flow, a characteristic of oils and oil products, is referred to as viscosity. Diesel fuel, an oil product, must have a sufficiently low viscosity to flow freely at the lowest temperature encountered, but it also must be high enough to properly lubricate the precision fitted parts in the fuel pump and injectors. The viscosity of the fuel also determines the size of the fuel spray which governs the atomization of the spray upon injection.

Fuel in any engine must be clean and diesel engines are no exception. In diesel engines, the fuel must be free of water and sediment. If water or sediment is allowed to enter the fuel pump, the precision fitted parts will freeze up in both the injection pump and injector. Also, spray tips can be blown off if water settles at the nozzle valve. Another element which must be considered in diesel fuel is the sulfur content. Sulfur must be kept at a low level. Tests have shown that increasing sulfur in diesel fuel combustion chamber by 1 percent increases valve wear and combustion chamber deposits significantly (over 125 percent).

Now that we have discussed some of the major requirements of diesel fuel, there are three types or grades of fuel available for use in military vehicles. The different grades are recommended according to the lowest temperatures expected in the area of operation. Diesel fuel DF-2 is used when the temperature is above 20°F; DF-1 is used for temperatures from -20°F to +20°F; and CF-A is used in arctic conditions or below -20°F. Paraffin forms (separates) in diesel fuel during cold weather. This occurs when an improper grade of fuel is used in very cold climates. Paraffin is present in all oil products and will clog fuel filters on the vehicle. In the event this does occur, the filters (primary, secondary, and final) and the intank filter sock must be replaced. Also, the remaining fuel must be drained and replaced with the proper grade of fuel.

At this time, an extensive discussion on alternate fuels is omitted due to the extent of problems they could cause. In short, alternate fuels are those used when the supply of the proper grade is not available and the movement of equipment is necessary. The decision to use alternate fuel must be made at a higher echelon of command (MTO) and then only used temporarily.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. List the three major requirements of diesel fuel.

   a. ______________________

   b. ______________________

   c. ______________________

2. State the reason for using a fuel with good ignition quality.

   ____

3. State how the ignition quality of a diesel fuel is identified.

   ____

4. State why the viscosity of diesel fuel is considered when determining the type of fuel to use.

   a. ______________________

   b. ______________________

   c. ______________________

5. Name two impurities which are removed by the filters prior to the fuel being injected into the combustion chamber.

   ____

6. Identify how the cetane rating of diesel fuel is determined.

   a. By the percentage of iso-octane
   b. By a comparison with fuel of known qualities
   c. By the percentage of naphthalene
   d. By the comparison of iso-octane and naphthalene

7. Name the element in diesel fuel that significantly influences the carbon and deposit formation and which must be kept as low as possible.

   ____

8. List the three grades of diesel fuel used in military vehicles and specify the temperature range of each.

   a. ______________________________

   b. ______________________________

   c. ______________________________

SUMMARY REVIEW

In this study unit, you have learned the types of fuels used in internal combustion engines; the volatility of fuel; the different stages of abnormal combustion; why additives are used in gasoline; and why unleaded gasoline is used so extensively in today's vehicles. Lastly, you learned the various requirements of diesel fuel.

In the next study unit, you will learn the principles of carburetion.

Answers to Study Unit #1 Exercises

Work Unit 1-1.

1. a. Natural gas
   b. Liquified petroleum gas
   c. Refined fossil fuels
2. c.
3. a. Formation (nucleus of flame)
   b. Hatching out
   c. Propagation
4. a. Detonation
   b. Pre-ignition
5. a. Lean fuel mixture
   b. Too low an octane
   c. Over advanced ignition timing
   d. Lugging the engine
   e. Excessive carbon buildup
6. a. Shattering of piston
   b. Cracked cylinder head
   c. Overheating
   d. Broken spark plugs
   e. High fuel consumption
   f. Loss of power
   g. Burst cylinder
7. a. Carbon deposits
   b. High valve temperature
   c. Hot spots due to cooling system defects
   d. Spark plugs that run hot
   e. Sharp edges in combustion chamber
   f. Detonation
8. a. A pinging noise
   b. Detonation
9. To decrease detonation tendencies
10. To reduce the hydrocarbon and carbon monoxide emissions

Work Unit 1-2.

1. a. Ignition quality
   b. Viscosity
   c. Cleanliness
2. To ensure spontaneous combustion and complete burning
3. By its cetane rating number
4. a. To ensure the fuel flows at low temperature
   b. To ensure the fuel lubricates the pump and injectors
   c. To obtain the optimum atomization of the fuel upon injection
5. Water and sediment
6. b.
7. sulfur
8. a. DF-2; temperatures above +20°F
   b. DF-1; temperatures from -20°F to +20°F
   c. CF-A; temperatures below -20°F

STUDY UNIT 2

GASOLINE FUEL SYSTEM

STUDY UNIT OBJECTIVE: WITHOUT THE AID OF REFERENCES, YOU WILL IDENTIFY THE PRINCIPLES OF CARBURETION. YOU WILL IDENTIFY THE PURPOSE OF A CHOKE, HOW CHOKE WORKS, AND THE DIFFERENCES BETWEEN A MANUAL AND AN AUTOMATIC CHOKE. YOU WILL ALSO IDENTIFY THE PURPOSE OF AN ENGINE MANIFOLD. LASTLY, YOU WILL IDENTIFY THE PURPOSE OF A FUEL PUMP, ITS VARIOUS COMPONENTS, AND THE PROCEDURES TO FOLLOW WHEN TESTING A FUEL PUMP.

Work Unit 2-1. PRINCIPLES OF CARBURETION

STATE THE PURPOSE OF THE FUEL SYSTEM ON AN INTERNAL COMBUSTION ENGINE.

LIST THE EIGHT MAIN COMPONENTS OF A FUEL SYSTEM.

STATE THE PURPOSE OF THE CARBURETOR.

STATE THE CAUSE OF FUEL FLOW THROUGH THE MAIN METERING CIRCUIT OF THE CARBURETOR.

LIST THE FIVE CIRCUITS OF THE CARBURETOR AND THE PURPOSE OF EACH CIRCUIT.

STATE THE ADJUSTMENT MADE TO THE IDLE CIRCUIT.

In the first study unit, the characteristics of gasoline and the combustion of the air-fuel mixture in the combustion chamber were discussed. In this study unit, the gasoline fuel system and how the ratio of air to fuel is regulated to obtain the air-fuel mixture for proper combustion at various speeds and loads will be discussed.

The purpose of the fuel system in an internal combustion engine is to provide the engine with a combustible mixture of fuel and air. The proportion of fuel to air must be correct regardless of speed and load on the engine. For instance, the best economy is obtained under normal conditions with a mixture of one part fuel to about 16 parts air (16 to 1), while for quick acceleration a mixture of one part fuel to about 12 parts air (12 to 1) is needed. In order to start an engine when it is cold, an extremely rich mixture is needed. How the extremely rich mixture is obtained for cold starts will be discussed in work unit 2-2. As mentioned in study unit 1, only the gasoline vapors burn. Therefore, the liquid fuel must be vaporized in order to have proper combustion. How this is accomplished will be discussed later in this work unit.

The main components of a fuel system are: fuel tank, fuel lines, fuel pumps, filter, carburetor, air cleaner, intake manifold, and emission controls (on some vehicles). The fuel tank (fig 2-1) stores the fuel to be used by the engine. The tank is normally made of sheet steel and has baffles to reduce the sloshing of fuel created by the movement of the vehicle. Also, a fuel level sending unit is installed in the tank to assist the operator in maintaining the supply of fuel. However, when the fuel level is maintained at a low level (less than 1/2 tank) for an extended period, condensation will be produced. This is due to the humidity in the air which enters the tank and the temperature difference during the day. When humid air cools, the humidity condenses and collects in the tank. If the level of condensation (water) rises to the level of the main fuel line, the water will be pumped through the lines and filters to the carburetor. Water will not burn, therefore, the engine will not run when water accumulates in the float bowl of the carburetor. The best way to prevent condensation is to keep the fuel level above three-quarters of a tank.

<u>Caution</u>: Fuel tanks are dangerous, even when apparently empty. DO NOT allow sparks or flames near the tank inlet or other holes.

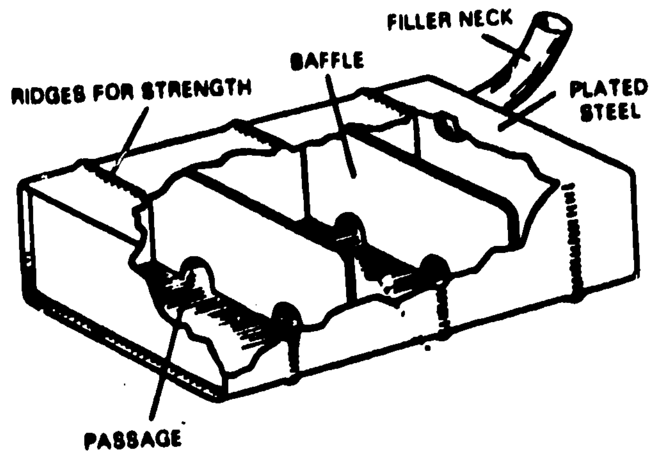


Fig 2-1. Fuel tank.

Fuel lines which are usually made of steel connect the fuel tank with the fuel pump and carburetor. The lines provide a path for the fuel to transfer from the tank to carburetor. Hoses are used at the tank and the pump to reduce leakage due to vibration.

Routing of the fuel lines is important. The line from the tank to the pump (engine compartment) is secured to the frame at various points to eliminate vibration and breakage. The line from the pump to the carburetor is routed near the exhaust manifold. Heat from the exhaust can cause the fuel line to get hot, particularly on hot days and when driving for an extended period. The heat will cause the fuel in the line to vaporize before reaching the carburetor. The heat can travel down to the fuel pump and also vaporize fuel there. This condition (vapor lock) will result in not enough fuel (liquid) entering the carburetor preventing the engine from running. The remedy is to cool the line and either reroute or insulate the line from the heat source.

A fuel pump is a mechanical or electrical device used to supply the carburetor (engine) with fuel from the tank. Fuel pumps will be discussed further in work unit 2-6.

A gasoline engine uses a carburetor to mix fuel with air in the proper proportions to produce a combustible mixture which provides the power of the engine. Carburetors will be discussed in more detail later.

A filter is normally placed in the line between the fuel pump and carburetor. This filter catches particles of rust and scale moving from the fuel tank through the lines. Another filter can be placed inside the inlet to the fuel bowl of the carburetor.

Air contains particles of dust which, if allowed to enter the engine, can cause excessive wear on the working parts (pistons, rings, and cylinder walls). The dust varies according to the area of operation. In the military, extremely dusty conditions can be attained when driving in off-road operations. An air filter is placed on the intake of the carburetor to remove the dust particles prior to entering the engine. Air filters will be discussed in work unit 2-4.

An engine, in a motor vehicle, normally has 4, 6, or 8 cylinders which require an air-fuel mixture but only one carburetor (except for high performance engines). A method to distribute the air-fuel mixture to the cylinders is required. This is the purpose of the intake manifold which will be discussed in work unit 2-3.

Emission controls, installed on an engine, reduce the emission of hydrocarbons by routing vapors from the fuel tank, and those vapors in the crankcase, into the carburetor air flow. Military tactical vehicles do not have a vapor recovery system (except for crankcase ventilation) and, therefore, will not be discussed in detail.

So far we have discussed the purpose and the components of a fuel system. You have learned that the purpose of a fuel system is to provide the engine with an air-fuel mixture for combustion in the cylinders. This will bring you to the carburetor which atomizes the fuel with the proper portion of air which produces a combustible mixture. As air is drawn into the cylinder by the downward movement of the piston, the suction produced brings air into the intake manifold through the carburetor venturi (an hour-glass shaped restriction in the carburetor throat). Actually, atmospheric nressure forces air to compensate for the low pressure created by the downward movement of the piston. The action of the venturi draws fuel into the air flow from the carburetor float bowl through either the high speed circuit or low speed circuit depending upon the position of the throttle valve and the speed of the engine.

The venturi principle (action) is a means of increasing the vacuum in the carburetor throat. To understand this, it is necessary to know that the total energy of all things remains constant but this energy can change from one form to another form. If one form of energy increases, then one or more other forms of energy must decrease to keep the total energy constant. As air travels through the air horn of the carburetor, the molecules must speed up to go through the venturi if all the molecules are to get through. Thus, the increased speed of air produces a decrease in pressure and temperature. This action (fig 2-2) is utilized to bring fuel into the air stream by placing a tube from the float bowl at the point of maximum vacuum (center of the venturi). Another item to contend with is the atomization of fuel into the venturi where pressure and temperature are reduced further by the evaporation of the fuel. Sometimes, the temperature can be reduced to the point where ice may be formed on the throttle valve, particularly in cold, humid climates.

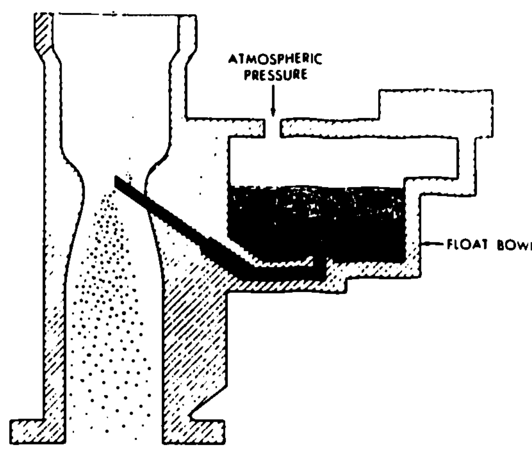


Fig 2-2. Simple carburetor showing venturi action and fuel flow through the high speed circuit.

Since the purpose of the carburetor is to mix fuel with air in proper proportions, we now must discuss how this takes place. Gasoline in the liquid form does not burn which means that the fuel must be in a vapor when the air-fuel mixture enters the combustion chamber. To accomplish this efficiently and rapidly, the fuel is atomized (reduced to fine particles) when mixed with the air flowing through the venturi. The smaller particles of fuel enhance the vaporization process. Atomization, along with heat from engine operation, completely vaporizes the fuel in the intake manifold as the air-fuel mixture travels to the combustion chamber.

Now, let's look back at the process discussed thus far. There is air flowing through a venturi with a main metering valve (tube) installed in the center of the venturi. This in itself will operate an engine at a constant speed (high speed circuit has been described) after the engine has reached operating temperature. The engine in a motor vehicle normally does not operate at a constant speed. Therefore, we must provide a means of varying the speed according to the load required (cold start, idle, acceleration, and high speed). To start an engine while it is cold requires a rich air-fuel mixture (sometimes 8 to 1) while high speed operation needs an air-fuel mixture ratio of 16 to 1. These two ratios are the extremes, and other operational requirements fall between the 8 to 1 and 16 to 1 ratios. Control of the air-fuel mixture is accomplished by the five circuits of the carburetor, the float circuit, low speed (idle) circuit, acceleration circuit, choke circuit and high speed circuit. The choke circuit which aids cold starts will be discussed in work unit 2-2.

Before an engine can be started or run, it must have fuel vapor mixed with air in the combustion chamber. Therefore, fuel must be available in the carburetor at all times. A reservoir in the carburetor is supplied with fuel by the fuel pump. This reservoir is called the float circuit or bowl (fig 2-3). The fuel enters through a needle valve which is attached to a float. The float and needle valve, when adjusted to the specifications in the TM of the vehicle, maintain the level of fuel in the bowl provided there is fuel in the tank and vapor lock conditions are not present.

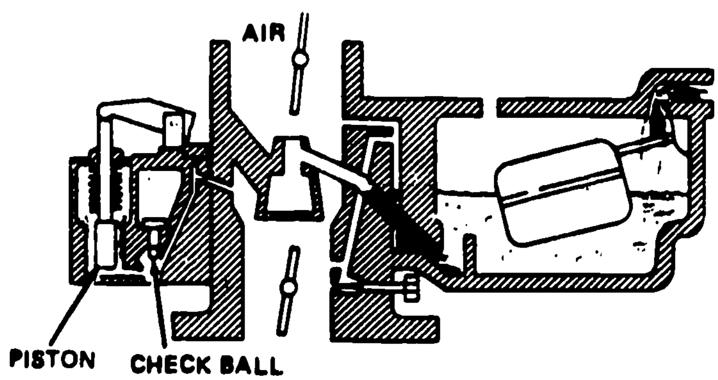


Fig 2-3. Float circuit.

We now have fuel in the carburetor and the engine is running at an idle. How does the fuel mix with the air flow? This is accomplished by the low speed (idle) circuit (fig 2-4). The purpose of the low speed (idle) circuit is to provide the engine with the proper combustible mixture (about 8 to 1) to operate at low speeds. In this circuit, passages are drilled in the carburetor body from the bowl to a point above the level of fuel, then down to the area where the throttle valve is located. You should note in figure 2-4, that at the highest point of this passage, an air bleed hole is drilled from the fuel passage to the carburetor throat and two holes are also drilled in the lower end of this passage, with an idle adjustment screw located in the lowest hole. When an engine is idling, the throttle valve is almost closed which restricts the flow of air into the engine and lowers the vacuum in the venturi. The lower vacuum is not enough to pull fuel through the main metering circuit. Therefore, since the lower hole in the idle circuit is below the throttle valve (where vacuum is greatest), fuel is pulled from the bowl toward the air bleed hole and is mixed with the air coming in through the air horn. This air-fuel mixture travels down through the passage to idle adjustment screw and into the intake manifold and cylinders. This causes the engine to run at an idle (low speed). Sometimes the engine runs rough at an idle. This is caused by an improper ratio of air and fuel (combustible mixture) admitted by the idle circuit. The idle adjustment screw regulates this ratio by adjusting the amount of air admitted into the circuit.

The procedures for adjustment at the idle will be covered in work unit 2-5 and the TM of the vehicle.

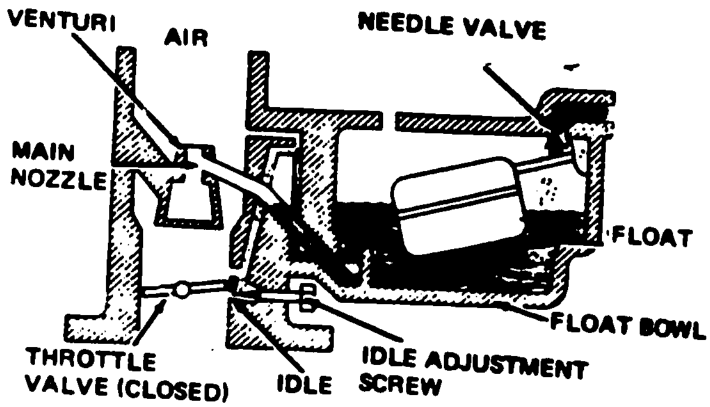


Fig 2-4. Low speed (idle) circuit.

When the throttle valve is opened slightly (fig 2-5), the vacuum in the intake manifold affects both the lower holes in the low speed circuit. This allows more fuel and air to enter the intake manifold and, therefore, slightly increases the speed of the engine.

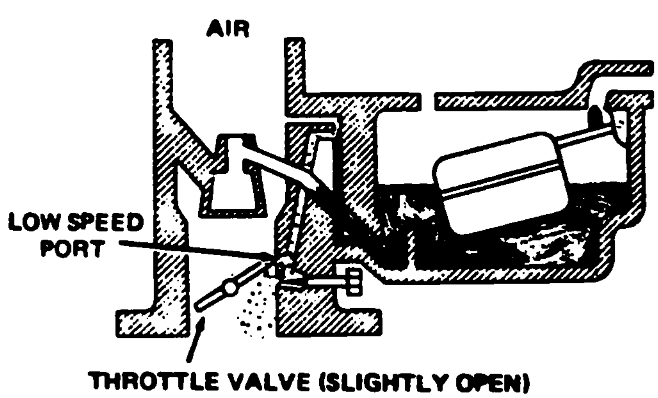


Fig 2-5. Low speed circuit (throttle valve open slightly).

The acceleration circuit (fig 2-6) is placed in a location where the supply of fuel is constant, normally the float bowl, and consists of a plunger with a leather cup fitted in a cylinder. As the accelerator is pressed by the operator, linkage on the carburetor moves the accelerator plunger down in the accelerator pump cylinder which forces fuel in the cylinder through a drilled passage into the throat of the carburetor. This procedure helps to eliminate the "dead spot" in the acceleration of the engine speed. Excessive pumping of the accelerator with the engine stopped (not running) will flood the engine (cause too much fuel or liquid (raw) fuel into the intake manifold) particularly when the engine is cold. When the accelerator is pressed, linkage also opens the throttle valve. This allows more air to enter the venturi which also pulls more fuel through the main metering circuit. However, the engine speed will not accelerate until the air-fuel mixture is in proportions (approx. 12 to 1) to accommodate the quick accel-ration of engine speed. In short, the accelerator pump circuit injects raw fuel into the air flow through the carburetor to increase (enrich) the air fuel mixture.

