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ABSTRACT

Developed as part of the Marine Corps Institute (MCI) correspondence training program, this course on engineer equipment mechanics is designed to advance the professional competence of privates through sergeants as equipment mechanics, Military Occupation Specialty 1341, and is adaptable for nonmilitary instruction. Introductory materials include specific information for MCI students and a study guide (guidelines to complete the course). The 13-hour course consists of four chapters or lessons. Each unit contains a text and a lesson sheet that details the study assignment is also provided. Topics covered in the lessons include test equipment, engine diagnosis and repair, diagnosis and repair of power train components, and diagnosing, troubleshooting, and repairing auxiliary equipment. (YLB)

UNITED STATES MARINE CORPS
MARINE CORPS INSTITUTE, MARINE BARRACKS
BOX 1775
WASHINGTON, D.C. 20013

13.41c
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1. PURPOSE

This publication has been prepared by the Marine Corps Institute for use with the MCI course, Engineer Equipment Mechanic.

2. APPLICABILITY

This manual is for instructional purposes only.

E. J. LLOYD
Lieutenant Colonel, U.S. Marine Corps
Director

INFORMATION

FOR

MCI STUDENTS

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

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 enough envelopes to mail all lessons back to MCI unless your lesson answer sheets are of the self-mailing type. If your answer sheets are of the preprinted 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 find a discrepancy and correct it, ensure that you correct this information on all your answer sheets. If you did not receive all your materials, use the enclosed Student Request/Inquiry (MCI-R14__) to notify MCI of this fact and what you require. (Note: The MCI-R14__ may be mailed to MCI without envelope or stamp).

2. LESSON SUBMISSION

Submit your lessons on the answer sheets provided. Complete all blocks and follow directions on the answer sheet for mailing. 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
44.1, Procedures of Legal Administration
Lesson 3
Military or office address
(RUC number, if available)

Otherwise, your answer sheet may be delayed or lost. If you have to interrupt your studies for any reason, contact your training NCO who will request a single six month extension of time, which is added to the original Course Completion Deadline (CCD) date. If you are not attached to a Marine Corps unit you may make this request by submitting the enclosed MCI-R14__, or by calling the Registrar Division on AUTOVON 288-4175/2299/6293 or commercial (202) 433-5174/2299/2691. You are allowed one year from the date of enrollment to complete this course. Your commanding officer is notified of your status through the monthly Unit Activity Report. In the event of difficulty, contact your training NCO or MCI immediately.

3. ENROLLMENT/MAIL TIME DELAY

Presented below are the Enrollment/Mail Time delays. Column I represents the First Class mail time from MCI to the designated geographical location or from your location to MCI. All correspondence is sent via First Class mail. Course materials are sent via Special Fourth Class Book Rate.) You should add five working days for our processing. Example: Eastern U.S. - 3 days mailing time to MCI + 5 working days MCI processing + 3 days mailing time back to the unit = 11 days. Column II represents Regular Mail from the time when the enrollment application is mailed until the unit receives the course. Example: Eastern U.S. - Enrollment application 3 days mailing time to MCI + 5 working days MCI processing + 6 days mailing time to the unit = 14 days.

GEOGRAPHIC AREA	COLUMN 1	COLUMN 2
EASTERN U.S.	3	14
WESTERN U.S.	4	19
FPO NEW YORK	5	21
DEPT. OF STATE MARINE SECURITY GUARD	7	24
HAWAII (NON-FPO)	5	12
FPO SAN FRANCISCO	7	27
FPO SEATTLE	6	23

Note: These times represent the service standard. The actual times may vary. If the delay you are experiencing is excessive, please contact the MCI Registrar by phone, message, or letter, so that we may take action.

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 lessons and for the final examination, along with a reference sheet (MCI R69), indicating the questions incorrectly answered. All lessons must be COMPLETED AND PASSED before you will be administered an exam. The grade attained on the final exam is your course grade.

5. FINAL EXAMINATION

ACTIVE DUTY PERSONNEL: When you submit your LAST LESSON, your exam 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 (equivalent or higher), and it must be validated by the administrator.

INACTIVE DUTY OR CIVILIAN EMPLOYEE: The exam may be supervised by a director of civilian personnel, civilian training officer, clergyman, or local school official

6. COMPLETION CERTIFICATE

The completion certificate will be mailed to your commanding officer. For non-Marines, it is mailed to your supervisor or directly to you, as appropriate.

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" and 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. DISENROLLMENT

Only your commanding officer can request your disenrollment from an MCI course since this action will adversely affect the unit's completion rate.

9. ASSISTANCE

Consult your training NCO in the event of course content problems. If he is unable to assist you, MCI is ready to help you whenever you need it. Please use the enclosed Student Course Content Assistance Request (T&E-1) or call the Autovon telephone number listed below for the appropriate course writer section.