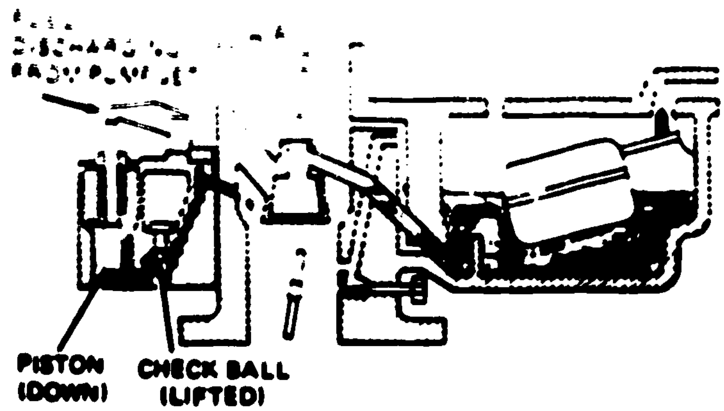


Fig 2-6. Acceleration circuit.

Now that we have discussed how the carburetor mixes the proper amounts of fuel and air at starting, low speeds, and acceleration, let's look at the high speed circuit. As noted previously, the air-fuel ratio varies with the speed (load) of the engine. For maximum economy of fuel, a ratio of about 16 to 1 is needed. This is accomplished by the high speed circuit (fig 2-7). The main metering jet (orifice) meters fuel into the air flow. As the air speed through the carburetor increases, the venturi action reduces the air pressure (creates vacuum) in the center of the venturi. This vacuum pulls fuel through the metering orifice and up the passage where the fuel is atomized by the air flowing through the carburetor. The low speed circuit does not operate when the vacuum is lowered by opening the throttle valve.

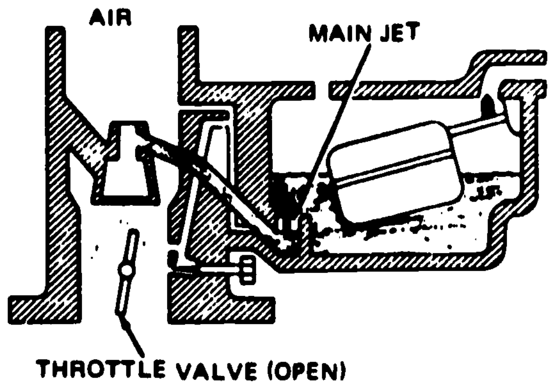


Fig 2-7. High speed circuit (main metering jet).

Another high speed circuit found in some types of carburetors is the metering rod (fig 2-8). This system uses a stepped (varying diameter) rod inserted in the metering orifice. As the throttle is opened, linkage moves the metering rod up, which increases the amount of fuel drawn into the air stream. This allows the engine to attain its maximum power (speed). Other systems, power enrichment, vacuum step up, etc., are used in various makes of carburetors, but will not be discussed in this course due to the fact that they are not being used on military vehicles. For any technical information, repair, or maintenance criteria refer to the appropriate technical manual or manufacturer's publication on the appropriate type of vehicle (carburetor).

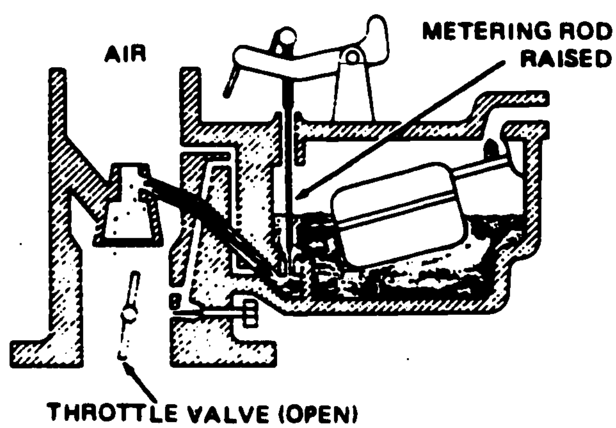


Fig 2-8. High speed circuit (metering rod).

Thus far, this work unit has discussed the various circuits of a carburetor that pertain to a single barrel carburetor. Multiple throat (barrel) carburetors have the same circuits for each throat and, therefore, operate the same, whether it be a quadrajet, two barrel, or single barrel. Multiple carburetors are installed on some special purpose vehicles (racing) and each carburetor operates the same as described in this study unit. Linkage adjustment is a major difficulty on the multiple carburetors.

One classification of a carburetor is by the draft (air flow). There are updraft, sidedraft, and downdraft carburetors which refer to the direction of air flow into the throat. Another classification is by the number of throats (barrels), single barrel, two barrel, and four barrel carburetors are used. Other classifications are used but vary according to the manufacturer.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. State the purpose of the fuel system on an internal combustion engine.

____

____

2. List the eight main components of a fuel system.

   a. ______________________________________

   b. ______________________________________

   c. ______________________________________

   d. ______________________________________

   e. ______________________________________

   f. ______________________________________

   g. ______________________________________

   h. ______________________________________

3. State the purpose of the carburetor.

____

4. State the cause of fuel flow through the high speed circuit of the carburetor.

____

5. List the five circuits of a carburetor on an internal combustion engine.

   a. ______________________________________

   b. ______________________________________

   c. ______________________________________

   d. ______________________________________

   e. ______________________________________

6. State the purpose of the low speed (idle) circuit of a carburetor.

____

7. State the adjustment made to the idle circuit.

____

8. State the purpose of the float circuit.

____

Work Unit 2-2. CHOKES

STATE THE PURPOSE OF A CHOKE ON AN INTERNAL COMBUSTION ENGINE.

LIST THE TWO TYPES OF CHOKES.

LIST THE SYMPTOMS OF EXCESSIVE CHOKING IN AN INTERNAL COMBUSTION ENGINE.

STATE THE POSITION OF THE CHOKE WHEN THE ENGINE IS AT OPERATING TEMPERATURE.

STATE HOW ENRICHING THE AIR/FUEL RATIO FOR STARTING A COLD ENGINE BY USE OF THE CHOKE IS ACCOMPLISHED.

STATE THE TWO METHODS EMPLOYED TO IMMEDIATELY LEAN THE AIR/FUEL MIXTURE AS SOON AS THE ENGINE IS STARTED.

In the previous work unit, the principles of carburetion (where the mixture of air and fuel is regulated) were discussed. However, when the engine is cold, a very rich mixture is required. Normal carburetion cannot, by design, accommodate the extremely rich mixture for cold starts. To accommodate the cold starting requirement, a choke is placed in the air horn of the carburetor. The choke is a butterfly valve which restricts the air flowing into the venturi. This allows the suction, created by the downward (intake) movement of the piston (intake manifold vacuum), to pull raw gasoline into the air flow, enriching the air-fuel mixture. Therefore, the purpose of a choke is to aid in starting a cold engine.

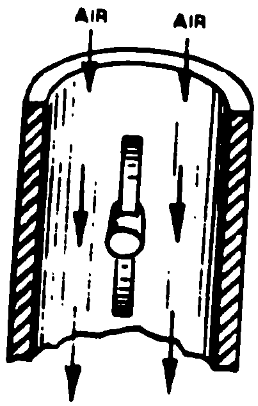
There are two types of chokes: manual and automatic. The manual choke is applied when the operator pulls on a cable or wire in the operator's compartment, while the automatic choke is applied automaticaly according to the engine temperature. The disadvantage of a manual choke is that the operator must decide when to open the choke (push the cable in) after the engine has warmed up. This is not only difficult to ascertain but it also may take several minutes. Therefore, the operator will normally allow the choke to be closed (at least partially) after the engine has warmed up. Excessive choking causes excessive carbon buildup on the spark plugs and combustion chamber while also increasing gas consumption and flooding of the engine. To overcome this, the automatic choke was developed.

The automatic choke, unlike a manual choke, normally uses heat produced by the engine to control the application of the choke valve at the top of the carburetor throat (air horn). The heat is supplied by exhaust manifold (normally) or coolant. Electric chokes have also been used, but for the purposes of this course, discussion will pertain to the exhaust heat actuated choke.

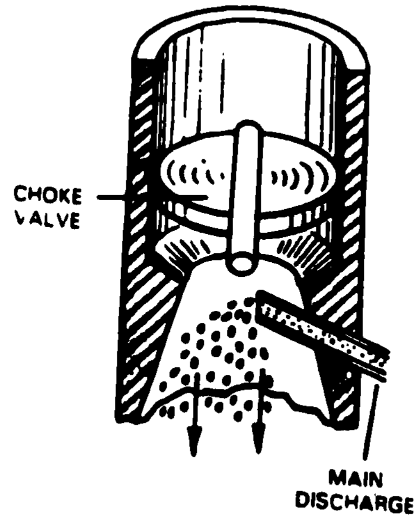
The exhaust heat actuated automatic choke depends primarily on the unwinding of a thermostatic coil spring as heat is applied. There are several methods of supplying heat to the choke: a thermostatic coil mounted on the carburetor with heat applied by a tube from the exhaust manifold; the thermostatic coil mounted in the exhaust manifold (or crossover) connected to the choke by linkage; routing coolant in or near the thermostatic coil on the carburetor; or a combination of exhaust heat, air velocity and intake manifold vacuum.

There are too many methods of applying automatic chokes to discuss them all in detail in this course. For repair and maintenance criteria, refer to the appropriate technical manual.

What occurs when the choke valve is closed? The answer is the carburetor air flow is restricted. When the restriction is above the venturi (compare to throttle), intake manifold vacuum moves into the carburetor throat (up to the restriction). As the piston travels down on the intake stroke, the suction pulls fuel from the float bowl (fig 2-9) through the high speed circuit, (due to the intake manifold vacuum). The increased air-fuel mixture aids in starting a cold engine. However, if the choke remains closed after the engine starts, flooding can occur. This is alleviated by one of two methods: by offsetting the choke valve (plate) or by having a spring-loaded poppet valve in the choke plate (fig 2-10). Either or both methods are used to allow air to enter the manifold as the engine starts which immediately leans the air-fuel mixture. As the engine warms up the automatic choke will open by exhaust heat acting on the thermostatic coil, while a manual choke will remain closed (or partially closed) until the operator pushes the choke cable in.



Choke open



Choke closed

Fig 2-9. Choke valve.

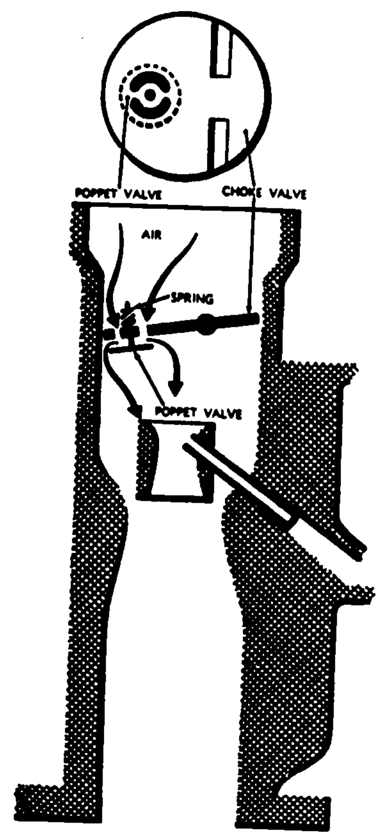


Fig 2-10. Details of choke valve.

The basic operation of a choke valve is for it to be open when the engine is at operating temperature and closed when the engine is cold. An added feature to help cold start an engine is an idle speed advance cam which automatically advances the idle speed to ensure that the engine will keep running with the enriched air-fuel mixture.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. State the purpose of a choke on an internal combustion engine.

   ____

2. List the two types of chokes used on internal combustion engines.

   a. ____

   b. ____

3. List the symptoms of excessive choking in an internal combustion engine.

   a. ____

   b. ____

   c. ____

4. State the position of the choke valve when the engine is at operating temperature.

   ____

5. State how enriching the air-fuel mixture for starting a cold engine is accomplished.

   ____

   ____

6. What two methods are used to immediately lean the air-fuel mixture as soon as the engine is started?

   ____

   ____

Work Unit 2-3. ENGINE MANIFOLOS

STATE THE PURPOSE OF AN INTAKE MANIFOLO.

STATE HOW ENGINE HEAT IS APPLIEO TO THE INTAKE AIR-FUEL MIXTURE ON INLINE ENGINES.

STATE HOW ENGINE HEAT IS APPLIEO TO THE INTAKE AIR-FUEL MIXTURE ON "V" TYPE ENGINES.

STATE WHY HEAT IS APPLIEO TO THE INTAKE AIR-FUEL MIXTURE.

STATE THE MAIN REASON FOR UNEQUAL FUEL OISTRIBUTION IN THE CYLINOERS OF AN ENGINE.

We have discussed carburetion or the mixing of fuel with air in proper proportions. Routing of this mixture to the cylinders is accomplished by the intake manifold. The manifold is the device which connects the carburetor to the cylinders. Some fuel distribution problems exist in the intake manifold. The major problem which affects fuel distribution is that the fuel is not completely vaporized in the intake manifold. Gasoline (fuel) will not burn in the liquid state. The vaporization is accomplished by raising the fuel (particles) to its boiling point. The boiling point is reached, to an extent, by applying heat to the center of the intake manifold just below the carburetor. On an inline engine the intake manifold is bolted to the exhaust manifold. In this case, a manifold heat control valve (fig 2-11) mounted in the exhaust manifold causes exhaust heat from the combustion chambers to be routed to the heat chamber just below the carburetor. As the chamber heats up, the air-fuel mixture is also heated to aid in vaporization particularly with a cold engine. Once the engine is at the operating temperature, the manifold heat control valve routes all exhaust gases to the exhaust pipe. After the engine warms up, the engine (source of heat) and particularly the combustion chamber completes the vaporization process.

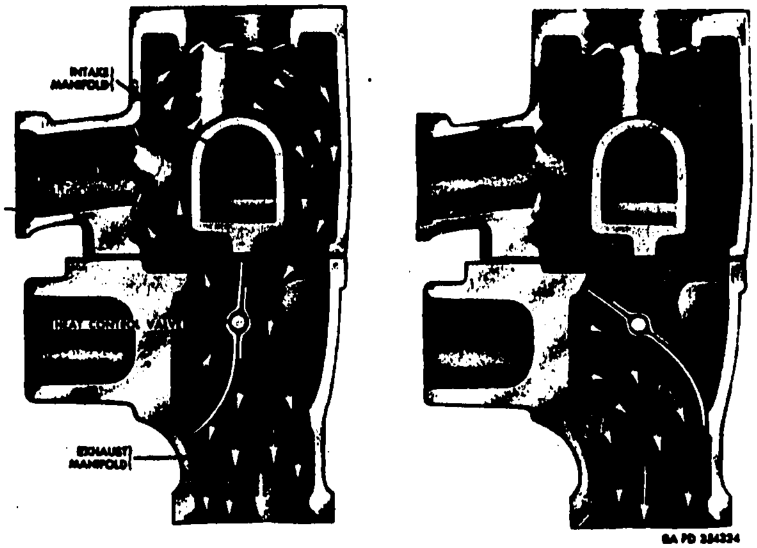


Fig 2-11. Manifold heat control valve.

In an V-type engine, exhaust heat is directed through an exhaust crossover passage in the intake manifold (fig 2-12). The effect is the same (i.e., applying heat to the air-fuel mixture which aids in the vaporization process). The complete exhaust system will be discussed in study unit 4.

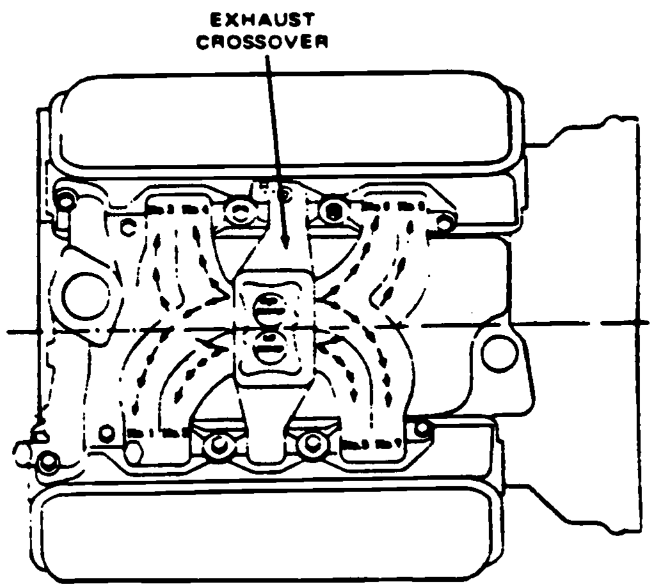


Fig 2-12. V-type intake manifold.

Inefficient vaporization of the fuel causes unequal air-fuel mixture in the individual cylinders. This happens because the unvaporized particles (hydrocarbons) of fuel have a tendency to travel in a straight line (inertia). The inertia of these heavy particles causes them to pass the branch of the intake manifold (fig 2-13) which directs the air-fuel mixture to the cylinders. The physical characteristics and shape of the manifold, composition of the fuel, heat supplied, and engine speed all seriously affect the air-fuel distribution. Unequal fuel distribution normally is evident when a cold engine is started. The rough idling, misfiring cylinders, and black smoke combined indicate that the cylinders are receiving an unequal air-fuel mixture. Unequal fuel distribution results in poor fuel economy and increased exhaust emissions. Because of this, automotive manufacturers are increasing the production of fuel injected engines.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. State the purpose of the intake manifold.

____

2. State how engine heat is applied to the air-fuel mixture on inline engines.

____

3. State how engine heat is applied to the air-fuel mixture on "V" type engines.

____

4. State why heat is applied to the air-fuel mixture.

____

5. State the main reason for unequal fuel distribution in the cylinders of an engine.

____

Work Unit 2-4. AIR CLEANERS

LIST THE FOUR TYPES OF AIR CLEANERS.

STATE THE PURPOSE OF AN AIR CLEANER.

STATE WHY THE AIR ENTERING AN ENGINE MUST BE CLEAN.

STATE THE PREFERRED METHOD OF SERVICING A PAPER ELEMENT AIR FILTER.

NAME THE AIR CLEANER THAT IS CONSIDERED THE MOST EFFICIENT.

In the previous work units, the discussion was centered on how air and fuel were mixed then transported into the cylinders for combustion. The air used in the internal combustion engine must be free of dust particles or excessive engine wear will result. Therefore, the purpose of an air filter is to filter out dust particles. There are four types of air cleaners used to filter out the dust particles: oil bath, oil wetted mesh, polyurethane, and paper element air cleaners.

The oil bath type air cleaner (fig 2-13) uses a copper mesh element built into the upper housing of the cleaner. The lower housing contains an oil sump (oil bath) which is maintained at a specified level. When the engine, is running air is drawn into the cleaner and is deflected down and across the oil surface. Dust particles are picked up by the oil (oil bath). The air then passes through copper mesh to remove oil particles and into the carburetor.

Servicing the cleaner should be in accordance with the TM or about every 5,000 miles. The oil must be emptied, the complete unit washed in solvent and the oil sump refilled with SAE 40 oil. Very dusty conditions require servicing of the air cleaner more often.

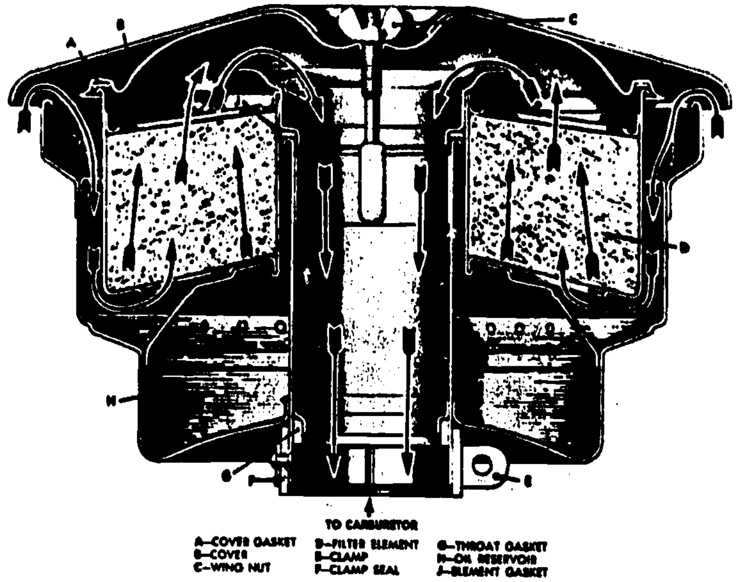


Fig 2-13. Oil bath air cleaner.

The oil wetted mesh type air cleaner is presently used on small gas engines, tractors, or stationary engines. In this type air cleaner, the air passes through an oil wetted mesh filter ring in which the oil picks up dust particles. This type cleaner has the disadvantage of being unable to remove extremely fine dust particles from the air.

Servicing must be frequent depending on the conditions. Normally, after each use the mesh must be washed in solvent or kerosene, squeezed dry, dipped in oil, and excess oil allowed to drain off.

The polyurethane cleaner (fig 2-14) is used on small displacement engines. The element is generally supported by a perforated metal ring. When cleaning the polyurethane element, care must be taken to prevent damage. The element must be washed in mineral spirits or kerosene, squeezed dry, dipped in oil and allowed to drain.

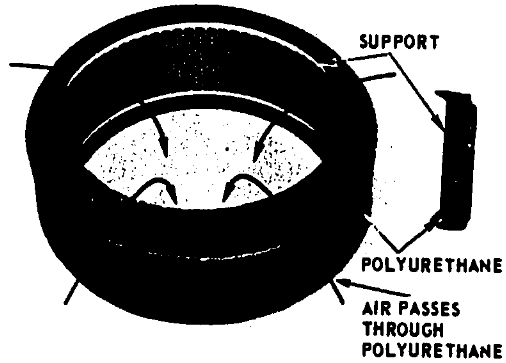


Fig 2-14. Polyurethane element.