PERSONNEL/ADMINISTRATION/LOGISTICS/CORRECTIONS	288-3259
COMMUNICATIONS/ELECTRONICS/AVIATION/NBC	288-3604
INFANTRY	288-3611
ENGINEER/MOTOR TRANSPORT/UTILITIES	288-2275
SUPPLY/FOOD SERVICES/FISCAL	288-2285
TANKS/ARTILLERY/SMALL ARMS REPAIR/AAV	288-2290

For administrative problems call the MCI Hotline: 288-4175

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

BEST COPY AVAILABLE

STUDY GUIDE

10. STUDY HINTS

By enrolling in this course, you have shown a desire to improve the skills you need for effective job performance, and MCI has provided materials to help you achieve your goal. Now all you need is to develop your own method for using these materials to best advantage.

The following guidelines present a four-part approach to completing your MCI course successfully:

- Make a "reconnaissance" of your materials;
- Plan your study time and choose a good study environment;
- Study thoroughly and systematically;
- Prepare for the final exam.

a. MAKE A "RECONNAISSANCE" OF YOUR MATERIALS

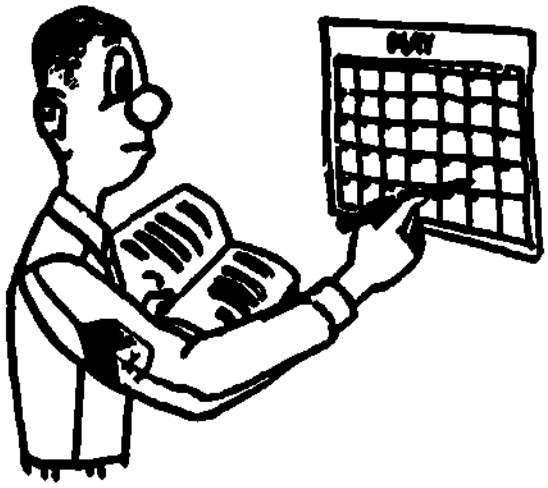
Begin with a look at the course introduction page. Read the COURSE INTRODUCTION to get the "big picture" of the course. Then read the MATERIALS section near the bottom of the page to find out which text(s) and study aids you should have received with the course. If any of the listed materials are missing, see paragraph 1 of this pamphlet to find out how to get them. If you have everything that is listed, you are ready to 'reconnoiter' your MCI course.

Read through the table(s) 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 lesson questions to get an idea of the types that are asked. If MCI provides other study aids, such as a slide rule or a plotting board, familiarize yourself with them. Now, get down to specifics!

b. PLAN YOUR STUDY TIME AND CHOOSE A GOOD STUDY ENVIRONMENT

From looking over the course materials, you should have some idea of how much study you will need to complete this course. But "some idea" is not enough. You need to work up a personal study plan; the following steps should give you some help.

(1) Get a calendar and mark those days of the week when you have time free for study. Two study periods per week, each lasting 1 to 3 hours, are suggested for completing the minimum two lessons required each month by MCI. Of course, work and other schedules are not the same for everyone. The important thing is that you schedule a regular time for study on the same days of each week.



(2) Read the course introduction page again. The section marked ORDER OF STUDIES tells you the number of lessons in the course and the approximate number of study hours you will need to complete each lesson. <u>Plug these study hours into your schedule.</u> For example, if you set aside two 3-hour study periods each week and the ORDER OF STUDIES estimates 2 study hours for your first lesson, you could easily schedule and complete the first lesson in one study period. On your calendar you would mark "Lesson 1" on the appropriate day. Suppose that the second lesson of your course requires 3 study hours. In that case, you would divide the lesson in half and work on each half during a separate study period. You would mark your calendar accordingly. Indicate on your calendar exactly when you plan to work on each lesson for the entire course. Do not forget to schedule one or two study periods to prepare for the final exam.

(3) Stick to your schedule.

Besides planning your study time, you should also choose a study environment that is right for you. Most people need a quiet place for study, like a library or a reading lounge; other people study better where there is background music; still others prefer to study out-of-doors. You must choose your study environment carefully so that it fits your individual needs.

c. STUDY THOROUGHLY AND SYSTEMATICALLY

Armed with a workable schedule and situated in a good study environment, you are now ready to attack your course, lesson by lesson. You will find your first study assignment and your first written assignment on page 1 of lesson 1. On this page you will also find the lesson objective, a statement of what you should be able to do after completing the assignments.

DO NOT begin by reading the lesson questions and flipping through the text for answers. If you do so, you will prepare to fail, not pass, the final exam. Instead, proceed as follows:

(1) Read the study assignments carefully. Make notes on the ideas you feel are important and mark any portion you have difficulty understanding.

(2) Reread the portions you marked in step (1). When you have mastered the study assignment, start to work on the written assignment.

(3) Read each question in the written assignment carefully.

(4) Answer all questions that you are sure of and leave the others blank.