The dry type or paper element filter (fig 2-15) is considered the most efficient filter and is the one that is most preferred. It consists of an accordian-pleated, special paper ring sealed on top and bottom with plastic rings. Most servicing situations require simple replacement of the element. If the element is not over 50 percent plugged, as determined by placing a light in the center of the ring and observing the outside, it may be cleaned by tapping the edge of the element on a hard surface or by blowing the dust particles out from the inside of the ring. Care must be taken not to damage the element, and cleaning should be done in accordance with the technical manual pertaining to the particular vehicle.

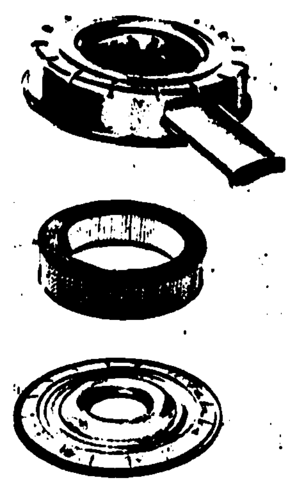


Fig 2-15. Dry type air filter.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. List the four types of air cleaners used on the internal combustion engine.

   a. ____________________

   b. ____________________

   c. ____________________

   d. ____________________

2. State the purpose of an air cleaner.

   ____

   ____

3. State why air entering an engine must be clean.

   ____

   ____

4. State the preferred method of servicing a paper element (dry) air filter.

   ____

5. Name the air filter considered to be the most efficient.

____

Work Unit 2-5. FUEL PUMPS

STATE THE PURPOSE OF A FUEL PUMP.

NAME THE TWO TYPES OF FUEL PUMPS.

STATE THE MINIMUM OPERATING PRESSURE OF A FUEL PUMP.

STATE THE MINIMUM AMOUNT OF FUEL A PUMP SHOULD DELIVER TO PROVIDE THE ENGINE WITH ENOUGH FUEL FOR ALL OCCASIONS.

LIST FOUR ADVANTAGES OF AN ELECTRIC FUEL PUMP.

DESCRIBE THE PROCEDURE USED TO TEST A FUEL PUMP'S DELIVERY VOLUME.

In the operation of an engine, fuel is mixed with air in the proper proportions. The air is clean (filtered), and the carburetor mixes the two elements. How does the carburetor get the fuel which the engine needs? A fuel pump sucks gasoline (fuel) out of the fuel tank through fuel lines and pushes the fuel into the carburetor reservoir (float bowl). In short, the fuel pump supplies the carburetor with fuel for use by the engine. Some fuel pumps (double action) also produce vacuum to operate some vacuum operated components such as windshield wipers. Double action fuel pumps are not used to a great extent since the incorporation of electric windshield wipers on vehicles.

There are two basic types of fuel pumps--mechanical and electric. A mechanical fuel pump (fig 2-16) uses cam action by an eccentric on the camshaft to produce movement of a diaphragm. The diaphragm movement creates the suction of fuel from the tank and the pressure to push the fuel to the carburetor through check valves (fig 2-17).

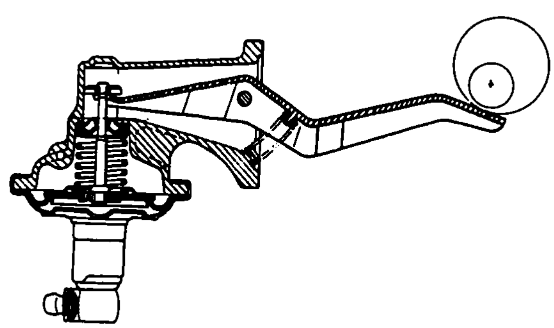
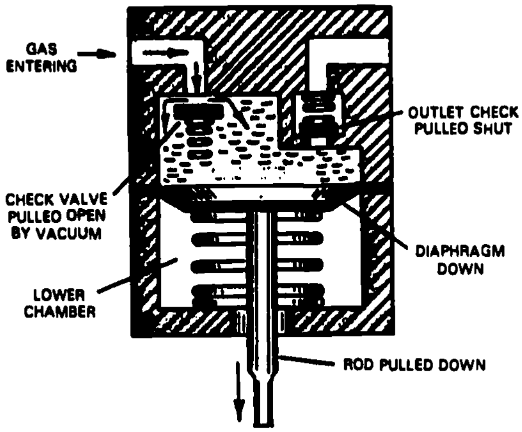
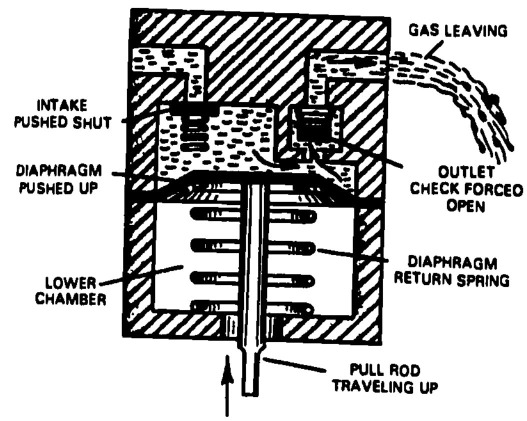


Fig 2-16. Mechanical fuel pump (cross section).



Suction stroke



Pressure stroke

Fig 2-17. Operation of mechanical pump.

Most mechanical fuel pumps used on vehicles are sealed and connot be repaired. Some pumps have screws around the diaphragm to hold the valve body and the lower body together. Although these pumps can be rebuilt, in most cases it is more practical to replace the pump when it does not operate in accordance with criteria contained in the technical manual of the vehicle.

Modern fuel pumps can give trouble-free service for many thousands of miles. However, when fuel supply problems exist, it is best to insure that the fuel tank has sufficient quantity of fuel first, then check the quantity of fuel delivered to the carburetor. To ascertain the quantity delivered, disconnect the fuel line at the carburetor and direct the line into a suitable container. Crank the engine with the coil wire removed.

The fuel should be expelled from the line in strong spurts. If no fuel comes out or there is an insufficient quantity (1 quart in one minute by ratio), the fuel pump is probably defective and should be replaced. This procedure does not eliminate the possibility of a restricted fuel filter, fuel line, or air leaks in fuel hoses. In diagnosing fuel pump problems, look for leaks (oil or fuel) at the pump and ascertain if fuel has entered the crankcase.

Another method of testing a fuel pump is by connecting a pressure gauge on a TEE in the carburetor inlet line. The pressure reading should be at least 5 psi and no more than 8 psi. Check the specifications in the particular TM when trouble-shooting.

Electric fuel pumps have advantages over the mechanical pump. First, several pumps can be used on one vehicle so that large amounts of fuel can be supplied and also, if one pump fails, another will continue to supply the fuel. There is a tremendous reduction of the tendency to vapor lock with an electric pump due to normal mounting away from the engine (heat source). Electric pumps supply fuel as soon as the ignition switch is turned on, while the mechanical pump requires the engine to turn (crank). Another advantage of an electric pump is that the fuel in the line, when pressurized, does not pulsate.

There are two types of electric fuel pumps--suction and pushing. A pushing pump is normally mounted in the tank pump. The suction pump is mounted between the tank and carburetor. Either pump whether, it is electric (suction or pushing) or mechanical, supplies fuel to the carburetor through a fuel filter which eliminates sediment from the fuel. One major disadvantage of an electric fuel pump is that it costs more than a mechanical pump.

Diagnosis of the electric pump is the same as a mechanical pump except that the engine does not have to be cranking. Just disconnect the line at the carburetor and turn the ignition on. If no fuel is delivered then the pump is defective or the supply line is blocked.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. State the purpose of a fuel pump.

 ____

 ____

2. Name the two types of fuel pumps.

 ____

3. State the minimum operating pressure of a fuel pump.

 ____

4. State the minimum amount of fuel a fuel pump should deliver to provide the engine with enough fuel for all occasions.

 ____

5. List four advantages of electric fuel pump.

 a. ______________________________

 b. ______________________________

 c. ______________________________

 d. ______________________________

6. Describe the procedure used to test a fuel pump's delivery volume.

 ____

 ____

SUMMARY REVIEW

In this study unit, you learned the principles of the gasoline fuel system, its components, and the principles of carburetion. In the next study unit, we will discuss the diesel fuel injection systems.

Answers to Study Unit #2 Exercises

Work Unit 2-1.

1. To provide the engine with a combustible mixture of fuel and air
2. a. Fuel tank
 b. Fuel lines
 c. Fuel pump
 d. Fuel filter
 e. Carburetor
 f. Air cleaner
 g. Intake manifold
 h. Emission controls
3. To meter and atomize the fuel with air in the proper proportion
4. Venturi action

5. a. Float circuit
   b. Low speed (idle) circuit
   c. Main metering circuit
   d. Acceleration circuit
   e. Choke circuit
6. To provide the engine with the proper combustible mixture for low speed operation
7. Idle mixture
8. To maintain a reservoir of fuel in the carburetor at all times

Work Unit 2-2.

1. To aid in starting a cold engine
2. a. Manual choke
   b. Automatic choke
3. a. Carbon buildup on spark plugs and combustion chamber
   b. Increased gas consumption
   c. Flooding
4. Open
5. When the choke is closed (engine cold), the intake manifold vacuum pulls fuel through the high speed circuit.
6. By offseting the choke valve (plate) and/or by having a spring-loaded poppet valve in the choke valve (plate)

Work Unit 2-3.

1. To connect the carburetor to the cylinders
2. By mounting the intake on the exhaust manifold and incorporating a manifold heat control valve diverting heat to the base of the carburetor
3. By incorporating an exhaust crossover passage in the intake manifold
4. To aid in the vaporization of the fuel
5. Inefficient fuel vaporization

Work Unit 2-4.

1. a. Oil bath
   b. Oil wetted mesh
   c. Polyurethane
   d. Paper element (dry)
2. To filter out dust particles
3. To reduce excessive wear
4. Replace the element
5. Paper element type filter

Work Unit 2-5.

1. To supply the carburetor with fuel
2. Mechanical and electrical
3. 5 psi
4. 1 quart per minute ratio
5. a. Several pumps can be used
   b. Reduction in the tendency for vapor lock
   c. Fuel supplied as soon as ignition is turned on
   d. Fuel does not pulsate
6. Disconnect the fuel line at the carburetor, direct the line into a container, operate the fuel pump, and observe the amount of fuel delivered.

STUDY UNIT 3

DIESEL FUEL SYSTEMS

STUDY UNIT OBJECTIVE: WITHOUT THE AID OF REFERENCES, YOU WILL IDENTIFY THE PRINCIPLES OF A DIESEL FUEL SYSTEM. AFTER IDENTIFYING THE PRINCIPLES OF A DIESEL FUEL SYSTEM, YOU WILL IDENTIFY THE VARIOUS TYPES OF DIESEL FUEL INJECTION SYSTEMS SUCH AS THE PRESSURED TIME (PT) FUEL INJECTION SYSTEM, THE UNIT INJECTOR SYSTEM, AND THE DISTRIBUTOR TYPE FUEL INJECTION SYSTEM.

In this study unit, discussion will be centered upon the three types of diesel fuel injection systems used on modern motor transport vehicles such as the M809 and M939 series vehicles, the M861 and LVS (Dragon Wagon), and the M1009 (CUCV).

Work Unit 3-1. TYPES OF DIESEL FUEL INJECTION SYSTEMS

STATE THE PURPOSE OF A DIESEL FUEL INJECTION SYSTEM.

LIST THE SIX FUNCTIONS A DIESEL FUEL INJECTION SYSTEM MUST PERFORM TO PROVIDE EFFICIENT OPERATION.

NAME THE COMPONENT WHICH CONTROLS FUEL PRESSURIZATION AND ATOMIZATION.

LIST THE THREE TYPES OF DIESEL FUEL INJECTION SYSTEMS USED ON MILITARY MOTOR VEHICLES.

STATE HOW FUEL IS METERED BY THE CUMMINS (COMMON RAIL) TYPE FUEL SYSTEM ON THE M809 OR M939 SERIES VEHICLES.

STATE THE FOUR FUNCTIONS OF THE UNIT INJECTOR.

STATE THE FOUR FUNCTIONS OF THE INJECTION PUMP INCORPORATED WITH A DISTRIBUTOR TYPE FUEL SYSTEM.

STATE THE TWO TYPES OF SUPERCHARGERS USED ON MILITARY VEHICLES.

The diesel fuel injection system is actually the heart of the diesel engine. There are many different designs used on engines today, but, regardless of the design or type of system, the purpose of the fuel injection system is to inject the correct amount of fuel into the engine at the proper time.

Fuel injection systems used on modern vehicles (diesel engines) have been perfected by many years of research and development. This research and development have resulted in the modern injection system which is lightweight, small, and reliable.

If the engine is to operate efficiently, the fuel system must perform the following functions: meter, time, pressurize, atomize, distribute, and control injection.

- Metering is measuring the proper amount of fuel supplied to the engine cylinders accurately, according to engine speed and load. This function can be done within the pump or at the injectors.

- Timing of the fuel injected is important during all phases of engine operation from start through full load and speed. The fuel must be injected when the piston is at or near top dead center (TDC) on the compression stroke. During the variance of engine speed, the timing is changed to allow for time lag between injection and ignition or other factors. Changing the time of injection is normally controlled by a governor built into the fuel (injection) pump.

- The fuel must be pressurized to be injected into the combustion chamber where the pressure of compression may be up to 500 psi. Pressurization opens the injector nozzle (spring loaded valve) and controls the atomization of the fuel through the holes in the tip or around the pintle. Since atomization occurs at high pressures 1800 to 4000 psi), the injector spring must allow the fuel pressure to rise to the specified opening pressure according to the technical manual or manufacturer's recommendations or improper atomization will occur.

- Fuel must be atomized in order to be burned efficiently because fuel, in liquid form, does not burn easily. The degree of atomization will vary according to combustion chamber design. For instance, an engine with precombustion chambers requires little atomization, while a direct injection engine relies solely on atomization and piston crown design to mix fuel with air for spontaneous combustion. Improper or inefficient atomization directly effects spontaneous combustion.

- Distribution of fuel must be accurate and occur at the proper time (according to the firing order). A distributor type system incorporates high pressure lines from the injection pump to each injector. The firing order or the distribution of high pressure fuel is determined at the hydraulic head of the injection pump. Other systems use a camshaft actuated rod to operate the injectors and the distribution of fuel to all cylinders is accomplished by a fuel manifold.

- The beginning and ending of fuel injection must be quick. Any delay will change the pump to engine timing. Hard starting, poor running, and excessive smoke are symptoms of a delay at the beginning or ending of fuel injection. Control of injection is accomplished by the incorporation of a delivery valve, retraction valve (in the fuel system), or a sharp drop on the cam lobe which operates the injector.

Many types of fuel injection systems are used on modern vehicles. The most common types used on military motor transport vehicles are pressure time (common rail), unit injector, and distributor systems. A general description of each is given below. More specific details will be given in later work units.

- The pressure time (common rail) system (fig 3-1), used exclusively on Cummins diesel engines, uses a gear driven pump to move fuel from the tank to the injectors. The fuel moving through the working parts provides lubrication and cooling for the injectors and pump. A flyweight governor controls the fuel pressure within the system and also the idle and top (maximum) speed. The throttle, regulated by the operator, controls the fuel flow and pressure to the injectors between idle and maximum speeds. The injector is operated by the camshaft. Fuel to all injectors is routed through passages in the cylinder head. The amount of fuel injected is controlled by the pressure of fuel in the manifold at the injector and the amount of time the fuel inlet orifice in the injector is open to receive fuel.

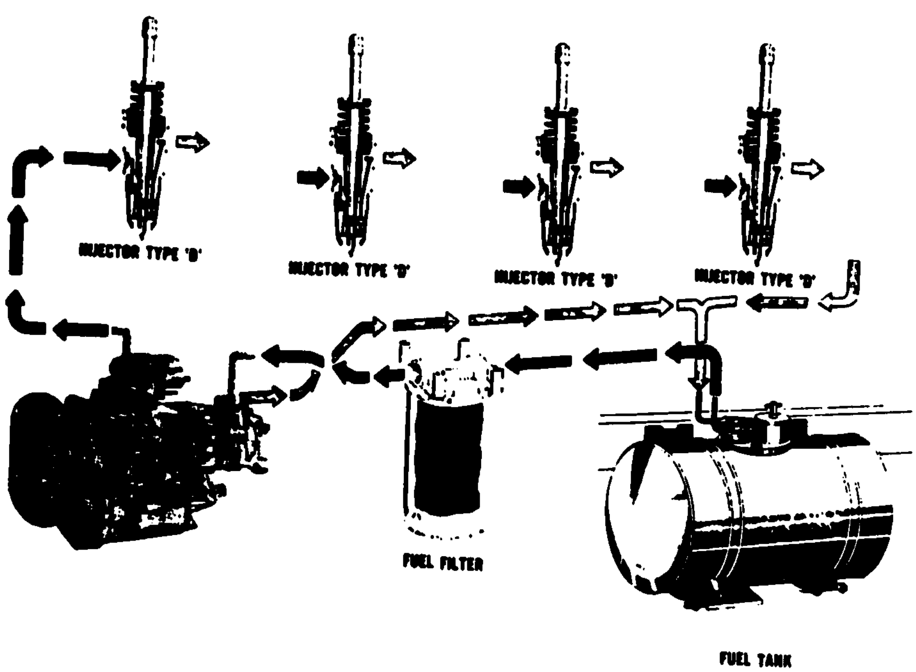


Fig 3-1. Pressure time (common rail) system fuel flow.

- The Detroit Diesel unit injector (fig 3-2) uses a low pressure gear pump which brings fuel from the tank through the fuel filter to the cam operated injector. The injector meters, times, pressurizes and atomizes fuel into the combustion chamber. A separate governor is connected to the control rack which varies the amount of fuel according to load and speed of the engine. The control rack turns the injector plunger, placing the helix in a position to control the closing of the inlet and exit ports. The position of the helix controls pressurization, metering, and injection of fuel.

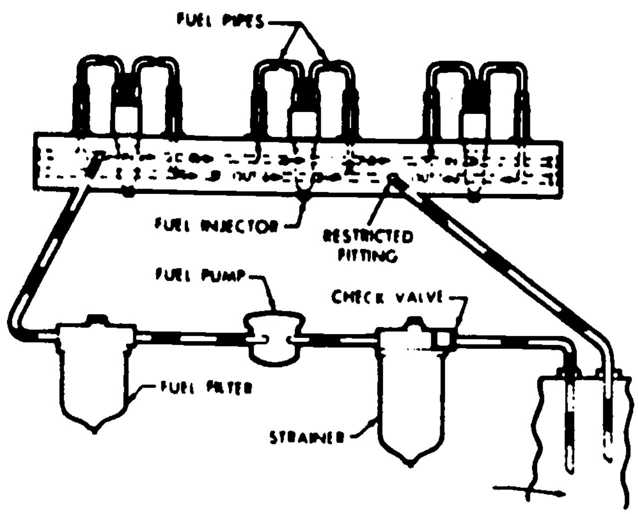


Fig 3-2. Typical unit injector system.

The distributor pump (fig 3-3) and injector nozzle system utilizes an engine-driven rotary injection pump that supplies and distributes pressurized fuel to the various cylinders. Metering of fuel and injection timing are controlled by the pump. The injector nozzle atomizes fuel in the combustion chamber when the pressurized fuel from the injection pump overcomes the spring load in the nozzle body.

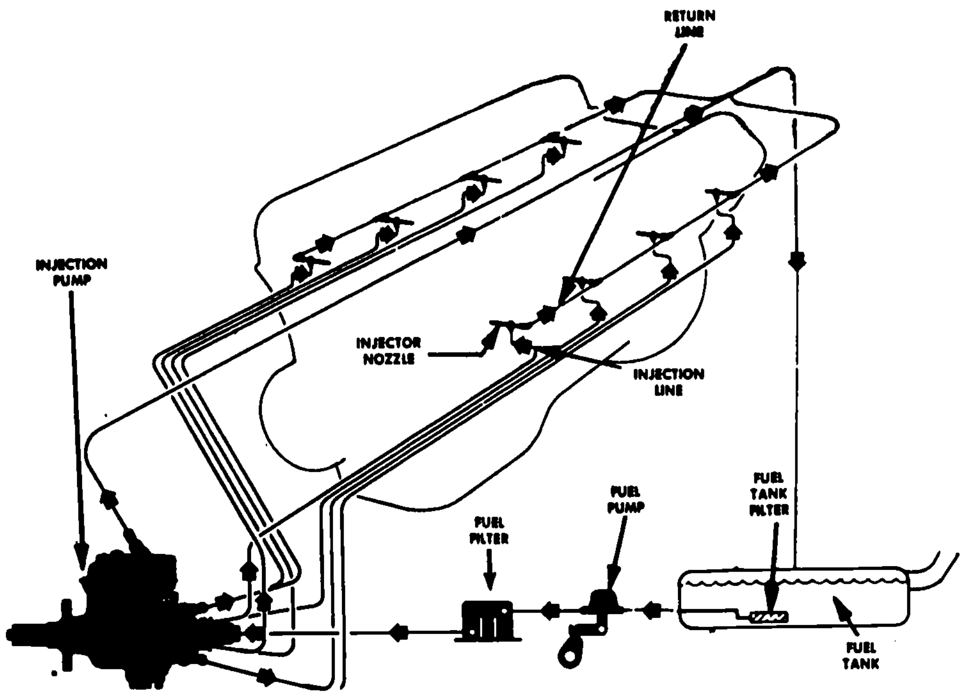


Fig 3-3. Distributor fuel injection.