(5) Reread the portions of the study assignment that explain the items you left blank.

(6) Complete the written assignment and send it to MCI for grading.

(7) Go on to the next lesson.

Follow the same procedure for each lesson of the course. If you have problems with the text or lesson questions that you cannot solve on your own, ask your section OIC or NCOIC for help. If he cannot aid you, request assistance from MCI on the MCI Student Course Content Assistance Request included in this pamphlet.

When you have passed the final lesson, the final exam will be sent to your training officer or NCO.

d. PREPARE FOR THE FINAL EXAM

How do you prepare for the final exam? Follow these three steps:

(1) Review each lesson objective as a summary of what was taught in the course.

(2) Reread all portions of the text that you found particularly difficult.

(3) Review all the lesson questions, paying special attention to those you missed the first time around.

If you follow these simple steps, you should do well on the final. GOOD LUCK!

PREFACE

Engineer equipment mechanic has been designed to provide lance corporals through staff sergeants with a source of study material which will enable them to perform more efficiently the duties of an engineer equipment mechanic, MOS 1341. It discusses some of the things to consider when diagnosing, troubleshooting, and repairing malfunctions of principal systems of engineer equipment. This is not a basic equipment course nor does it cover all the equipment, procedures, duties, and responsibilities of an engineer equipment mechanic. It is a general discussion of techniques for diagnosing, troubleshooting, and repairing systems of engineer equipment. This, coupled with other courses offered by MCI and OJT, will enable the 1341 mechanic to qualify in his MOS.

There is a continuous need for good, experienced diagnostic and troubleshooting mechanics in the engineer field. Excessive repair costs are continuously incurred due to inexperienced mechanics jumping into a repair job without first making a diagnosis and then troubleshooting for the cause. To explain these two terms, let us say that diagnosis is the ability to determine what part or component has malfunctioned and troubleshooting is the art of determining the cause of that malfunction.

This course includes coverage in the tools and test devices necessary for a mechanic to diagnose and troubleshoot components of engineer equipment. Succeeding chapters deal with standard gasoline and diesel engines; power trains; and auxiliary equipment used on Marine Corps engineer equipment. This course, coupled with on-the-job training, will enable you to be a more proficient mechanic. Be a mechanic, not a parts changer.

SOURCE MATERIALS

TM 00872 A-15	Crane-Shovel, Crawler-Mounted with Attachments, Dec 1961
TM 00872 B-15	Crane-Shovel, Crawler-Mounted, Model M37(M63), Jan 1965
TM 00873 D-15	Crane-Shovel, Crawler-Mounted, Model 2N(M62), Jan 1963
TM 01551 D-15	Bay City Crane, Truck-Mounted, Diesel-Engine-Driven, Mar 1964
TM-EN-01551 A-15	Crane-Shovel, Truck-Mounted, Diesel-Engine-Driven, Jun 1961
TM 04078 A-15	Tractor, Diesel-Engine-Driven, Model 100, Dec 1964
TM-07542A-12	Loader, Scoop-Type, Full-Tracked, JI Case Model MC 1150, 15 Oct 1972
TM-ENG-2475	Adams Model 550 Motor Grader, Nov 1957
TM 2815-15/1	Detroit Diesel Engines, (reissued Oct 72)
TM 5-2805-204-14	Engine, Gasoline, Military Standard Models, Jul 1965
TM 9-8000	Principles of Automotive Vehicles, Jan 1956
NAVPERS 10644F	Construction Mechanic 3 and 2, rev 1966
NAVPERS 10645C	Construction Mechanic 1 and C, rev 1970
SFTEE-1362	Fuel and Electrical Trouble Diagnosis, Test Equipment
	Wisconsin Air-Cooled, Heavy-Duty Engines, Wisconsin Motor Corp., Milwaukee, Wisconsin
	Euclid Maintenance Manual for 82-30/C6 Crawler-Tractor, The Service Department, Euclid, Division of General Motors, Hudson, Ohio, Apr 1966

UNITED STATES MARINE CORPS
MARINE CORPS INSTITUTE, MARINE BARRACKS
BOX 1775
WASHINGTON, D.C. 20013

ENGINEER EQUIPMENT MECHANIC

Course Introduction

ENGINEER EQUIPMENT MECHANIC is designed to advance the professional competence of privates through sergeants as equipment mechenics, It will instruct them in the testing end diagnostic equipment and in the methods of conducting tests. In addition, the course gives coverage on diagnosing and troubleshooting of engines, power trains, and auxiliary equipment. Ideally, the course should be used in conjunction with on-the-job training in order to meet the MOS qualification requirements for the equipment mechanic,

ORDER OF STUDY

Lesson Number	Study Hours	Reserve Retirement Credits	Subject Matter
1	2	0	Test Equipment
2	3	1	Engine Diagnosis and Repair
3	3	1	Diagnosis and Repair of Power Train Components
4	3	1	Diagnosing, Trouble shooting, and Repairing Auxiliary Equipment
	2	1	FINAL EXAMINATION
	13	4	

EXAMINATION: Supervised final examination without textbooks or notes: time limit, 2 hours.

MATERIALS: MCI 13.41c, Engineer Equipment Mechanic, Lesson sheets and answer sheets.

RETURN OF MATERIALS: Course materials become the property of the student upon successful completion of the course.

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

CONTENTS

Chapter 1

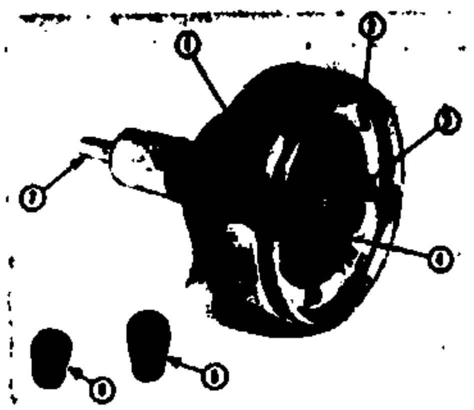
TEST EQUIPMENT

1-1. GENERAL

The type of test equipment authorized for your unit will be determined by the echelon of maintenance authorized, the T/E, the unit's mission, and the type and quantity of equipment to be supported. Test equipment is helpful and necessary in some cases for the correct diagnosis and troubleshooting of malfunctions. This chapter will discuss only the test equipment used to diagnose and troubleshoot malfunctions. Some of these items are more common to motor transport maintenance, but can be used on engineer items of equipment.

1-2. TACHOMETER

Most engineer equipment is equipped with a tachometer, but because of continuous operation you should not rely upon its being accurate. A hand-held mechanical tachometer is used to measure engine rpm and to check the accuracy of equipment tachometers. The tachometer shown in figure 1-1 will indicate rpm for both right and left rotating shafts. The shafts must be clean and dry because the rubber-tip adapters act as the friction surface for the tachometer and will slip, giving a false reading. Force the tip into the shaft only with enough force to prevent slipping and not so hard that the instrument parts will bind. The tachometer shaft must be held directly in line with the center of the rotating part. Handle it with care and store it in a place where it will not be bumped. When using the tachometer you should be extra careful or your hands or clothing may get tangled in the moving machinery.



1. Tachometer assembly
2. Clockwise scale
3. Counterclockwise scale
4. Indicator needle
5. Tip adapter for shafts with center hole
6. Tip adapter for flat surfaces
7. Shaft

Fig 1-1. Hand-held tachometer.

1-3. COMPRESSION GAGE

The compression test set shown in figure 1-2 is for use on diesel engines; the tester for gasoline engines performs the same function, but on a lower scale and it has fewer adapters. To use the tester, remove the injector, injection nozzle, or spark plug from the cylinder to be tested and crank or run the engine at the speed specified. The highest reading on the gage indicates the compression pressure in the cylinder. Readings lower than specified indicate bad valves or valve adjustments, bad cylinder head gasket, worn rings, or cracked parts. The compression test will not pinpoint the trouble, but it will enable you to proceed with further tests to locate the problem. For example, an engine using excessive amounts of oil, but having the specified compression is an indication of worn valve guides or oil leaking at some other point. The tester and adapters are usually issued as a set in a box; keep them clean and dry. The adapters are rubber or some other soft material or a machined fit; damage to these components will allow leakage and cause a false reading.

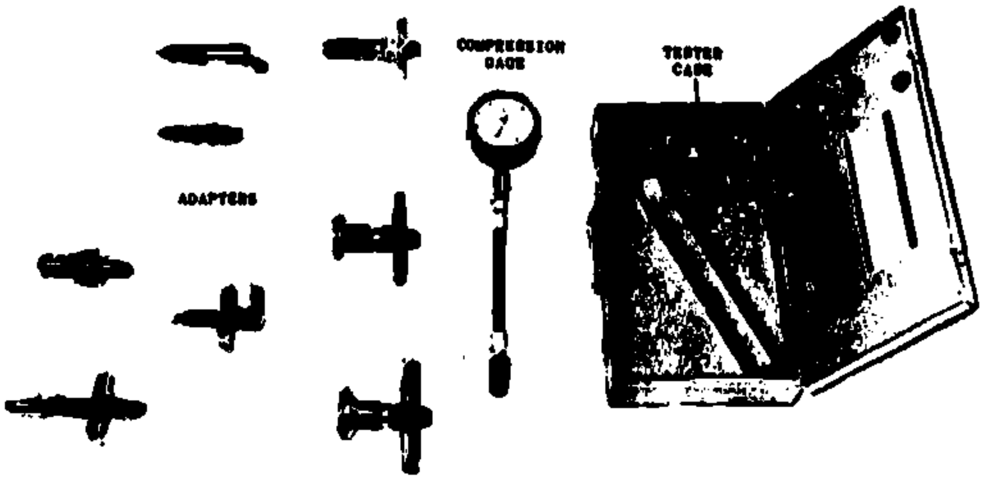


Fig 1-2. Diesel engine compression test set.