Other components of the diesel fuel system are the tank, fuel filters, and return lines. The fuel tank stores fuel, the filters remove impurities and moisture, and the fuel return lines provide a route for excess fuel to return to the tank after circulating through the injectors. These items are common to all vehicles.

Superchargers are used on some vehicles. A supercharger is a device used to force air into the cylinders. There are two types: turbochargers and blowers.

- The turbocharger (fig 3-4) is comprised of two impellers on a single shaft. The unit is mounted on the exhaust manifold to utilize the exhaust gas pressure to turn the impellers. As the shaft turns, the intake impeller (turbine) pulls air in and forces it into the intake manifold for use by the engine. Since the turbocharger pressurizes the intake air, all exhaust gas remaining in the cylinder is pushed out before the exhaust valve closes. This scavenging process improves engine power.

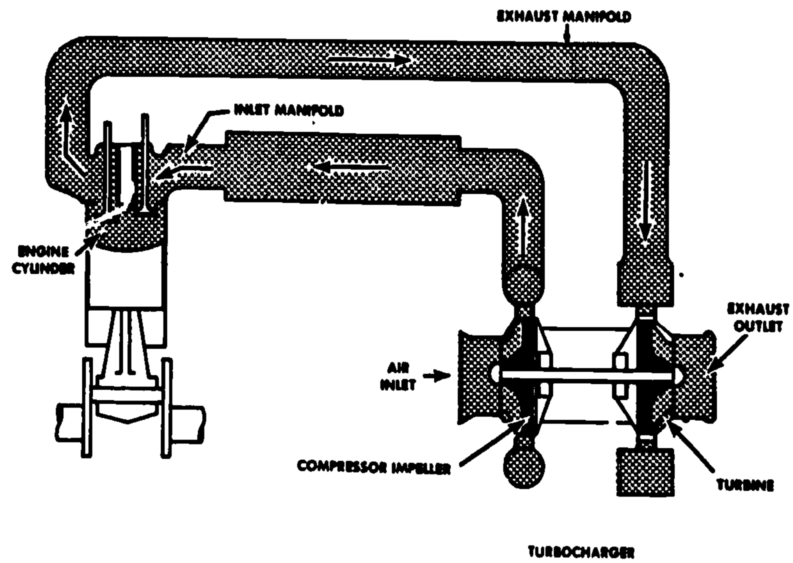


Fig 3-4. Turbocharger.

- The blower used on military vehicles is the "ROOTES" type (fig 3-5). It consists of two rotors closely meshed and is gear driven from the engine. This positive displacement blower causes air to be forced into the engine cylinders. The effect is the same as with a turbocharger.

The application of superchargers incorporated on military vehicles is being diminished. At present, most engines are naturally aspirated. Maintenance and repair criteria are contained in the particular technical manual of the vehicle and/or engine.

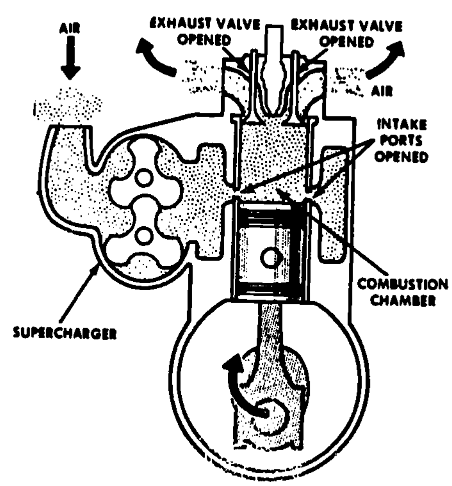


Fig 3-5. Positive displacement blower.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. State the purpose of a diesel fuel injection system.

   ____

2. List the six functions a diesel fuel injection system must perform to provide efficient operation.

   a. ____

   b. ____

   c. ____

   d. ____

   e. ____

   f. ____

3. Name the component of a diesel fuel injection system which controls pressurization and, therefore, atomization of fuel into the cylinder.

   ____

4. List the three types of fuel injection systems used on military vehicles.

   a. ____

   b. ____

   c. ____

5. State how fuel is metered by a Cummins (common rail) type fuel system on the M809 or M939 series vehicles.

   ____

   ____

6. State the four functions of the unit injector.

   a. ____

   b. ____

   c. ____

   d. ____

7. State the two types of superchargers used on military vehicles.

   a. ____

   b. ____

Work Unit 3-2. PRESSURE TIMED (PT) FUEL INJECTION SYSTEM

STATE THE PRINCIPLE OF THE PT FUEL SYSTEM.

STATE THE OPERATING PRESSURE RANGE OF THE PTG FUEL PUMP ON THE M939 SERIES VEHICLE.

NAME THE COMPONENT WHICH CONTROLS FUEL FLOW AT LOW IDLE AND HIGH IDLE.

STATE HOW FUEL FLOW FOR LOW IDLE IS PROVIDED.

STATE THE PURPOSE OF BYPASS FUEL.

NAME THE COMPONENT WHICH CONTROLS FUEL FLOW (PRESSURE) IN THE FUEL MANIFOLD BETWEEN IDLE AND MAXIMUM ENGINE SPEEDS.

NAME THE COMPONENT THAT CONTROLS THE TIMING (OPENING AND CLOSING) OF THE FUEL INLET ORIFICE.

NAME THE COMPONENT WHICH ALLOWS FUEL PRESSURE TO BUILD IN THE PT FUEL PUMP TO START THE ENGINE.

The M809 and M939 series vehicles use the Cummins NHC 250 engine. The naturally aspirated, six-cylinder, inline, liquid cooled engine utilizes the somewhat unique Cummins pressure time (PT) fuel system. This system is composed of a PTG-AFC (plugged) fuel pump (fig 3-6) mounted on the air compressor, fuel manifold, PT (type 0) injector, and fuel return lines. Of course a fuel tank, supply lines, and filter are common to all internal combustion engines. The pressure time (PT) fuel system is derived by the fact that fuel metered into the cylinder depends on two things, the fuel pressure at the metering orifice (controlled by the fuel pump) and the time the orifice is open to receive fuel (controlled by the cam actuated injector plunger). The air fuel control (AFC) device incorporated in the pump is plugged when used on naturally aspirated engines such as the NHC 250.

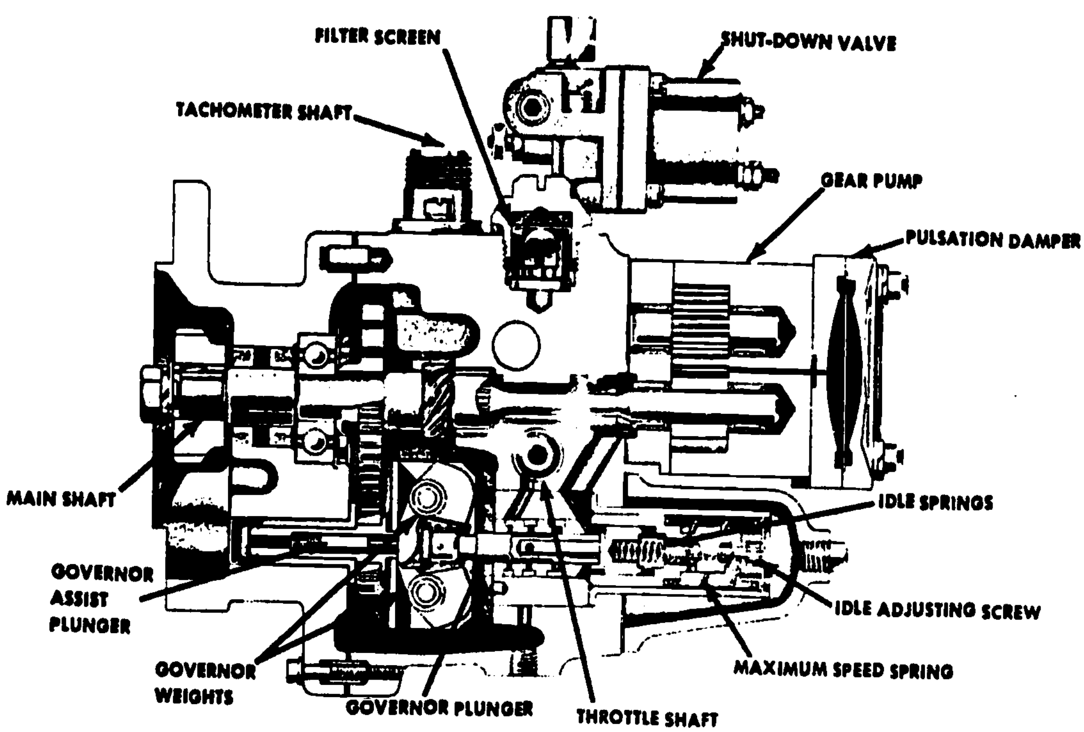


Fig 3-6. PTG fuel pump (cross section).

Now let's learn the operation of the PTG fuel pump. The principle of the PT system is based on the fact that changing the pressure of the fuel (liquid) in a line also changes the amount of fuel (liquid) delivered. The PT pump draws fuel from the tank and delivers it to each injector and also provides a means of controlling the pressure of the fuel being delivered. Therefore, it is a variable pressure fuel pump. Fuel pressures developed by the PTG pump vary from 26 psi at idle to approximately 176 psi at the top rated speed of the engine.

Take a look at figure 3-7. Fuel enters the gear pump, moves through a screen to the governor, then through the throttle shaft, and lastly, through the shut-down valve to the injectors. Pulsations created by the gear pump are eliminated by a pulsation damper (refer to fig 3-6).

As noted previously, the PTG pump is a variable pressure pump. In this type pump, the fuel flow is controlled by the governor (fig 3-7) at idle and maximum speeds. If the operating speed is somewhere between low idle and high idle, fuel flow is regulated by the throttle which is controlled by the operator. At low idle, the governor maintains sufficient fuel pressure (flow) by the use of a plunger and spring which allow the idle port to open, allowing enough fuel to maintain engine idle speed. At maximum speed (RPM) the governor plunger shuts off fuel (limits fuel pressure) to the injectors thus limiting speed. A bypass port is incorporated in the governor housing which allows fuel to circulate through the pump for lubrication and cooling of the working parts.

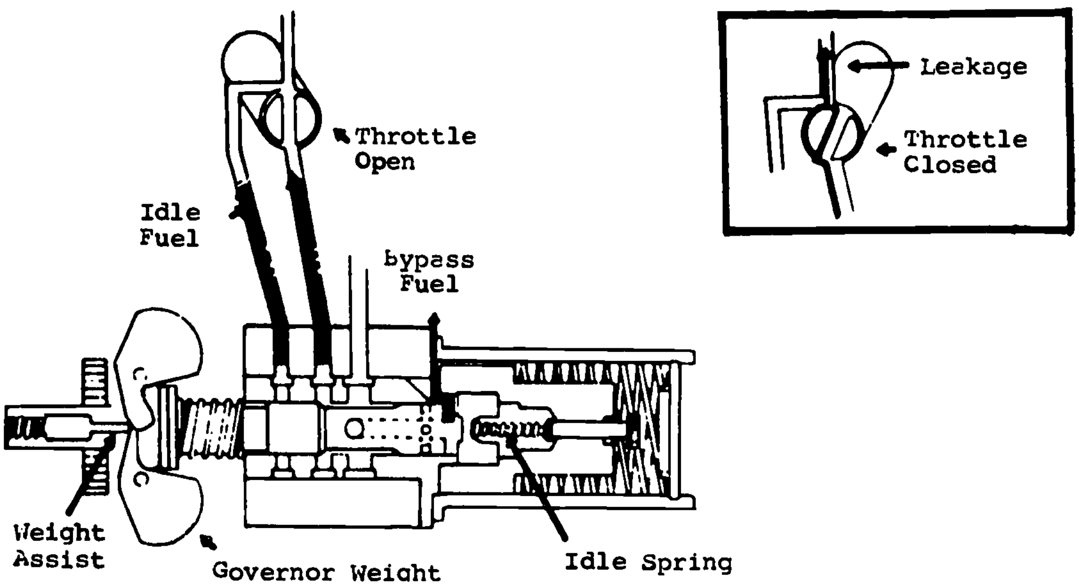


Fig 3-7. Governor (showing fuel flow).

You should note in figure 3-7 that the throttle shaft leakage allows fuel to pass from the governor around the throttle shaft to maintain low idle speed. For part load operation (between low idle and high idle) fuel flow is regulated by the throttle shaft. Thus the throttle controls fuel flow (pressure) between idle and maximum speeds.

Let's take a closer look at the governor. When the engine is not running, the idle spring plunger is positioned against the governor plunger (fig 3-8). With the engine at idle, fuel pressure from the gear pump flows through the governor barrel and forces the idle spring plunger from the governor plunger (refer to fig 3-8), thus providing bypass fuel to lubricate and cool the fuel pump. When the throttle is opened fuel pressure is increased in the fuel manifold. As engine speed increases, the governor weights move the governor plunger against the governor spring guide. This increases the fuel pressure in the pump and also in the fuel manifold according to the throttle position. Therefore, the initial movement of the throttle immediately increases the amount of fuel passing through the metering orifice in the injector. As engine speed increases, the governor allows fuel pressure to build in the pump. This procedure makes the throttle control fuel pressure in the fuel manifold thereby adjusting the amount of fuel delivered to the cylinders according to its position.

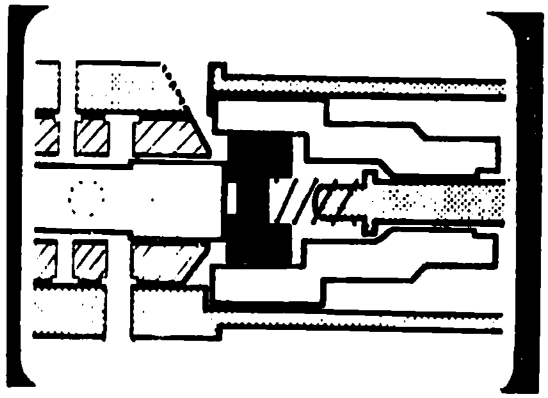


Fig 3-8. Idle spring and plunger (engine not running).

The fuel manifold is a drilled passage in the cylinder heads connecting the injector to the fuel supply. A return system is also provided to allow fuel to flow through the working parts of the injector for cooling and lubrication.

If you recall, in work unit 3-1, the metering of fuel to the cylinders of the PT system is a function of fuel pressure and the time the metering orifice is open to allow fuel to enter the injector pressure chamber. Timing the opening of the inlet orifice in the injector is a function of the camshaft. The camshaft lobe is machined to provide this part of the metering process (fig 3-9).

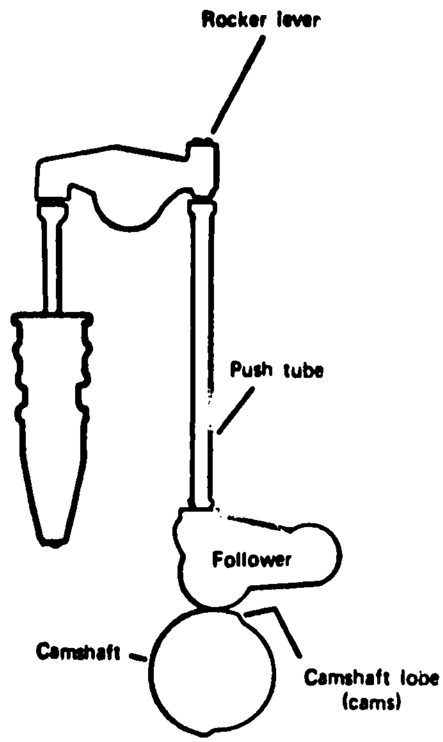
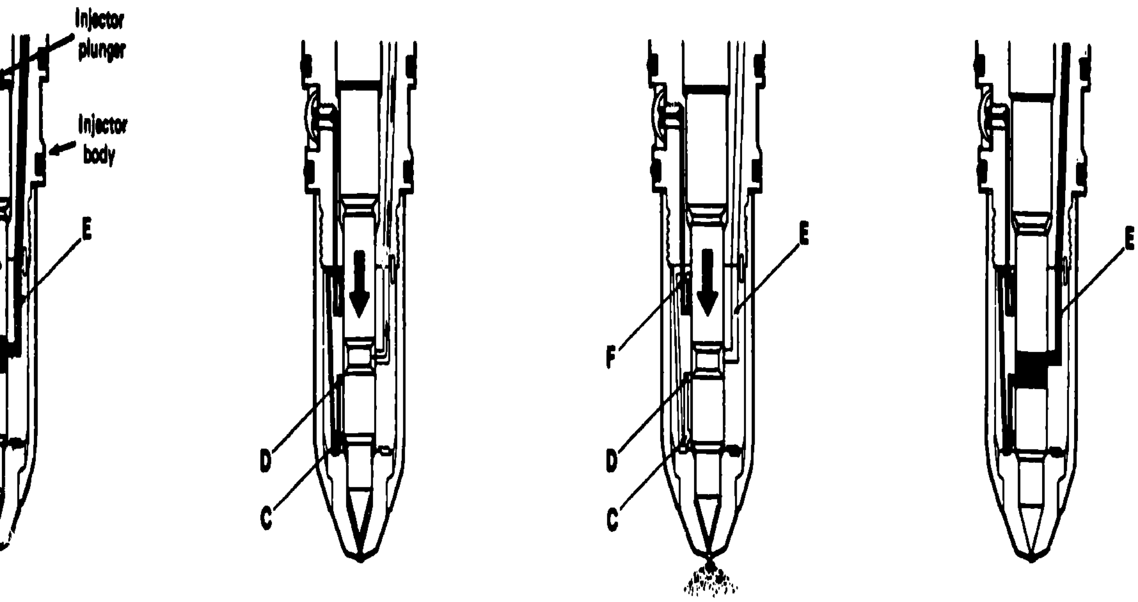


Fig 3-9. Injector operating train.

As noted previously in this work unit, the fuel pump is essentially a pressure pump which provides the fuel at varying pressures (26 to 176 psi) according to throttle position. This is only one step in the metering of fuel. The second step is accomplished in the injector which meters, pressurizes, and atomizes (injects) the fuel into the combustion chamber. To better understand this, study figure 3-10 which describes the complete operating cycle at the injector.



(fuel circulates)
ssure enters the
and flows through
ce(B), internal
d the annular groove
cup and up passage
tank. The amount
through the injector
the fuel pressure
orifice (B). Fuel
is determined by
d and throttle.

Upstroke complete (fuel enters injector cup) As the injector plunger moves upward, metering orifice (C) is uncovered and fuel enters the injection cup. The amount is determined by the fuel pressure. Passage (D) is blocked momentarily stopping circulation of fuel and isolating the metering orifice from pressure pulsations.

Downstroke (fuel injection) As the plunger moves down and closes the metering orifice, fuel entry into the cup is cut off. As the plunger continues down, it forces fuel out of the cup through tiny holes at high pressure as a fine spray. This assures complete combustion of fuel in the cylinder. When fuel passage (D) is uncovered by the plunger undercut, fuel again begins to flow through return passage (E) to the fuel tank.

Downstroke complete (fuel circulates). After injection the plunger remains seated until the next metering and injection cycle. Although no fuel is reaching the injector cup, it does flow freely through the injector and is returned to the fuel tank through passage (E). This provides cooling of injector and also warms the fuel in the tank.

Fig 3-10. PTD fuel injector operating cycle.

Note that fuel is continuously circulating through the injector and metering of the fuel takes place when the plunger moves up, opening the metering orifice. The amount of fuel entering the pressure chamber in the injector cup is determined by both the pressure of the fuel and the amount of time the metering orifice is open.

All fuel to the injectors flows through the shut-down valve (fig 3-11). The shut-down valve is an electrical switch which shuts off fuel to the injectors when no current is present. The switch is controlled by the accessory (ignition) switch in the cab. A manual control is provided on the valve in case of electrical power failure.

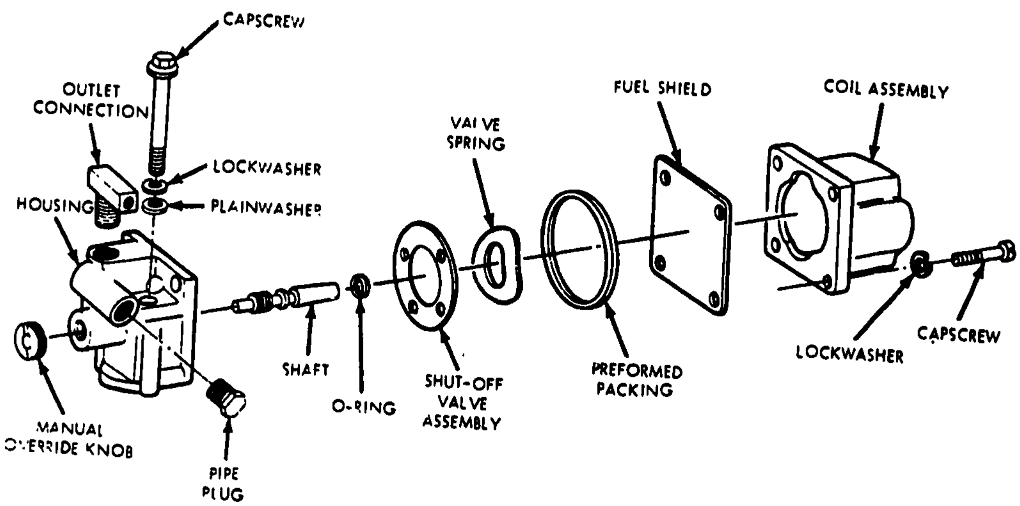


Fig 3-11. Fuel shut-down valve.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. State how the fuel is metered by the PT system.

____

2. State the principle of the PT fuel system.

____

3. State the operating pressure range of the PTG fuel pump.

____

4. Name the component that controls fuel flow at low idle and high idle.

____

5. State how fuel flow for low idle is provided.

____

6. State the purpose of bypass fuel.

____

7. Name the component which controls fuel flow (pressure) in the fuel manifold between idle and maximum engine speeds.

____

8. Name the component which controls the amount of time the inlet orifice is open.

____

9. Name the component which allows fuel pressure to build in the PT fuel pump to start the engine.

____

Work Unit 3-3. UNIT INJECTOR SYSTEM

LIST THE COMPONENTS OF A UNIT INJECTOR FUEL SYSTEM.

STATE THE FUNCTION OF THE FUEL PUMP.

STATE THE FUNCTION OF A UNIT INJECTOR.

STATE THE FUNCTION OF THE RESTRICTED FITTING.

STATE WHY THE FUEL PUMP CIRCULATES AN EXCESSIVE AMOUNT OF FUEL.

STATE HOW FUEL IS METERED IN A UNIT INJECTOR.

DEFINE EFFECTIVE STROKE IN A UNIT INJECTOR.

LIST THE SIX STEPS (IN ORDER) IN TUNING A UNIT INJECTOR FUEL SYSTEM.

The Detroit Diesel unit injector system is used on the M561 (GAMMA Goat) and will also be used on the Logistic Vehicle System (LVS, Dragon Wagon). Although the M561 uses a 3-53 engine while the LVS will have a 8V-92TA, both have a two-stroke cycle. The components and operation of the fuel systems are very similar.

The components (fig 3-12) of the unit injector fuel system consist of:

A gear pump supplying fuel at low pressure to the injector.

A fuel strainer and a fuel filter to remove sediment.

The injectors which meter, time, pressurize, and atomize fuel into the cylinder.

A control tube which connects the control rack of each injector to the governor.

Steel fuel lines that serve as inlet and return lines (maybe woven).

Fuel manifolds are drilled passages in the cylinder head(s) for inlet and return fuel.

A restricted fitting to maintain fuel pressure to the injector.

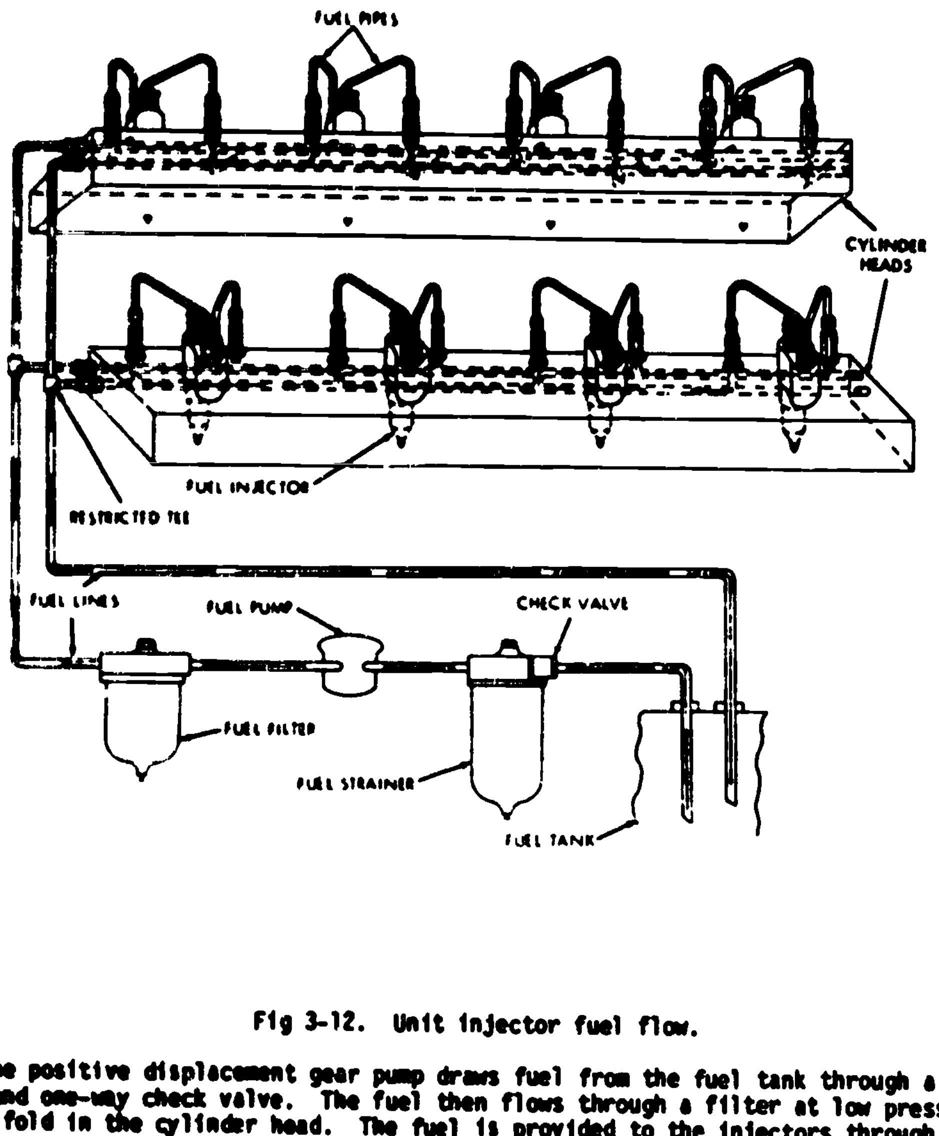


Fig 3-12. Unit injector fuel flow.

The positive displacement gear pump draws fuel from the fuel tank through a fuel strainer and one-way check valve. The fuel then flows through a filter at low pressure to the inlet manifold in the cylinder head. The fuel is provided to the injectors through inlet (jumper) tubes. The unused fuel returns via an outlet tube to the return fuel manifold and restricted fitting to the fuel tank.

The pump circulates an excess amount of fuel through the injectors which purge air from the system and cool the injectors. A pressure relief valve is incorporated in the pump to relieve excess pressure developed when the fuel filter is clogged.

After leaving the pump, the fuel passes through a filter and enters the fuel manifold which distributes fuel to each injector. Fuel pressure in the manifold is maintained by the restricted fitting (refer to fig 3-12) at the end of the return fuel manifold. Fuel which is allowed to pass through the restricted fitting returns to the fuel tank.

Fuel enters the injector (fig 3-13) through an inlet filter then moves down the body of the injector. Fuel flows through the upper part of the barrel filling the area below the plunger and travels through the lower port into the fuel return manifold. There is a machined area (helix) on the plunger positioned to accomplish the metering of the fuel to be injected into the cylinder. The amount of fuel metered is accomplished by the control tube moving the rack and gear attached to the plunger of each injector. This movement is controlled by the governor and positions the helix to meter fuel according to the load and speed of the engine.

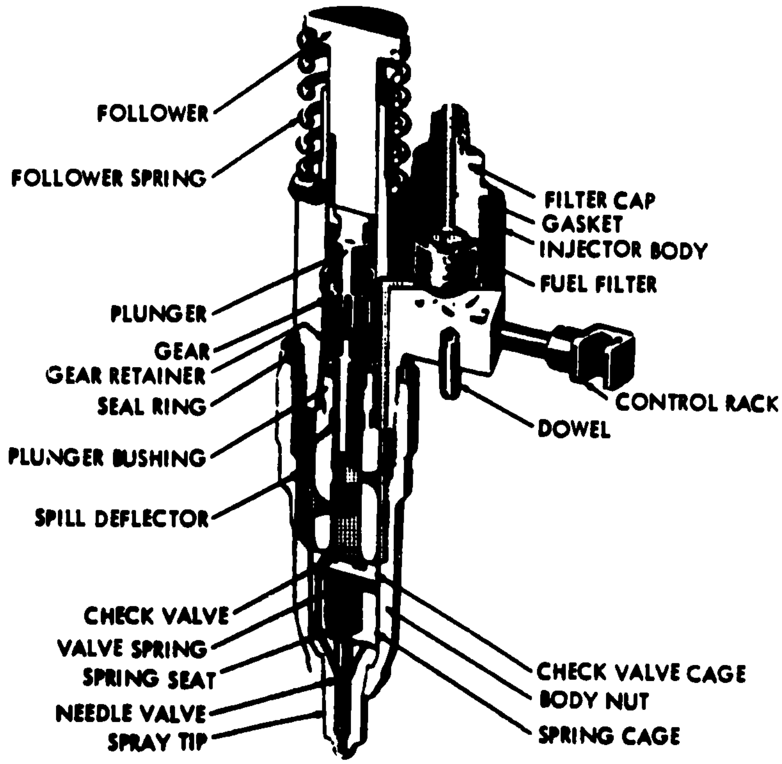
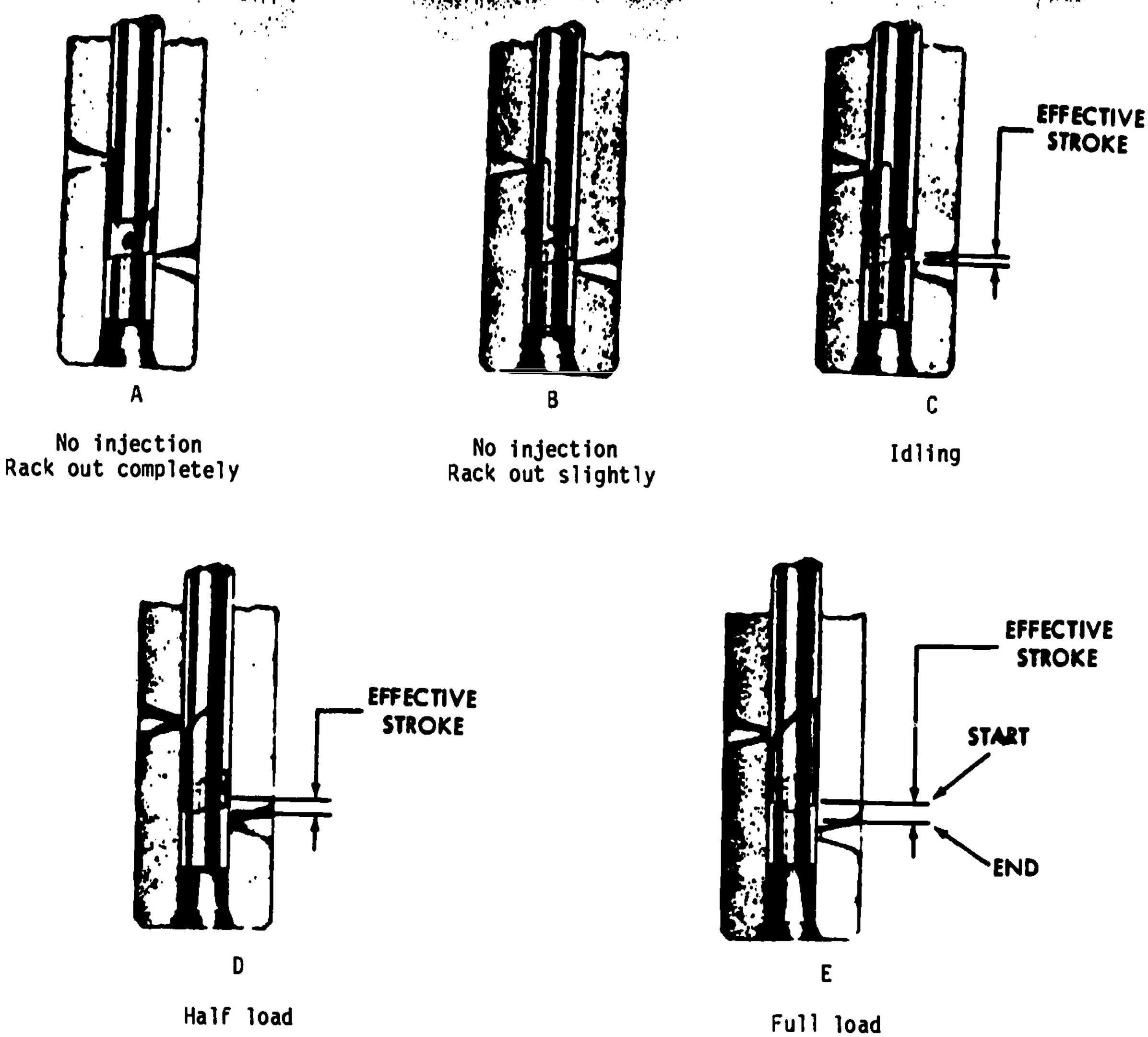


Fig 3-13. Unit injector.

A closer look at the metering of fuel reveals that the plunger, in its movement up and down, closes both the upper and lower ports to pressurize and inject fuel. Movement of the rack turns the plunger which also varies the effective stroke (fig 3-14), thereby varying the amount of fuel injected. Increasing the effective stroke allows more fuel to be injected. Not creating an effective stroke by positioning of the rack in the no fuel position, places the helix where either the upper or lower port remains open during the pressurization stroke. Effective stroke is the distance the plunger moves to pressurize and inject fuel (the distance the plunger moves after both ports are closed).



Varied degrees of injection from no injection to full load by rotation of plunger.

Fig 3-14. Fuel metering (unit injector).

Not all of the fuel that enters the injector is injected into the cylinder. Excess fuel circulates through the injector for cooling and lubrication and then exits to the fuel return manifold. A restricted fitting is placed at the end of the return manifold to maintain fuel pressure in the injectors and the inlet (supply) manifold. Return fuel is then routed back to the fuel tank.

Servicing of the unit injector is not difficult. However, due to special handling of lapped (precision fitted) parts and special equipment that is required, disassembly of the injector will not be discussed. The procedures delineated in the technical manual of the specific vehicle or engine should be followed.

A guide for engine tune up and adjustment is provided in Appendix II. The procedures for engine tune up must be followed in the correct order or engine efficiency will suffer. The procedures for engine tuneup are as follows:

a. Adjust the exhaust valve clearance.
b. Adjust injector timing.
c. Adjust governor gap.
d. Position injector rack control levers.
e. Adjust high idle, no load.
f. Adjust idle speed.

Note: Procedures for tuneup will vary according to engine and governor types. Check the technical manual of the particular vehicle.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. List the components of a unit injector fuel system.

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

   e. ______________________________

   f. ______________________________

   g. ______________________________

2. State the function of the fuel pump.

   ____

3. State the function of a unit injector.

   ____

4. State the function of the restricted fitting.

   ____

5. State why the fuel pump circulates an excessive amount of fuel.

   ____

6. State how fuel is metered in a unit injector.

   ____

7. Define effective stroke in a unit injector.

   ____

8. List the six steps (in order) to follow when tuning a unit injector fuel system.

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

   e. ______________________________

   f. ______________________________

Work Unit 3-4. DISTRIBUTOR TYPE FUEL INJECTION (6.2L DIESEL)

STATE THE FOUR FUNCTIONS PERFORMED BY THE DISTRIBUTION FUEL INJECTION PUMP ON THE M1009 (CUCV).

GIVEN A TEMPERATURE BELOW 20°F, STATE WHY DIESEL FUEL MUST BE OF A DIFFERENT GRADE.

STATE THE FUNCTIONS INCORPORATED IN THE FUEL FILTER IN THE M1009 (CUCV) FUEL FILTER.

STATE WHEN THE FUEL HEATER ON THE M1009 (CUCV) FUEL FILTER ACTIVATES.

STATE WHY INJECTION PUMP TIMING ON THE M1009 (CUCV) MUST BE DONE WITH PRECISION.

STATE WHEN THE INJECTION PUMP IS REMOVED FOR TESTING.

STATE WHEN THE AUTOMATIC ADVANCE MECHANISM SHOULD START TO WORK AND EXPLAIN WHY.

STATE THE TWO OPERATIONS OF THE VENT WIRE ASSEMBLY IN THE INJECTION PUMP ON A M1009.

STATE THE TWO WAYS THE METERING VALVE IN THE M1009 INJECTION PUMP OPERATES.

STATE HOW FUEL IS PRESSURIZED WITHIN THE INJECTION PUMP OF THE M1009 (CUCV).

STATE THE FUNCTION OF THE DELIVERY VALVE.

STATE HOW THE INJECTION OF FUEL IS ADVANCED FOR HIGH SPEED OPERATION.

In the previous work units, you were introduced to two types of fuel injection systems, the common rail (PT) and the unit injector system. In this work unit, we will discuss the operation of a distributor type fuel system. The distributor system in this work unit is incorporated on two military vehicles, the M1009 (CUCV) and M998 (HMMWV). Both vehicles use the 6.2L diesel engine. The major difference between this system and the others previously discussed is the use of an injector pump and nozzles injecting the fuel into precombustion chambers. The Roosa Master Fuel injection pump is a single cylinder, opposed plunger, inlet metering, distributor type unit used in high speed diesel engines. Metering, pressurization, distribution, and timing of injection are performed by the injection pump. Atomization of the fuel into a precombustion chamber is performed by the injector nozzle.

Fuel is pumped from the fuel tank through a filter sock which separates paraffin and other sediment from the diesel fuel. Paraffin forms in fuel oil (diesel) during cold weather below 20°F. As a precautionary measure, you should insure that the proper grade of diesel is used according to the anticipated weather conditions. In a cold climate (below -20°F) use fuel designed for arctic use. In addition to the filter sock, a bypass valve is installed in the fuel line to allow fuel to flow when the sock is clogged. In order for this operation to happen (bypass) there must be at least 4 gallons of fuel in the tank. Therefore, the tank must be kept above 1/4 full.

The lift pump is a mechanical diaphragm pump, operated by an eccentric on the camshaft, mounted on the right front of the engine (refer to fig 3-16). The pump brings fuel from the tank and supplies about 5 1/2 pounds of pressure through the fuel filter. This pump appears like any single diaphragm fuel pump used on gasoline engines and serves the same purpose.

The fuel filter on the M1009 (CUCV) incorporates a two-stage pleated paper type filter, water separator, water sensor, and a fuel heater (look at fig 3-16). The filter element will remove particles 10 microns in size and larger, providing clean fuel for injection. The filter should be changed (replaced) according to manufacturer's recommendations or the lubrication order (LO) pertaining to the vehicle to insure that the clean fuel reaches the injection pump. During the filtering process, water is removed and collected in the bottom of the filter. When enough water is accumulated in the filter, a sensor will activate the fuel light on the dashboard. Water in the filter can be drained by opening the drain cock and vent on the filter base. The fuel heater, mounted in the filter base, activates when the temperature is below 20°F and will then turn off when the fuel reaches 50°F. This provides protection against wax (paraffin) separating from the fuel and clogging the filter. The heat will only be on until the under hood temperature gets hot enough to heat the fuel. However, this does not heat the fuel in the tank. Therefore, the correct grade of diesel fuel must be in the tank prior to starting the vehicle. Testing the heater with an ammeter should draw 8.6 amps (approx); it must be tested below 20 degrees ambient temperature.

The injection pump (fig 3-15) is mounted on the front gear train under the intake manifold. Precision timing must be achieved if high efficiency is to be attained. Therefore, after the timing chain is installed, the injection pump drive gear has to be mounted on the camshaft and the driven gear timed to the drive gear (align timing marks on the gears).

Now, the timing mark on the front cover must be determined. To accomplish this, a special tool must be used and torqued to 50 lb/ft; refer to the appropriate Technical Manual. Reestablishing the timing mark must be done upon replacement of the timing chain or overhaul of the engine. Removal of the injection pump should be done after you have eliminated other possible causes of the malfunction, such as clogged filters, fuel lines, malfunctioning lift pump, etc. In other words, use a trouble-shooting guide (Appendix III or the TM).