1-4. PRESSURE GAGES

Gages to measure air and oil pressure are required to check engine and component oil pressures and brake or clutch mechanism air pressure. These gages are made in a variety of sizes and types and in some cases the mechanic will use a new part like the one installed on the machine. When available, the test gages should be used because they are calibrated and are designed to withstand some overload. When checking oil or air pressure, select a gage that will indicate the highest reading expected. Although the gages will withstand some overload, cold oil and maladjusted compressors will sometimes exceed the expected reading. Before removing the plug to install the gage or before removing the gage after the job is completed, bleed the system to reduce the pressure. Oil in some systems has enough pressure to force it into the skin, and air pressure will force small particles into the skin. When not in use, keep the open end of the gage covered to protect the gage from dirt and to protect the screw threads.

1-5. VACUUM GAGE AND FUEL PUMP PRESSURE TESTER

The tester is a single gage with a flexible hose and adapters. The gage is marked to indicate pounds of pressure and inches of vacuum. It can be used to assist in diagnosing problems caused by lack of fuel, ignition timing, defective valves or gaskets, or improper carburetor adjustments. The vacuum gage and fuel pump pressure tests are used with other tests to pinpoint mechanical problems.

a. Vacuum test. This test is made by connecting the gage to the intake between the carburetor and the engine. The connection may be at the base of the carburetor or at a plug near the center of the intake manifold. Some engines are not equipped to be tested with the vacuum gage; there is no place to connect the gage. After the gage is connected and the engine is operating at normal operating temperature, note the inches of vacuum on the gage. A steady needle that is between 18 and 21 inches vacuum is normal (fig 1-3). A steady reading below 18 inches (fig 1-4) indicates a loss of power due to a condition that is affecting all cylinders. The loss of power may be due to late ignition timing, improper sealing of piston rings, or mechanical drag caused by tight bearings. An improperly adjusted carburetor is usually indicated by a reading that slowly drifts from one reading to another (fig 1-5). Should the needle pulsate (jump) steadily from one reading to another (fig 1-6), there is a complete loss of power on one or more cylinders. The power loss may be caused by leaky valves, blown head gasket, restricted intake manifold, or faulty ignition. An occasional pulsation of the needle indicates ignition failure or sticking valves. If the reading starts between 18 and 21 inches vacuum and gradually falls lower when the engine rpm is held steady at approximately 2000 rpm, the cause is probably a restricted exhaust system.

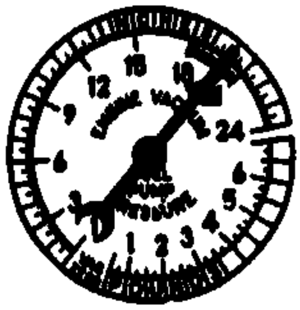


Fig 1-3. Normal vacuum reading

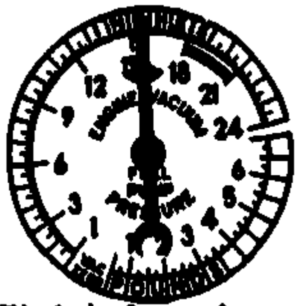


Fig 1-4. Loss of power affecting all cylinders.