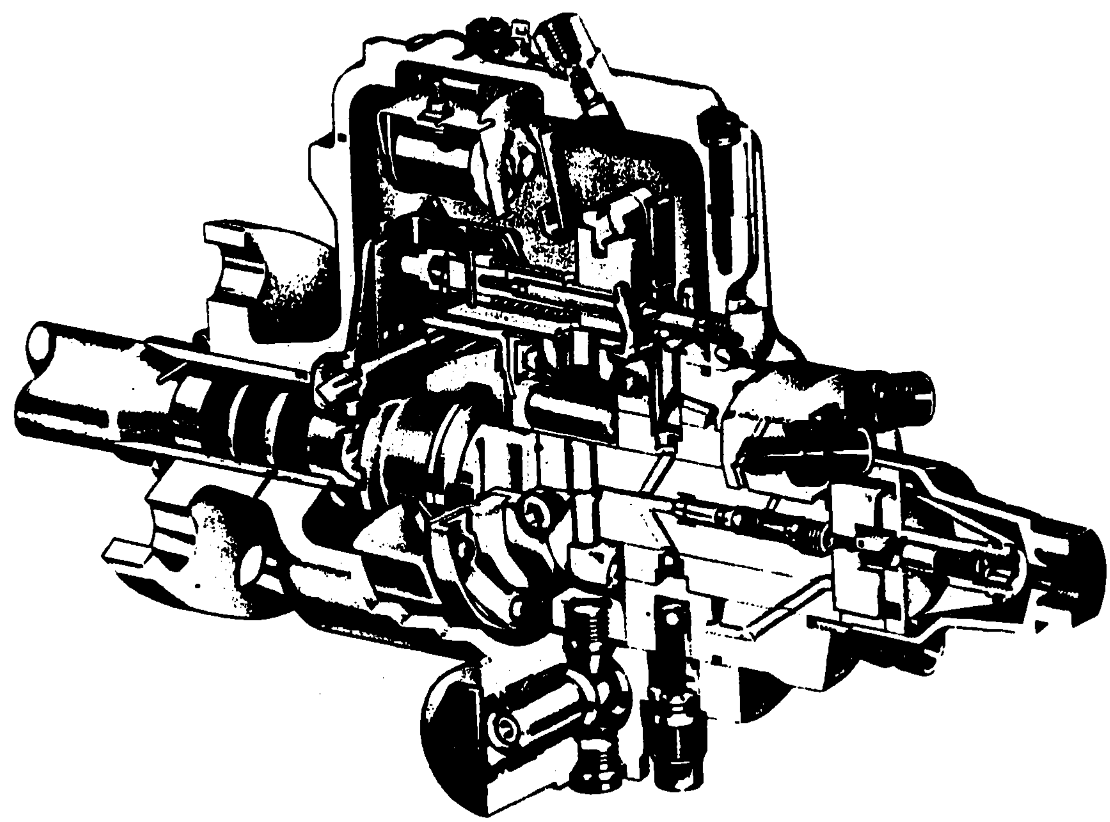


Fig 3-15. Distributor injection pump (cutaway).

Fuel is drawn into the pump by the vane type transfer pump and is routed to the automatic advance mechanism housing cover and metering valve. For a complete fuel flow through the distributor fuel system, look at figure 3-16.

The automatic advance mechanism controls the advance and retard of fuel delivery. This mechanism starts working during high speed driving to insure that the fuel pulse arrives at the cylinder in time for the compression stroke when the piston is at top dead center. This is where compression is at its highest point. If it were not for the advance mechanism, the fuel would not arrive at the cylinder before the piston had already started downward on the power stroke. Thus, the automatic advance mechanism insures smooth engine performance. The mechanism consists of a power piston, a servo valve, a servo spring, a servo piston, and a cam advance pin.

A vent wire assembly controls the amount of fuel that is returned to the fuel tank from the injection pump. It is located in a short passageway behind the metering valve bore. Excess fuel coming from the transfer pump flows by the vent wire, taking any air which has entered the transfer pump along with it. After passing the vent wire assembly, the fuel enters the governor compartment. From here, excess fuel leaves the pump through the return line. The amount of fuel that enters the return line is controlled by the size of the wire in the assembly. If the amount of return fuel does not meet specification requirements, the existing vent wire can be exchanged for one of a different size.

Most of the fuel goes through the metering valve. The metering valve operates in two ways: (1) By the throttle lever, when the vehicle is operating at intermediate speeds; (2) by the governor linkage, when the vehicle is at minimum and maximum engine speeds. The metering valve allows a measured amount of fuel to pass into the center of the hydraulic head where the distribution rotor is turning. Fuel goes to the center of the rotor, which has two inlet passages at one end and an outlet passage at the other end. As the rotor turns, the inlet passages line up with ports in the hydraulic head. When this occurs, the fuel is forced into the pumping chamber.

The pumping chamber consists of two sets of rollers, shoes, and plungers, which rotate inside a cam ring. The cam ring has lobes on the inside, one for each engine cylinder. The force of the fuel coming into the pumping chamber, together with the centrifugal force generated by the rotor, moves the plungers apart. The plungers move outward, a distance which is directly proportional to the volume of the fuel passing the metering valve. As the rotor turns, the rollers contact the peaks of the cam ring lobes, pushing the plungers together. It is this action which pressurizes the fuel to the degree required to open the nozzles.

The fuel, which is now at injection pressure, is forced back along the center passage of the rotor and into the discharge port. The fuel is pumped out of the rotor when the discharge port of the rotor lines up with one of the discharge outlets in the hydraulic head. As the rotor turns, its single port discharges a pulse of fuel into each of the eight hydraulic head outlets in sequence.

Each discharge fitting is connected to a nozzle by a high pressure line. The fuel is pumped through the discharge fitting, through the high pressure lines, and into the nozzle and the engine's cylinder. Fuel enters the nozzle at a rate and amount that varies with the demands of the engine. When the engine fuel demand is low, such as at idle, the fuel pulses are smaller and farther apart than when the engine is running at wide open throttle. At wide open throttle, larger amounts of fuel, spaced closely together, force the nozzles to open more often and to stay open longer to meet the needs of a high speed engine.

Fuel from the injection pump has now been metered, pressurized, timed, and distributed to each nozzle. When the fuel reaches the nozzle, it will arrive with enough pressure to open the nozzle and enough fuel to meet the engines requirements. Also, each pulse of fuel will be timed to arrive at the cylinder as the piston reaches top dead center (TDC).

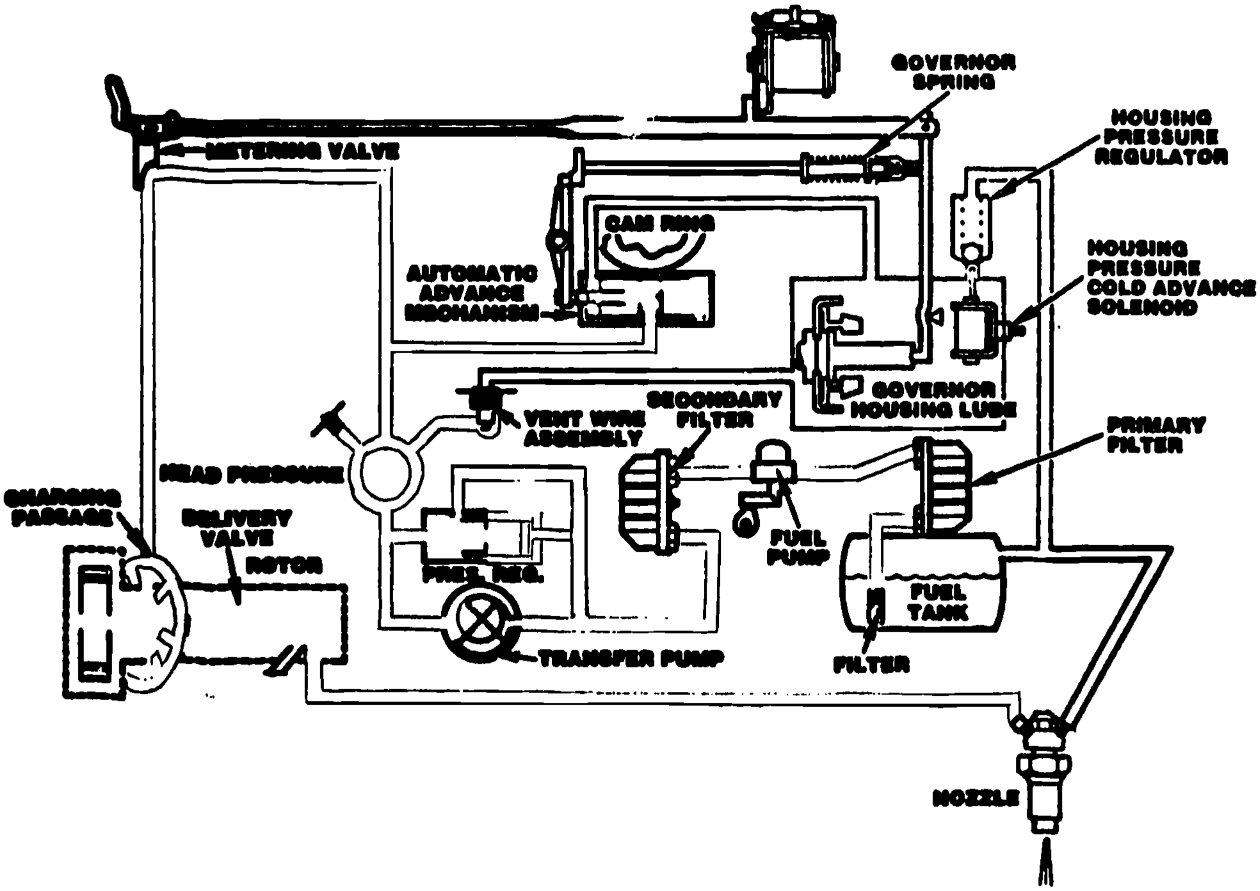


Fig 3-16. Fuel flow (6.2L diesel).

The delivery valve (fig 3-17), located in the center of the distributor rotor, helps the nozzle to reseat (close) rapidly and prevents fuel from dribbling into the precombustion chamber. Pressurized fuel coming from the pumping chamber forces the delivery valve plunger slightly out of its bore. Fuel passes the plunger and out the discharge port. When fuel pressure drops, the delivery valve plunger immediately reseats, causing a rapid drop in injection line pressure.

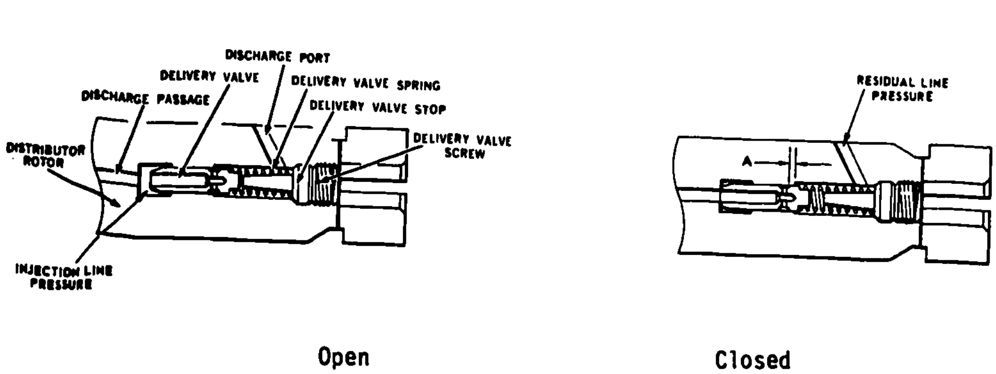


Fig 3-17. Delivery valve operation.

There are three mechanisms in the Stanadyne DB 2 fuel injection pump which serve to advance injection timing: (1) the automatic advance, (2) the mechanical light load advance, and (3) the housing pressure cold advance (HPCA) solenoid.

- In the automatic advance mechanism, the cam advance pin links the advance mechanism to the cam ring. This pin is connected to the advance mechanism at its lower end and to the cam ring at its upper end. In this way, when the advance piston shifts position, the cam ring also shifts position because of the linkage provided by the cam pin. This movement, or rotation, of the cam ring results in the advance of fuel delivery. The action of the power and servo pistons is dependent upon fuel pressure from two sources: the housing pressure behind the servo piston and the transfer pressure behind the power piston. When the engine is cranking, the fuel behind the servo piston is at housing pressure and the power piston is seated against the housing. As the vehicle's speed increases, the transfer pressure rises as a result of increasing pump speed. When this happens, the transfer pump sends fuel to a chamber behind the power piston. When transfer pressure behind the power piston exceeds housing pressure, the force of this accumulating fuel overcomes the resistance of the servo piston and spring, and the power piston shifts position. The power piston pushes the cam advance pin and rotates the cam ring in the direction opposite to the rotation of the distributor rotor and the rollers, shoes, and plungers. Because of this rotation, the rollers contact the cam lobes earlier and injection timing is advanced. When the transfer pressure drops, the timing will be retarded because the cam ring will rotate in the other direction.

- The light load mechanism provides advance when the engine is operating at low speed or at light load when the transfer pressure is too low to move the advance piston. The light load advance consists of an external face cam and rocker lever assembly. At the top of the pump, this assembly is connected to the throttle shaft. At the lower end, the rocker lever contacts the protruding end of the servo advance plunger. The throttle shaft moves the face cam and lever assembly which in turn moves the servo plunger toward the cam pin. This action changes the reference point of the servo spring. At a predetermined angle, the surface of the face cam becomes a flat plane, so that further throttle movement does not affect servo plunger, and the spring reference point becomes fixed. After this point, advance action is regulated by transfer pump pressure, as was discussed earlier.

- The housing pressure cold advance solenoid is one of the three solenoids which affects the injection pump's operation. The HPCA solenoid makes it easier to start the vehicle in cold weather by reducing the housing pressure in the advance mechanism. The HPCA solenoid is located at the return fitting, under the pump housing cover. The HPCA solenoid is activated by the coolant temperature switch which is mounted on the engine. When coolant temperature is low, the solenoid is energized and the plunger is extended to lift the check ball off its seat. With the check ball out of place, the housing pressure is reduced to almost zero. With practically no housing pressure to overcome, the transfer pump pressure behind the power advance piston can easily advance the cam ring.

The fast idle solenoid increases idle speed when the engine coolant temperature is below 125°F. This solenoid is mounted outside of the pump on the throttle cable bracket. The fast idle solenoid is energized by a signal from the coolant temperature switch. When energized, the solenoid plunger extends and holds the throttle off the low idle stop.

The fuel shut-off solenoid stops the engine by cutting off the fuel flow. It is located inside the pump housing cover. The fuel shut-off solenoid acts on the governor linkage hook to rotate the metering valve. When the ignition is turned off, the solenoid is deenergized and the return spring pulls the solenoid arm to the "OFF" position. The movement of the arm to the "OFF" position moves the governor linkage hook, rotating the metering valve to cut off fuel delivery.

The min-max governor (fig 3-18) maintains idle speeds with varying engine loads and also limits the maximum speed of the engine. The main components of the governor are: the governor weights, the governor arm, the low idle spring, the idle spring guide, the main governor spring, the main governor spring guide, and the guide stud.

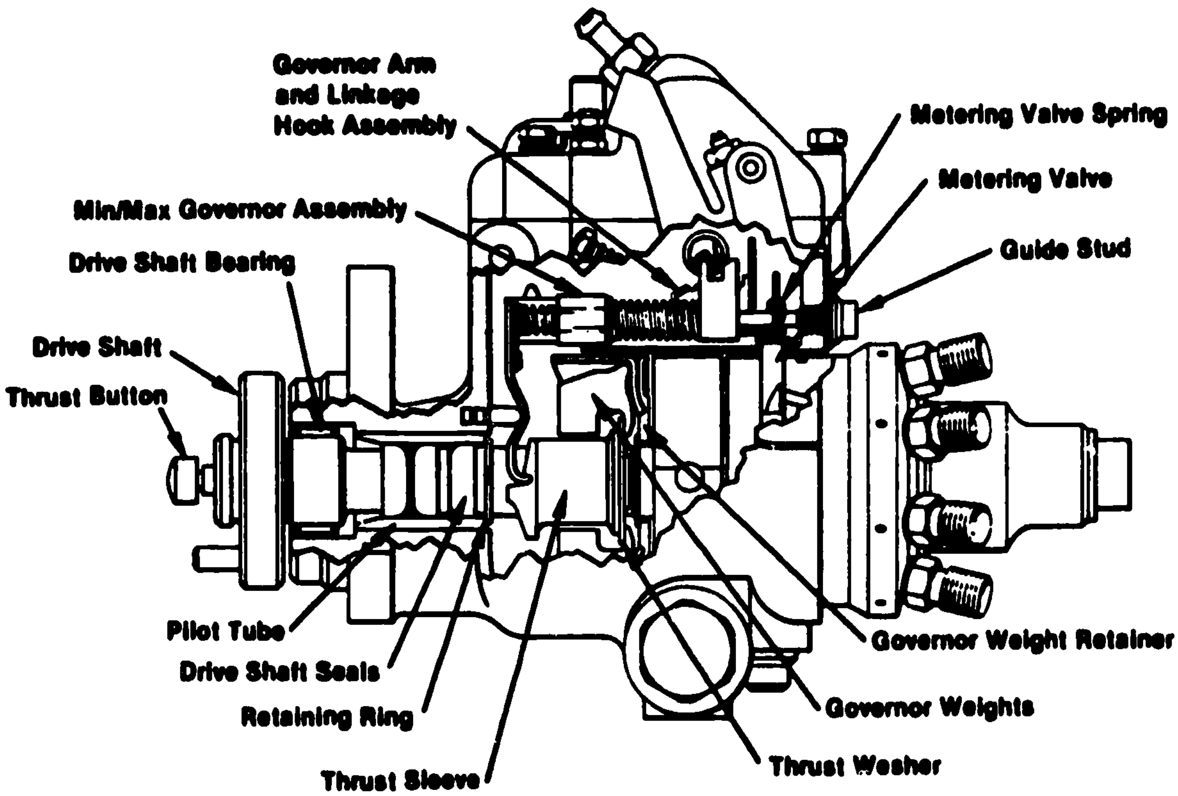


Fig 3-18. Distributor fuel injection pump.

The governor weights spin around with the rotation of the drive shaft. Their centrifugal force controls the metering valve at minimum and maximum engine speeds. At idle speed, the governor weights exert very little force, so that the spring on the governor keeps the metering valve almost closed. At high engine rpm, the force of the governor weights moves a pivot arm, compresses the spring, and rotates the metering valve to an almost closed position. At intermediate speeds, the vehicle operator directly controls the metering valve through the throttle. In this case, the force of the governor weights and the min-max spring tension are balanced, so that neither has the power to control the metering valve.

The pressure regulator protects the transfer pump from being damaged as a result of excessive output pressure. Pressure can become excessive, either because of increased pump speeds or because of restrictions in the outflow line. The pressure regulator valve relieves this pressure when it reaches a preset limit. Under normal operating conditions, the valve spring holds the piston forward, blocking the valve's output line. Under this condition, the valve has no effect on the system. If the output flow from the pump is restricted, out pressure increases. High pressure fuel pushing on the face of the valve piston compresses the spring. If the pressure is high enough to overcome the force of the spring, the piston will be pushed back, uncovering the valve's output line. Fuel is allowed to flow back to the pump's input side, relieving the output pressure. A viscosity compensating device maintains the constant pressure of fuel, regardless of variations in fuel viscosity. This device is incorporated into the design of the pressure regulator mechanism.

When an engine malfunction has been isolated to the fuel injection pump you should (refer to Appendix III or trouble-shooting guide in the TM) investigate each of the components of the pump to determine which would most likely cause the symptoms. Check to see if the head and rotor are seized or binding by rotating the drive shaft. Clean the outside of the pump, remove the cover, and inspect the inside for contamination such as water, metal particles, rust, or other foreign matter. Move the throttle lever back to observe the components of the governor. If these procedures fail to locate the malfunction, the pump will have to be tested on a test stand. The procedures on the test stand will not be discussed here because of the necessity of special equipment. For procedures on disassembly and repair of the injection pump refer to the technical manual.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. State the four functions performed by the distributor fuel injection pump on the M1009 (CUCV).

   a. ____________________

   b. ____________________

   c. ____________________

   d. ____________________

2. State why arctic diesel fuel must be used when the air temperature is below -20°F.

   ____

3. State the four functions incorporated in the M1009 (CUCV) fuel filter.

   a. ____________________

   b. ____________________

   c. ____________________

   d. ____________________

4. State when the fuel heater in the M1009 (CUCV) fuel filter activates.

   ____

5. State why injection pump timing on the M1009 (CUCV) must be done with precision.

   ____

6. State when the injection pump is removed for testing.

   ____

7. State when the automatic advance mechanism should start to work and explain why.

   ____

   ____

8. State the two operations of the vent wire assembly in the injection pump on the M1009 (CUCV).

   a. ____________________

   b. ____________________

9. State the two ways the metering valve in the M1009 injection pump operates.

   a. ____________________

   b. ____________________

10. State how fuel is pressurized within the injection pump on the M1009 (CUCV).

    ____

11. State the function of the delivery valve.

    ____

12. State how the injection of fuel is advanced for high speed operation.

____

SUMMARY REVIEW

In this study unit, you learned the types of diesel fuel systems, in particular, the pressure time, unit injector, and distributor fuel systems. In the next study unit, you will be introduced to exhaust systems.

Answers to Study Unit #3 Exercises

Work Unit 3-1.

1. To inject the correct amount of fuel into the engine at the proper time
2. a. Meter
   b. Time
   c. Pressurize
   d. Atomize
   e. Distribute
   f. Control injection
3. Injector or the injector spring
4. a. Common rail
   b. Unit injector
   c. Distributor
5. By fuel pressure provided to the injector and the time the fuel inlet orifice is open to receive fuel
6. a. Meter fuel
   b. Time injection
   c. Pressurize fuel
   d. Atomize fuel in the combustion chamber.
7. a. Turbocharger
   b. "ROOTES" type blower

Work Unit 3-2.

1. By the fuel pressure at the metering orifice and the time the orifice is open
2. Changing the pressure of the fuel in a line also changes the amount of fuel delivered.
3. 26 psi to approximately 176 psi
4. Governor
5. By use of a plunger and spring which allow the idle port to open allowing enough fuel to pass, maintaining idle speed
6. To allow fuel to circulate through the pump for cooling and lubrication.
7. Throttle
8. Camshaft
9. Fuel shut-down valve

Work Unit 3-3.