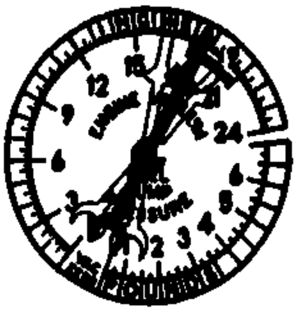


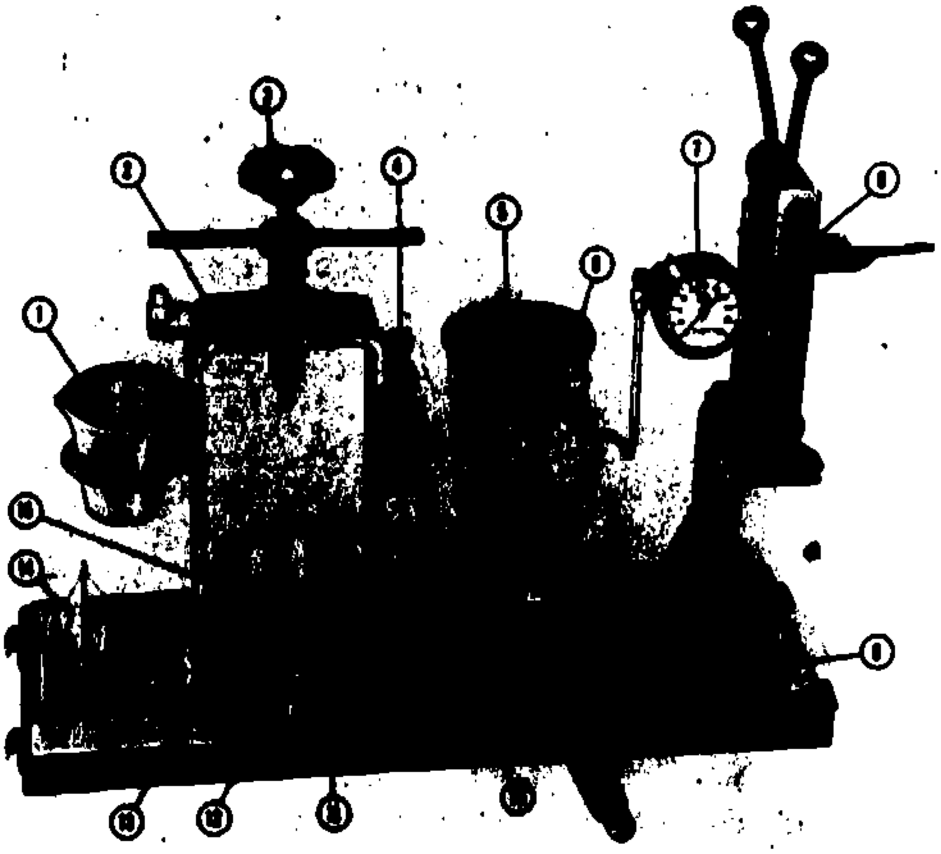
Fig 1-5. Improper carburetor adjustment causes slow oscillation.

Fig 1-6. Loss of power on one or more cylinder causes steady pulsation.

b. Fuel pump pressure test. Before starting the test, check the TM for fuel pump pressure specifications. Disconnect the fuel line from the carburetor and connect the tester to the line. Crank the engine and note the fuel pressure; the engine will run on the gas that is in the carburetor. DO NOT allow gasoline to fall onto a hot engine. Fuel pump pressure lower than specified may be due to restricted lines, clogged filter, or faulty pump.

1-6. DIESEL FUEL SYSTEM TEST EQUIPMENT

This set (fig 1-7) consists of a pump, gages, adapters, and a spray cup. It is used for testing unit injectors and nozzles. It is a component of the contact maintenance truck. As field conditions usually prevent the repair of unsatisfactory fuel system parts, replacement, not repair, is recommended. This test set is used by higher echelon repair facilities to determine the cause of defective unit injectors and nozzles so that repairs may be made, when applicable, or to insure that the injectors and nozzles are functioning properly.



1. Plastic spray cup
2. Cummins test fixture and accessories
3. Plunger screw knob
4. Low-pressure tester
5. Injector test pump
6. Hydraulic gage, 0-500 psi
7. Gage and fuel line assembly
8. Test head
9. Mounting base
10. Flexible connector
11. Reverse flow block
12. Spacer block
13. Adapter
14. Burette
15. Spacer block

1. Connector nut
2. Connector nuts (N-4)
3. Connector nut (N-5)
4. Connector tube (N-1)
5. Connector nut (N-7)
6. Connector nut (N-8)
7. Ermeto adapter (N116)
8. Mounting plate

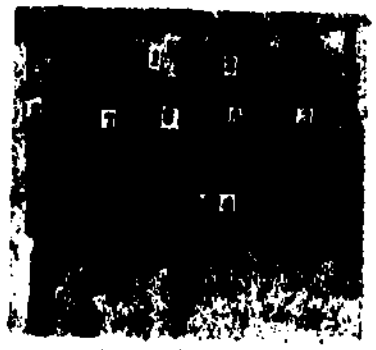


Fig 1-7. Diesel fuel system test equipment.

1-7. ELECTRICAL TEST SETS

a. General. Many good electrical components have been replaced because the mechanic did not know how to perform a test or did not know that test equipment was available. The electrical testing equipment normally used by engineer equipment mechanics is considered to be motor transport equipment. However, the maintenance shop vehicles are now equipped with some test equipment. The low-voltage circuit tester (LVCT) and the multimeter can be used to test most components of the engineer equipment electrical system. There are other components of the set such as the coil-condenser tester, generator and voltage regulator tester, volt-amp tester, and dwell-tach tester, but the LVCT and the multimeter will perform most tests required on engineer items of equipment. When properly used, they enable the mechanic to locate defective electrical components. Parts can be tested to determine their condition; this will help eliminate waste. The sets are precision instruments and must be handled with care. They are usually repaired by ordnance or electronic maintenance personnel. The only maintenance performed by the user is cleaning of the set and replacement of the battery.

b. Components and use.