1. a. Gear pump
   b. Strainer
   c. Injectors
   d. Control tube
   e. Fuel lines
   f. Fuel manifold
   g. Restricted fitting
2. To supply the injectors with fuel at low pressure
3. To meter time, pressurize and atomize fuel into the cylinders
4. To maintain fuel pressure in the inlet manifold
5. To maintain fuel flow through the injector for cooling and lubrication
6. By the movement of the rack which positions the helix controlling the closing of the upper and lower ports
7. The distance of the plunger movement after the upper and lower ports are closed, thereby pressurizing and injecting fuel into the cylinder
8. a. Adjust the exhaust valve clearance.
   b. Adjust the injector timing.
   c. Adjust the governor gap.
   d. Position the injector rack control levers.
   e. Adjust the high idle no load.
   f. Adjust the idle speed.

Work Unit 3-4.

1. a. Metering
   b. Pressurization
   c. Distribution
   d. Timing
2. Because paraffin separates from the fuel below 20°F
3. a. Two-stage pleated paper filter
   b. Water separator
   c. Water sensor
   d. Fuel heater
4. When the temperature is below 20°F
5. To attain high efficiency
6. When all other causes of the malfunction outside the pump have been eliminated
7. During high speed driving to insure the fuel pulse arrives at the cylinder in time for the compression stroke
8. a. Removes air from fuel entering the pump
   b. Controls the amount of fuel that is returned to the fuel tank
9. a. By the throttle at intermediate speeds
   b. By the governor linkage at minimum and maximum speeds
10. By the force of the two plungers being pushed together
11. To help the nozzle to reseat and prevent fuel from dribbling into the precombustion chamber
12. By the automatic advance mechanism rotating the cam ring

STUDY UNIT 4

EXHAUST SYSTEM

STUDY UNIT OBJECTIVE: WITHOUT THE AID OF REFERENCES, YOU WILL IDENTIFY THE PURPOSE OF AN EXHAUST SYSTEM, HOW TO MINIMIZE EXCESSIVE NOISE, THE MAJOR CAUSE OF EXHAUST SYSTEM FAILURE, AND HOW COMMON EXHAUST PROBLEMS ARE ALLEVIATED. YOU WILL ALSO IDENTIFY THE SYMPTOMS OF CARBON MONOXIDE POISONING.

The internal combustion engine produces waste gases and noise. The gases (exhaust) emitted must be carried past the passenger compartment to insure that the operator and passengers do not become victums of carbon monoxide poisoning. Excessive noise must be reduced so the operation of the vehicle can be more pleasant. Therefore, an exhaust system is incorporated as a component of the internal combustion engine.

Work Unit 4-1. EXHAUST SYSTEM

STATE THE PURPOSE OF THE EXHAUST SYSTEM.

STATE WHY EXHAUST GASES ARE CONSIDERED DANGEROUS.

LIST THE SYMPTOMS OF CARBON MONOXIDE POISONING.

STATE HOW THE NOISE OF ENGINE OPERATION IS MINIMIZED.

STATE THE MAJOR CAUSE OF EXHAUST SYSTEM FAILURE.

STATE HOW COMMON PROBLEMS OF EXCESSIVE NOISE AND BACK PRESSURE ARE ALLEVIATED.

The internal combustion engine produces an excessive amount of noise and poisonous gas. Therefore, an exhaust system must be incorporated with the engine to reduce the noise and carry the exhaust gases away from the operator's/passenger's compartment. To do this, the engine (vehicle) must have a manifold, exhaust pipe, catalytic converter (on some vehicles), muffler, and tailpipe (fig 4-1). Exhaust gases contain carbon monoxide (CO) which is a deadly, colorless, odorless gas. When CO enters the operator's/passenger's compartment of a vehicle, it will cause headaches, drowsiness, nausea, and, in increased quantities, unconsciousness or death. These symptoms make the exhaust system an important component which must be in serviceable condition at all times.

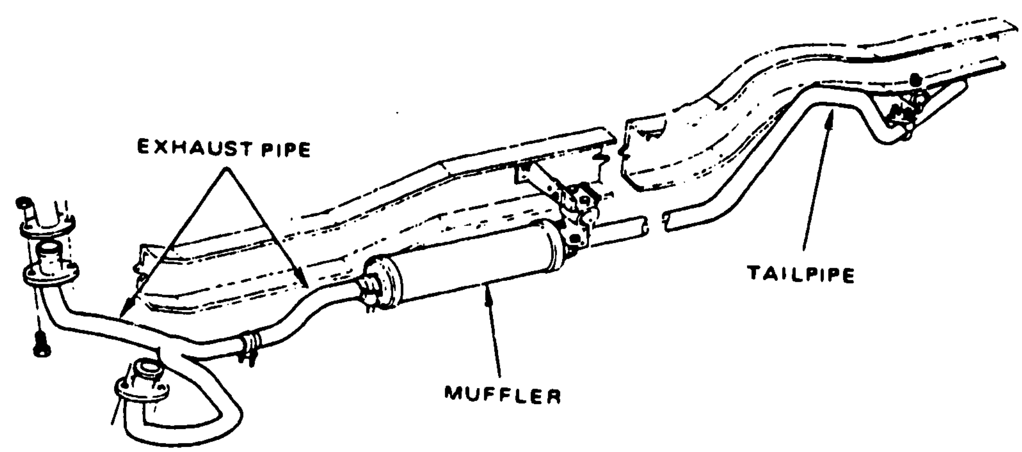
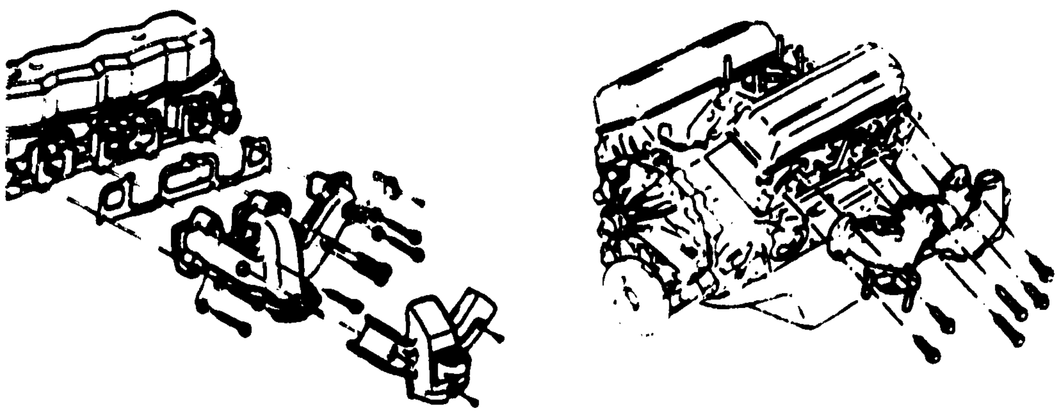


Fig 4-1. Typical exhaust system.

The purpose of the exhaust manifold is to collect exhaust gases produced in the cylinders and direct the gases to the exhaust pipe. The exhaust manifold is bolted to the side of the engine (fig 4-2). On inline engines there is one exhaust manifold while on V-8 engines (opposed, V-4, and V-6 also) there is one on each bank (side) of the "V". On "V" type engines, a completely separate system may be incorporated on each side (bank) or a crossover pipe may join the two sides together.

A major consideration in the exhaust system design is back pressure. Excessive back pressure in the exhaust system will cause loss of power. Excessive back pressure will normally be created when the muffler exit is blocked by corrosion causing one or more baffles to break loose and cover the exit. When the muffler has leaks or creates excessive back pressure, the muffler must be replaced.



Inline "V" Type

Fig 4-2. Exhaust manifold.

The exhaust pipe connects the engine manifold with the muffler (or catalytic converter) to carry spent gases and noise away from the engine compartment. The tailpipe continues carrying the gases away from the passenger compartment after the sound is muffled.

A catalytic converter (fig 4-3) is added to vehicles (engines) which use unleaded gasoline. Basically, a catalytic converter contains chemically treated pellets or honeycomb to transform noxious emissions (hydrocarbons) into less harmless carbon dioxide and water vapor. The pellets or honeycomb are coated with platinum and rhodium (or palladium) or with platinum only. The container is constructed of stainless steel. Honeycomb elements are wrapped in a stainless steel mesh. The catalytic converter operates at approximately 1500°F. to reduce the exhaust emissions; therefore, heat shields must also be provided.

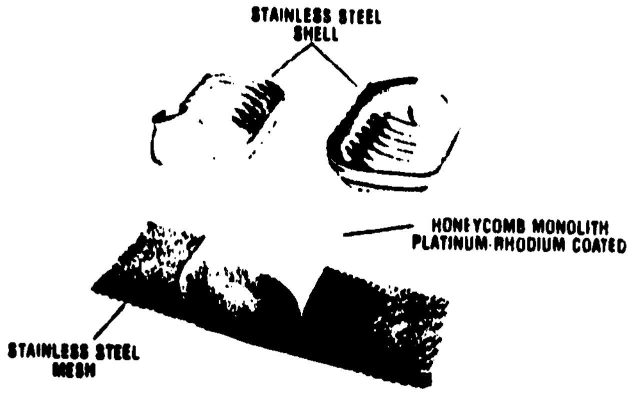


Fig 4-3. Catalytic converter.

It is known that noise is reduced when it strikes a barrier (baffle). With an internal combustion engine exhaust gases are routed through a muffler (fig 4-4) which suppresses noise by passing the gases through a series of baffles. The muffler is also designed to minimize the back pressure produced by the baffles. If back pressure is excessive, some of the burned gases will remain in the cylinder and dilute the incoming combustible gas. This will reduce engine power and, if great enough, will not allow the engine to start or run.

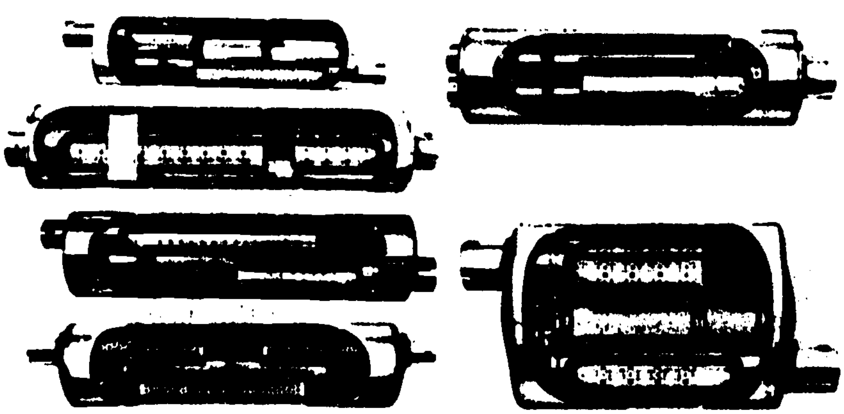


Fig 4-4. Types of mufflers.

Mufflers, exhaust pipes, and tailpipes wear out largely due to corrosion. Road conditions (salt on icy roads), humidity, and rain corrode the outside of these components. However, the major cause of exhaust system failure is corrosion produced by heat (of the exhaust gases) and condensation (water) inside the pipes and, particularly, the muffler. About one gallon of water is formed for every gallon of fuel burned. As the water passes through the exhaust system, acids are formed and the water quickly corrodes (rusts) the interior of the system. The corrosion creates holes in the exhaust system which causes the common problems associated with the exhaust system, excessive noise and excessive back pressure. These problems are solved by replacing the bad component or by complete installing a new exhaust system. Excessive noise caused by leaks in the system and excessive back pressure caused by corrosion of the baffles in the muffler which blocks the exit to the tailpipe are only repaired by replacement of the components. Hangers and supports, mounted on the frame of the vehicle, will keep the exhaust system in place and not dragging the ground.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. State the purpose of the exhaust system.

____

____

2. State why exhaust gases are considered dangerous.

____

3. List the symptoms of carbon monoxide poisoning.

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

   e. ______________________________

4. State how the noise of engine operation is minimized.

____

5. State the major cause of exhaust system failure. ______________

____

6. State how the common problems of excessive noise and back pressure are alleviated.

____

SUMMARY REVIEW

In this study unit you learned how the exhaust system incorporated with an internal combustion engine reduces noise and carries harmful gases away from the operator's compartment. The symptoms of carbon monoxide poisoning were also discussed.

Answers to Study Unit #4 Exercises

Work Unit 4-1.

1. To reduce noise and carry the exhaust gases away from the operators/passenger compartment.
2. Exhaust gas contain carbon monoxide, a colorless, odorless, deadly gas.
3. a. Headache
   b. drowsiness
   c. nausea
   d. unconsciousness
   e. death
4. By passing exhaust gas through a series of baffles in the muffler.
5. Corrosion inside the exhaust pipes and particularly the muffler due to heat and condensation.
6. By replacing the bad components.

AUTOMOTIVE FUEL AND EXHAUST SYSTEMS

REVIEW LESSON

Instructions: This review lesson is designed to aid you in preparing for your final exam. You should try to complete this lesson without the aid of reference materials, but if you do not know an answer, look it up and remember what it is. The enclosed answer sheet must be filled out according to the instructions on its reverse side and mailed to MCI using the envelope provided. The questions you miss will be listed with references on a feedback sheet (MCI-R69) which will be mailed to your commanding officer with your final exam. You should study the reference material for the questions you missed before taking the final exam.

A. Multiple Choice: Select the ONE answer that BEST completes the statement or answers the question. After the corresponding number on the answer sheet, blacken the appropriate circle.

Value: 1 point each

1. The three types of fuel used in internal combustion engines are

   a. gasoline, diesel, and coal.
   b. kerosene, LPG, and coal.
   c. natural gas, liquid petroleum gas, and fossil fuels.
   d. gasoline, diesel, and natural gas.

2. The volitility of a fuel is

   a. the ability of fuel to flow.
   b. oxidation.
   c. the boiling point of fuel.
   d. the heat value of fuel.

3. The three stages of normal combustion include formation (nucleus), propagation, and

   a. spreading.
   b. hatching out.
   c. pre-ignition.
   d. detonation.

4. An explosion of the fuel-air mixture in the combustion chamber describes

   a. detonation.
   b. pre-ignition.
   c. normal combustion.
   d. propagation of combustion.

5. Detonation may be caused by

   a. retarded ignition timing.
   b. excessive carbon build up in the combustion chamber.
   c. high octane fuel.
   d. rich fuel-air mixture.

6. A loss of power in an engine may be caused by

   a. normal combustion.
   b. detonation of fuel-air mixture.
   c. a defective fuel pump.
   d. a defective distributor.

7. High valve temperatures or hot spark plugs can cause

   a. propagation of flame front.
   b. normal combustion.
   c. pre-ignition.
   d. lean fuel mixture.

8. Pre-ignition may lead to

   a. advanced timing of the spark.
   b. detonation.
   c. normal combustion.
   d. delayed formation of combustion.

9. Additives, such as tetraethyl lead, in gasoline tend to

a. decrease detonation tendencies.
b. increase fuel consumption.
c. decrease fuel consumption.
d. retard ignition timing.

10. Automotive engineers have designed engines to use a higher combustion temperature to reduce exhaust emissions. What type of fuel do these engines use?

a. Methanol
b. Unleaded gasoline
c. Leaded gasoline
d. Alcohol

11. Viscosity and cleanliness are two major requirements of diesel fuel. What would be a third requirement?

a. Octane
b. Volitility
c. Boiling point
d. Ignition quality

12. A diesel fuel of good ignition quality will insure that the fuel will

a. ignite spontaneously and burn completely.
b. lubricate the precision fitted parts.
c. obtain optimum atomization upon injection.
d. produce paraffin.

13. The ignition quality of a diesel fuel is identified by its

a. octane rating.
b. cetane rating.
c. iso-octane content.
d. naphthalene content.

14. Why must the viscosity of diesel fuel be considered when determining the type of fuel to use?

a. To insure the fuel flows freely and lubricates properly
b. To insure the fuel atomizes correctly
c. To insure the fuel flows freely, lubricates the pump and injectors, and atomizes correctly at the lowest temperature encountered
d. To insure the fuel lubricates and atomizes properly

15. Two impurities normally filtered out of diesel fuel by the fuel system on a vehicle are

a. water and sediment.
b. sulfur and paraffin.
c. paraffin and carbon.
d. water and paraffin.

16. Cetane rating of diesel fuel is determined by

a. the percentage of iso-octane content.
b. a comparison with a fuel of known quantities of alpha methyl napthalene.
c. the percentage of naphthalene.
d. the comparison of iso-octane and naphthalene.

17. Which of the following elements significantly influences carbon and deposit formation in the combustion chamber of a diesel engine?

a. Water
b. Iron
c. Sulfur
d. Carbon

18. Diesel fuel must be designed for the climatic conditions expected during a field problem or combat. Which type of diesel fuel would you use if you were to operate vehicles in Korea during the winter and expect temperatures from -30° to -10° F?

a. DF 1
b. CF A
c. DF 2
d. 92 Octane rating

19. The purpose of the fuel system on an internal combustion engine is to provide the engine with

a. enough fuel.
b. air at the proper rate.
c. water for cooling.
d. a combustible mixture of fuel and air.

20. The components of a fuel system include a fuel tank, carburetor, filter, and

a. intake manifold.
b. exhaust system.
c. ignition system.
d. cooling system.

21. The purpose of a carburetor is to

a. meter and vaporize fuel in the intake manifold.
b. meter and distribute fuel to the cylinders.
c. meter and atomize fuel with air in proper proportions.
d. vaporize and distribute fuel into the intake.

22. Fuel is brought into the air flow through the high speed circuit by the

a. accelerator pump.
b. venturi action of the air flow.
c. choke.
d. fuel pump.

23. A carburetor consists of five circuits and a throttle valve. The five circuits are the choke, float bowl, high speed,______________, and ______________ circuits.

a. medium speed, low speed
b. fuel pump, venturi
c. low speed, accelerator
d. venturi, accelerator

24. The low speed circuit routes air from the air horn past a siphon in the float bowl to a point below the throttle valve. This will provide

a. a combustionable mixture for low speed operation.
b. a combustionable mixture for medium speed operation.
c. the engine with fuel at all speeds.
d. the venturi action needed to pull fuel into the air stream at high speeds.

25. The low speed circuit adjustment screw at the lower portion of the carburetor controls the

a. engine speed.
b. idle speed.
c. idle mixture.
d. venturi action.

26. Where is a reservoir of fuel maintained in the carburetor?

a. In the float circuit (bowl)
b. In the fuel pump
c. In the choke circuit
d. In the venturi

27. The choke is a device which

a. allows the engine to run at high speeds.
b. allows the engine to run at low speeds.
c. aids in starting an engine when it is cold.
d. aids in leaning the fuel-air mixture when the engine is cold.

28. An automatic choke senses the heat in the engine and automatically enriches the fuel-air mixture. What type of choke is applied by the operator?

a. Vacuum
b. Manual
c. Thermostatic coil
d. Exhaust heat valve

29. Excessively choking a gasoline engine causes carbon buildup on spark plugs and in the combustion chamber. What would immediately indicate that the choke has failed to open?

a. High engine temperature and lack of fuel
b. Black smoke in the exhaust and high engine temperature
c. Increased gas consumption and flooding
d. Flooding and lack of fuel

30. During normal operation of a vehicle (warm engine) the choke valve is

a. closed.
b. partially closed.
c. partially open.
d. open.

31. When the choke is closed, raw fuel is pulled through the

a. low speed circuit.
b. accelerator circuit.
c. float circuit.
d. high speed circuit.

32. An offset choke valve (plate) allows the immediate leaning of the fuel/air mixture when a cold engine starts. By what other method is this accomplished?

a. By closing the choke
b. By a poppet valve in the choke plate
c. By pressing the accelerator pedal
d. By closing the idle mixture valve

33. The fuel-air mixture, upon leaving the carburetor, travels through the ______________ which furthers the vaporization process and connects to the cylinders.

a. venturi
b. manifold heat valve
c. exhaust manifold
d. intake manifold

34. On in-line engines, heat is applied to the fuel-air mixture to aid in vaporization by

a. mounting the carburetor on the exhaust manifold.
b. mounting the intake manifold on the exhaust manifold.
c. incorporating a heat passage (crossover) in the intake manifold.
d. routing a coolant hose near the carburetor.

35. Why is heat applied to the fuel-air mixture?

a. To aid in the metering of fuel
b. To prevent ice from forming in the carburetor
c. To aid in the vaporization process
d. To prevent vapor lock

36. The main reason for unequal fuel distribution is inefficient

a. fuel vaporization.
b. heat control valve.
c. cooling system.
d. carburetion.

37. The four types of air filters are: oil bath, oil wetted mesh, paper element, and

a. polypropalene.
b. polyurethane.
c. polysaturated.
d. oil saturated paper.

38. Dust particles entering the engine's intake are removed by

a. operating the engine with the hood closed.
b. the oil filter.
c. the air filter.
d. moving the vehicle to a less dusty condition.

39. The air entering an engine must be clean or ______________ will result.

a. excessive filtration
b. excessive wear
c. a lean fuel-air mixture
d. a dirty carburetor

40. The preferred method of servicing a paper element (dry) air filter is to

a. blow the dirt out from the inside of the element with air.
b. tap the element on a hard surface.
c. replace the element.
d. wash the element in solvent.

41. The most efficient air filter is the

a. oil bath.
b. oil wetted mesh.
c. paper element (dry).
d. polyurethane.