(1) Adapter kit (fig 1-8). The connections necessary for testing and diagnosing fungus-proof and radio-suppressed electrical systems are contained in the adapter kit. The components of the kit are designed to be plugged into the circuit of shielded systems and provide a method of attaching the test equipment. The kit contains a generator field control which is a rheostat for controlling the current through the generator field when making tests.

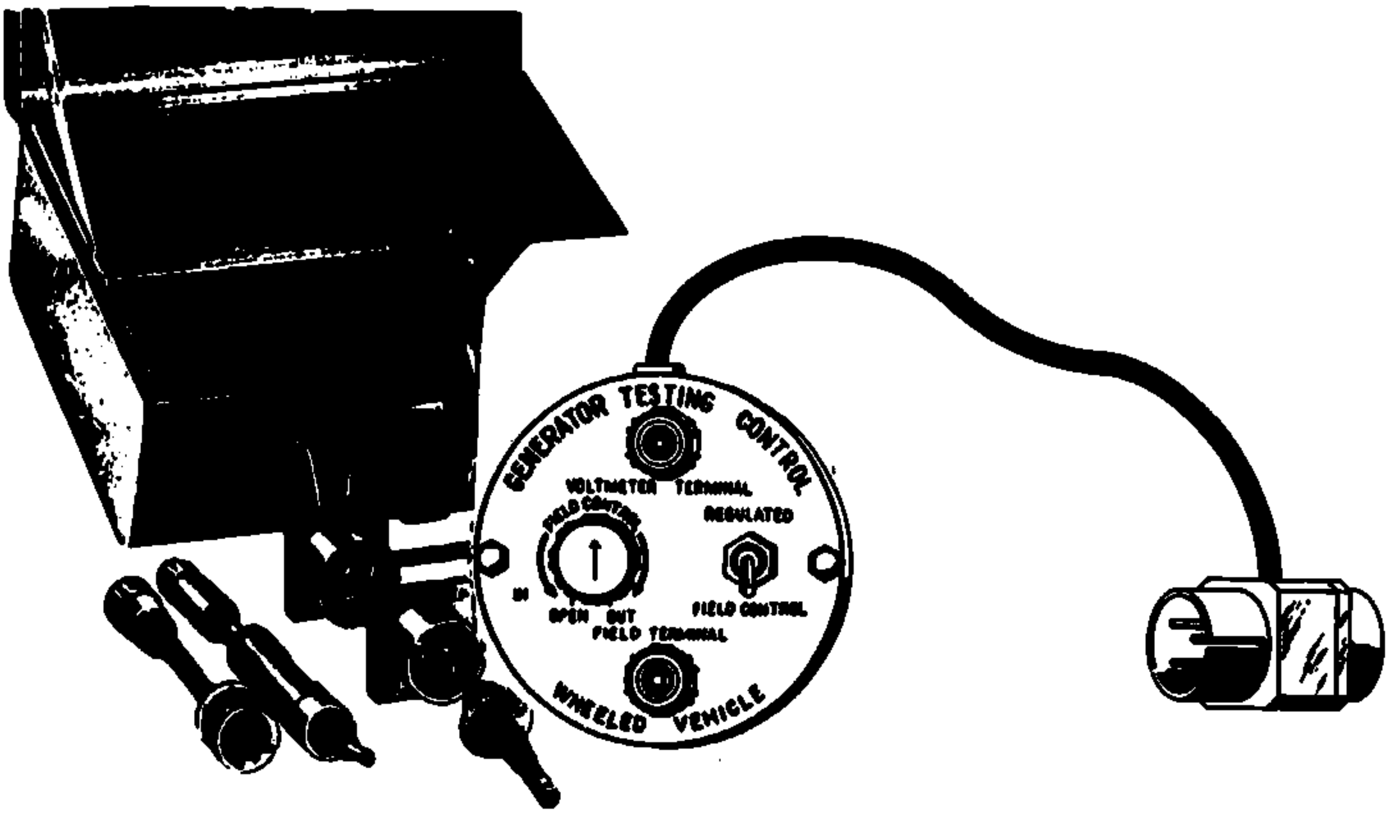


Fig 1-8. Model WPW adapter kit.

(2) Heavy-duty battery starter tester (fig 1-9). This set is used to test battery capacity, starter and battery cables, and starting motors. It has a scale for reading volts and a scale for reading amperes. Procedures for using the set are usually provided with the set. The procedures discussed here are for general use when there are no specific instructions with the set or in the TM.