42. A fuel pump supplies fuel to the

a. engine.
b. carburetor.
c. fuel tank.
d. cylinders.

43. Two types of fuel pumps are

a. positive displacement and suction.
b. nonpositive displacement and pushing.
c. mechanical and electrical.
d. mechanical and positive displacement.

44. A fuel pump is considered to be good if the minimum pressure is at least

a. 5 psi.
b. 8 psi.
c. 5 kpm.
d. 8 kpm.

45. To satisfy fuel demands for all operating occasions a fuel pump must deliver about

a. one quart of fuel per hour.
b. one pint of fuel per minute.
c. one quart of fuel per minute.
d. one gallon of fuel per minute.

46. Electric fuel pumps have several advantages. They include: several pumps may be used, fuel does not pulsate, reduced tendency for vapor lock, and

a. fuel is supplied when the starter is activated.
b. fuel is supplied when the switch is turned on.
c. the pump does not become defective.
d. the pumping action does not spurt.

47. To check the delivery volume of a fuel pump, you would disconnect the fuel line at the ______________ and

a. fuel pump, observe the pressure.
b. fuel pump, observe the vacuum gauge.
c. carburetor, observe the pressure.
d. carburetor, observe the quantity delivered.

48. The purpose of a diesel fuel injection system is to inject the correct amount of fuel into the combustion chamber at

a. the proper instant.
b. a predesignated pressure.
c. a synchronized pressure.
d. the anachronous moment.

49. A diesel fuel system must perform several functions for the engine to run efficiently. They include the distribution, atomization, pressurization, timing, ______, and ______________ of fuel.

a. compression, vaporization
b. metering, controlled injection
c. viscosity, injection
d. injection, vaporization

50. In a diesel fuel injection system, pressurization and atomization are controlled by the

a. fuel pump of filter.
b. governor.
c. pressure regulator.
d. injector or injector spring.

51. The three types of diesel fuel injection systems used on motor transport vehicles are the distributor, unit injector, and ______________ systems.

a. pump controlled (jerk)
b. common rail
c. Roosa Master
d. electronic

52. The M809 and M939 vehicles use a Cummins (common rail) fuel system. How is the fuel metered in these vehicles?

a. By the pressure regulator
b. By the governor
c. By the fuel pressure at the fuel inlet orifice and the time the inlet orifice is open
d. By the distance the injector plunger moves to receive fuel

53. A unit injector on a Detroit diesel engine has five functions. These include timing injection, pressurizing fuel, atomizing fuel, controling injection, and

a. distributing fuel to cylinders.
b. regulating fuel pressure.
c. metering fuel.
d. regulating return fuel.

54. Some military vehicles use a supercharger. One type is a positive displacement "Rootes" blower while another is a(n)

a. electric fan.
b. exhaust powered turbocharger.
c. naturally aspirated blower.
d. venturi.

55. In the PT fuel system, fuel is metered by the

a. pressure of fuel at the metering orifice and the time the orifice is open.
b. regulated fuel pressure and the governor.
c. fuel metering valve.
d. pressure regulator at the plunger inlet.

56. The principle of the PT fuel system is that by changing the pressure in a fuel line the ____________________ also changes.

a. timing of injection
b. rate of atomization
c. amount of fuel delivered
d. time the metering orifice is open

57. The PTG fuel pump operates between

a. 26 and 100 psi.
b. 26 and about 176 psi.
c. 30 and about 150 psi.
d. 30 and 200 psi.

58. Fuel flow of the PT system at low idle and at high idle is controlled by the

a. pressure regulator.
b. delivery valve.
c. governor.
d. throttle.

59. A spring and plunger in the governor assembly controls fuel flow through a port at 26 psi for

a. intermediate speeds.
b. low idle.
c. high idle.
d. low idle and high idle.

60. In a PTG fuel pump bypass fuel provides

a. fuel through the injectors.
b. fuel for intermediate speeds.
c. lubrication of the injectors.
d. cooling and lubrication of the pump.

61. In a PTG fuel pump the fuel pressure (flow) between idle and maximum speeds is controlled by the

a. pressure regulator.
b. throttle.
c. governor.
d. idle port.

62. The opening of the inlet port in the PT-D fuel injector is controlled by

a. fuel pressure.
b. governor action.
c. the camshaft.
d. the position of the throttle.

63. Which of the following components allows fuel pressure to build in the PTG fuel pump and also permits fuel to flow to the injectors?

a. Fuel shutdown valve
b. Governor
c. Transfer pump
d. Pressure regulator

64. The components of a unit injector fuel system include a gear type fuel pump, unit injectors,

a. distributor head, and pressure relief valve.
b. control tube, and PT-D injector nozzle.
c. control tube, and restricted fitting.
d. restricted fitting, and high pressure lines.

65. The gear type pump on a Detroit diesel engine supplies fuel to the injectors at _________ pressure.

a. high
b. low
c. variable
d. moderate

66. A unit injector performs five functions. They are the atomization of fuel, pressurization, timing of injection,

a. supplying fuel, and control of injection.
b. distribution, and metering of fuel.
c. controlling injection, and distribution of fuel.
d. metering fuel, and controlling injection.

67. The restricted fitting in the fuel return line of a unit injector fuel system maintains

a. fuel pressure in the inlet manifold.
b. fuel in the return line to the tank.
c. fuel pressure in the return line to the tank.
d. high pressure throughout the fuel system.

68. The fuel pump incorporated with the unit injector fuel system provides an excessive amount of fuel for

a. metering and the return fuel.
b. cooling and lubricating the unit injector.
c. cooling the fuel pump.
d. maintaining an adequate level of fuel in the tank.

69. The control tube on an engine with the unit injector fuel system is operated by the governor. Movement of the rack

a. controls maximum engine speed.
b. controls minimum engine speed.
c. meters fuel according to load.
d. varies the amount of fuel supplied by the pump.

70. In a unit injector, the distance the plunger moves after the upper and lower ports are closed by the position of the helix is

a. the effective stroke.
b. varied by the return fuel.
c. governed by the fuel pump.
d. the maximum stroke.

71. When tuning a unit injector fuel system, positioning the injector rack control levers is done after adjusting the

a. high idle no load.
b. idle speed, and high idle no load.
c. fuel pump pressure.
d. exhaust valve clearance, injector timing, and governor gap.

72. The fuel injection pump on the M1009 (CUCV) meters, pressurizes, distributes, and ______________ the fuel.

a. times
b. atomizes
c. injects
d. controls the pressure of

73. Paraffin formation in diesel fuel is critical to the operation of the M 1009 (CUCV). At what temperature does paraffin begin to form?

a. 30° F
b. 10° F
c. 20° F
d. 0° F

74. The fuel filter on the M1009 (CUCV) incorporates a two-stage pleated paper filter, water separator,

a. fuel heater, and water sensor.
b. fuel heater, and filter sock.
c. water sensor, and pressure regulator.
d. pressure regulator, and fuel bypass.

75. At what point when trouble-shooting the M1009 (CUCV) fuel system do you remove the injector pump for testing?

a. When the malfunction first indicates the injection pump or other fuel system components
b. When the cause is in the fuel system
c. After all other causes of the malfunction have been eliminated
d. After the cause indicates a problem other than in the fuel pump

76. The automatic advance mechanism insures that the fuel pulse arrives at the cylinder during

a. low speeds.
b. intermediate speeds.
c. the start up of the engine.
d. high speeds.

77. The vent wire assembly in the M1009 (CUCV) injection pump removes air from the fuel and

a. controls the amount of return fuel.
b. controls the amount of bypass fuel.
c. allows air to cool the injection pump.
d. allows fuel to enter the transfer pump.

78. The metering valve in the distributor injection pump receives fuel by the

a. fuel shutdown valve and the transfer pump.
b. advance mechanism and the vent wire assembly.
c. throttle at intermediate speeds and the governor at minimum or maximum speeds.
d. transfer pump and discharge plungers.

79. The plungers and cam ring act together to

a. pressurize the fuel for delivery to the injectors.
b. meter the fuel.
c. aid the discharge valve to retain residual pressure in the high pressure line.
d. aid the transfer pump intake of fuel.

80. Aiding the nozzle plunger to reseat, which prevents fuel from dribbling into the precombustion chamber, is a function of the

a. vent wire assembly.
b. metering valve.
c. cam ring and plungers.
d. delivery valve.

81. Timing the injection of fuel for high speed operation is advar by the

a. governor acting on the pressure valve.
b. advance mechanism rotating the cam ring.
c. throttle increasing the metered fuel.
d. governor restricting the bypass fuel.

82. The reduction of noise is one purpose of an exhaust system. Another purpose would be to

a. carry exhaust gas away from the operator/passenger compartment.
b. reduce emissions.
c. recirculate exhaust gases to the engine.
d. reduce exhaust back pressure.

83. Why is exhaust gas from an internal conbustion engine considered dangerous?

a. Because exhaust gas contains volatile hydrocarbons
b. Because the exhaust of an engine contains carbon dioxide at a deadly level
c. Because the gas contains carbon monoxide, a colorless, odorless, deadly gas
d. Because a catalytic converter must be used to reduce the deadly properties contained in the exhaust gas

84. A result of carbon monoxide poisoning can be death. Symptoms include unconsciousness, drowsiness, headaches, and

a. a period of blackouts.
b. sleepiness.
c. fatigue.
d. nausea.

85. The noise produced by an internal combustion engine is reduced by

a. the catalytic converter.
b. passing the exhaust through a series of baffles in the muffler.
c. the distance to the end of the tailpipe.
d. allowing the exhaust to recirculate through the engine.

86. Exhaust system failure is caused chiefly by

a. external damage to the system.
b. improper repair of malfun ns.
c. corrosions produced by hea and condensation.
d. external corrosion produced by constant contact with salts distributed on roads to melt ice.

87. Common problems of excessive noise, back pressure, or carbon monoxide in the passenger's compartment may be corrected by

a. replacing the bad components.
b. repairing the holes in the system.
c. tuning the engine.
d. not operating the vehicle on icy roads.

APPENDIX I

TROUBLE-SHOOTING FUEL SYSTEM (M939)

1. ENGINE WILL NOT CRANK

Step 1. Check for mechanical or hydraulic seizure. Remove fuel injectors for crankshaft rotation test.

a. Try to rotate crankshaft manually using engine barring tool.

b. If crankshaft will not rotate, go to step 2.

c. If crankshaft rotates and liquid is discharged, check if liquid is coolant or fuel.

d. If liquid is coolant, replace cylinder heads.

e. If liquid is fuel, replace fuel injectors.

Step 2. Engine must be inspected for extent of internal damage.

Replace engine.

2. ENGINE CRANKS, FAILS TO START

Step 1. Check for defective fuel shutoff valve.

Remove, inspect, and replace, if necessary, with new fuel shutoff valve.

Step 2. Check for broken fuel supply pump drive shaft.

a. Remove tachometer cable from fuel pump; crank engine and observe if drive shaft end in pump housing is rotating.

b. If drive shaft does not rotate, replace fuel pump.

Step 3. Check for incorrect fuel injector and valve adjustments.

Step 4. Check for possible dirty or damaged fuel injectors.

Remove, inspect, and replace if necessary with new fuel injectors.

Step 5. Adjust valve and injector clearances.

Step 6. Replace fuel pump.

3. ENGINE IDLE-ROUGH, ERRATIC

Check for incorrect injector and valve adjustments.

Adjust injector and/or valves.

Replace injectors.

If rough idle continues, replace fuel pump.

4. EXCESSIVE FUEL CONSUMPTION

Adjust injector.

Replace fuel injectors.

5. EXCESSIVE EXHAUST SMOKE AT IDLE AND UNDER LOAD

Step 1. Check for incorrect fuel injector and valve.

Adjust if necessary.

Step 2. Check for possible dirty or damaged fuel injectors. Remove, inspect, and replace, if necessary, with new fuel injectors.

Step 3. Replace fuel pump.

If malfunction is not corrected, go to step 4.

Step 4. Check cylinder heads.

a. Remove cylinder heads and check for:

1) Cylinder head warp.

2) Faulty gaskets.

3) Burned valves.

b. While cylinder heads are removed, check cylinder liners and pistons for:

1) Worn or scored cylinder liners.

2) Broken piston rings.

6. ENGINE FAILS TO STOP

Step 1. Check fuel shutoff valve and solenoid.

Step 2. Replace defective fuel shutoff valve.

7. ENGINE MISSES

Step 1. Check fuel injectors (see malfunction 5).

If malfunction is not corrected, go to step 2.

Step 2. Check for improper valve seating, burnt valves.

8. LOWER POWER-LOSS OF POWER

Step 1. Check for incorrect fuel injector and valve adjustments, adjust if necessary.

Step 2. Check fuel injectors (see malfunction 4).

If malfunction is not corrected, go to step 3.

Step 3. Replace fuel pump with calibrated replacement unit.

If malfunction is not corrected, go to step 4.

Step 4. Check cylinder heads (see malfunction 5, step 4).

9. ENGINE OVERSPEEDS

Replace fuel pump with calibrated replacement unit.

10. ENGINE LUBRICATING OIL DILUTED BY FUEL

See malfunction 5.

11. ENGINE FUEL KNOCKS

Step 1. Check valve and injector timing.

Step 2. See malfunction 4.

TROUBLE-SHOOTING DETROIT DIESEL FUEL SYSTEM

1. ENGINE WILL NOT ROTATE

   Step 1. Trouble-shoot starter.

   Step 2. Hand crank engine at least one complete revolution. Caution: When using a wrench on the crankshaft bolt at the front of the engine, do not turn the crankshaft in a counterclockwise rotation because the bolt will be loosened. If engine cannot be rotated through a complete revolution, internal damage is indicated and engine must be disassembled to ascertain cause of binding.

   Step 3. Remove fuel injectors. Turn engine over several times to displace liquid from cylinders through injector openings. Remove hand hole covers, clean air box and determine type of liquid, causing condition. Replace hand hole covers and fuel injectors. Start engine. If engine cannot be rotated freely, internal damage is indicated. Disassemble engine and replace damaged parts.

2. HARD STARTING

   Step 1. Perform fuel flow test. If air is present with all fuel lines and connections assembled correctly, replace faulty injectors.

   Step 2. Perform fuel flow test. If fuel flow is inadequate, clean, inspect, repair, or replace valve seat assembly.

   Step 3. Replace gear and shaft assembly or fuel pump housing.

   Step 4. Check condition of fuel pump drive and blower drive and replace defective parts.

   Step 5. Repair fuel filter or strainer.

   Step 6. Repair defective or damaged fuel hoses and fuel injector pipes.

   Step 7. Inspect for binding of governor to injector linkage that will prevent governor from positioning injector racks into FULL FUEL position. Remove any bind found and readjust governor and injector controls.

3. UNEVEN RUNNING OR FREQUENT STALLING

   Step 1. Trouble-shoot cooling system.

   Step 2. Check engine fuel spill back and if return is less than 0.8 per gallon per minute, refer to trouble-shooting fuel system.

   Step 3. Check injector timing and setting of race. Remove and replace faulty injectors.

   Step 4. Check compression. If low, replace engine or rebuild.

   Step 5. Check for governor instability and adjust governor.

4. LACK OF POWER

   Step 1. Incorrect setting of governor gap, injector rack, injector height, or valve clearance will result in lack of power. Engine should be adjusted according to appropriate test and adjustment procedure. Check engine gear train timing. Improperly time gear train timing. Improperly timed gear train will result in loss of power due to valves and injectors being actuated at the wrong time in the engine's operating cycle.

   Step 2. Perform engine fuel flow test. If less than 0.8 gallons per minute is returning to the fuel tank, trouble-shoot fuel system.

   Step 3. Inspect and clean cylinder sleeve ports through hand hole covers in cylinder block. Check blower for obstructions or damage. Clean, repair, or replace faulty rts.

   Step 4. Che.. for low compression.

Step 5. Trouble-shoot fuel system.

Step 6. Check ambient air temperature. Power decrease of 0.15 to 0.5 horsepower per cylinder for each 10°F. temperature rise above 90°F will occur.

Step 7. Trouble-shoot turbocharger.

APPENDIX III

TROUBLE-SHOOTING 6.2 LITER FUEL SYSTEM (M1008)

1. BLEED AIR FROM FUEL SYSTEM

Step 1. Open plug on top of fuel filter.

Step 2. Crank engine for 10 seconds at a time or until fuel flows continually from plug outlet.

Step 3. Close plug on top of fuel filter.

Step 4. Crank engine for 10 seconds at a time until engine starts.

Step 5. If engine will not continue to run, repeat steps 1 through 3 until engine idles and runs properly.

2. ENGINE CRANKS, BUT WILL NOT START

Step 1. Check to see if there is fuel in tank.

Refuel if necessary.

Step 2. Check starting procedures.

Correct starting procedures are in TM 9-2320-289-10.

Step 3. Check glow plugs.

Replace if necessary.

Step 4. Check glow plug control system.

Replace if necessary.

Step 5. Check for fuel to injector pump.

Caution: Direct fuel spray away from source of ignition.

Step 6. Check for restricted fuel filter.

Replace if necessary.

Step 7. Check fuel pump operation.

If no fuel flows, replace fuel pump.

Step 8. Check for plugged or crimped fuel lines.

Clear restriction in fuel lines.

Step 9. Check for contaminated or incorrect fuel.

Remove fuel tank and replace fuel as necessary.

Note: If STE/ICE is available, perform NG 30- engine crank-no start. (See TM 9-2320-289-20)

Step 10. Inspect injector pump for malfunction.

Remove injector pump for repair.

3. ENGINE STARTS, BUT WILL NOT CONTINUE TO RUN AT IDLE.

Step 1. Check for plugs, crimps and leaks in fuel lines.

Check restriction in fuel return lines and repair leaks.

Step 2. Check glow plugs operation.

Replace glow plugs or controller as necessary.

Step 3. Check operation of injector pump.

Report to DS maintenance.

Step 4. Check for contaminated or incorrect fuel.

Remove fuel tank and replace fuel as necessary.

Step 5. Check operation of fuel pump.

Replace if necessary.

4. ENGINE STARTS, IDLES ROUGH (WITHOUT ABNORMAL NOISE OR SMOKE)

Step 1. Check operation of injector pump.

Report to DS maintenance.

Step 2. Check fuel lines for plugs, crimps, and leaks.

Clear restriction in fuel lines and repair leaks.

Step 3. Check for air fuel system.

Install clear plastic tubing on fuel return line from engine. If bubbles appear in tubing when engine is cranking or running, this indicates an air leak. Locate and repair leak.

Step 4. Check for incorrect or contaminated fuel.

Remove fuel tank and replace fuel as necessary.

Step 5. Inspect for injection nozzle(s) malfunction. Remove and replace as necessary.

5. ENGINE COLD-STARTS AND IDLES ROUGH WITH EXCESSIVE NOISE AND/OR SMOKE, BUT CLEARS UP AFTER WARM UP

Step 1. Check break-in mileage.

Break in engine at 2000 miles (3200 km) or more.

Step 2. Check for inoperative glow plugs.

Replace glow plugs as necessary.

Step 3. Check for injector nozzle(s) malfunction.

6. ENGINE WILL NOT RETURN TO IDLE

Step 1. Check external linkage for damage.

Step 2. Check injection pump for internal damage.

7. FUEL LEAKS ON GROUND - NO ENGINE MALFUNCTIONS

Step 1. Inspect for loose or broken fuel line or connection. Examine complete fuel system, including fuel tank, fuel pump and injector lines. Determine source and cause of leak.

Repair leak.

Step 2. Inspect injector pump internal seal.

Remove injector pump for repair.

8. NOTICEABLE LOSS OF POWER

Step 1. Check air cleaner element and polywrap.

Remove and install new air cleaner or service as necessary. (Refer to TM 9-2320-289-10.)

Step 2. Check for plugged fuel filter.

Install new fuel filter as necessary.

Step 3. Check for plugged fuel tank vacuum vent in fuel cap. Remove fuel cap.

If loud "hissing" sound is heard, vent is plugged (slight hissing sound is normal).

Replace as necessary.

Step 4. Check for plugged fuel system from fuel tank to injector pump.

Flush out fuel line from tank to injector pump as necessary.

Step 5. Check for pinched fuel lines in system.

Replace as necessary.

Step 6. Check for incorrect or contaminated fuel.

Remove fuel tank and replace fuel as necessary.

Step 7. Check for external compression leaks.

Apply "Leak-Tec" to all nozzles and glow plugs. If leaks appear, tighten nozzle or glow plug.

Step 8 Check for damaged exhaust system.

Repair or replace as necessary

Step 9. Inspect for compression leaks at all nozzles and glow plugs.

If leak is found, tighten nozzle or glow plug.

Step 10. Remove nozzles and check for plugging.

Repair or replace.

9. NOISE--"RAP" FROM ONE OR MORE CYLINDERS (SOUNDS LIKE CONNECTING ROD BEARING KNOCK)

Step 1. Inspect for nozzle(s) sticking open or with very low nozzle opening pressure. Remove nozzle for test and replace as necessary.

10. EXCESSIVE BLACK SMOKE AND/OR OBJECTIONABLE OVERALL COMBUSTION NOISE

Step 1. Inspect injector pump for internal problem.

Remove injector pump for repair.

11. ENGINE WILL NOT SHUT OFF USING KEY

Step 1. Check operation of fuel shut down valve. Repair as necessary.

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