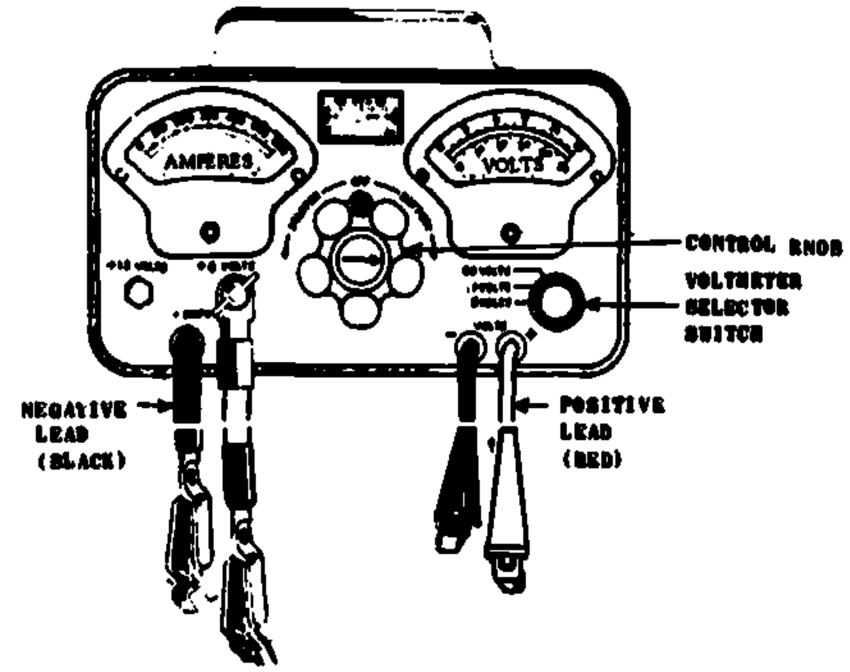


Fig 1-9. Heavy-duty battery starter tester.

(a) Battery capacity test (fig 1-10). The capacity test is made if visual inspection and preliminary tests fail to locate the electrical trouble or if electrical troubles are reoccurring. Before making the capacity test, the electrolyte must be at the proper level and have a specific gravity of at least 1.225 at 60°F or above.

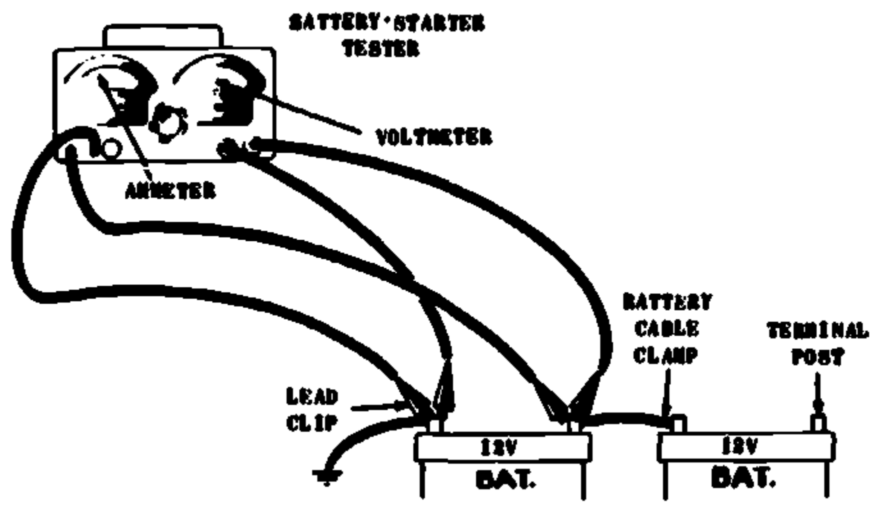


Fig 1-10. Battery capacity test connections.

Step 1. Turn the control knob of the tester to the OFF position and connect the ammeter leads as illustrated (fig 1-10).

Step 2. Turn the voltmeter selector switch to 15-VOLTS and connect the voltmeter leads. NOTE: The tester leads are to be connected to the battery terminal and not to lead clips.

Step 3. Turn the control knob clockwise to BATTERY and adjust so that the tester ammeter reads a discharge rate equal to 3 times the ampere-hour rating of the battery. (The ampere-hour rating of the battery is listed in supply publications.

Step 4. With the ammeter reading the specified load for 15 seconds (NO LONGER), note the voltmeter reading, then turn the control knob to the OFF position. If the tester is pulling the specified loads for periods longer than 15 seconds it will burn up the tester and leads or completely discharge the battery.

Step 5. The readings on the voltmeter indicate the battery condition. For a 12-volt battery, 9.6 is good, 9 to 9.6 is fair, and less than 9 volts is unsatisfactory.

Step 6. Only the 12-volt battery is mentioned because most engineer equipment is equipped with one or more 12-volt batteries. Test each battery individually to insure that each is in satisfactory condition.

(b) Cable test (fig 1-11). Starting and charging system difficulties are sometimes caused by excessive cable resistance. Only the voltmeter part of the tester is used to make the cable resistance test. When the voltmeter is properly used, a reading of more than .1 volt indicates excessive resistance which may be due to poor connections or defective cables. The tests are made by connecting the voltmeter leads across each connection and cable in turn. Correct any deficiencies noted before proceeding to the next cable or connection.

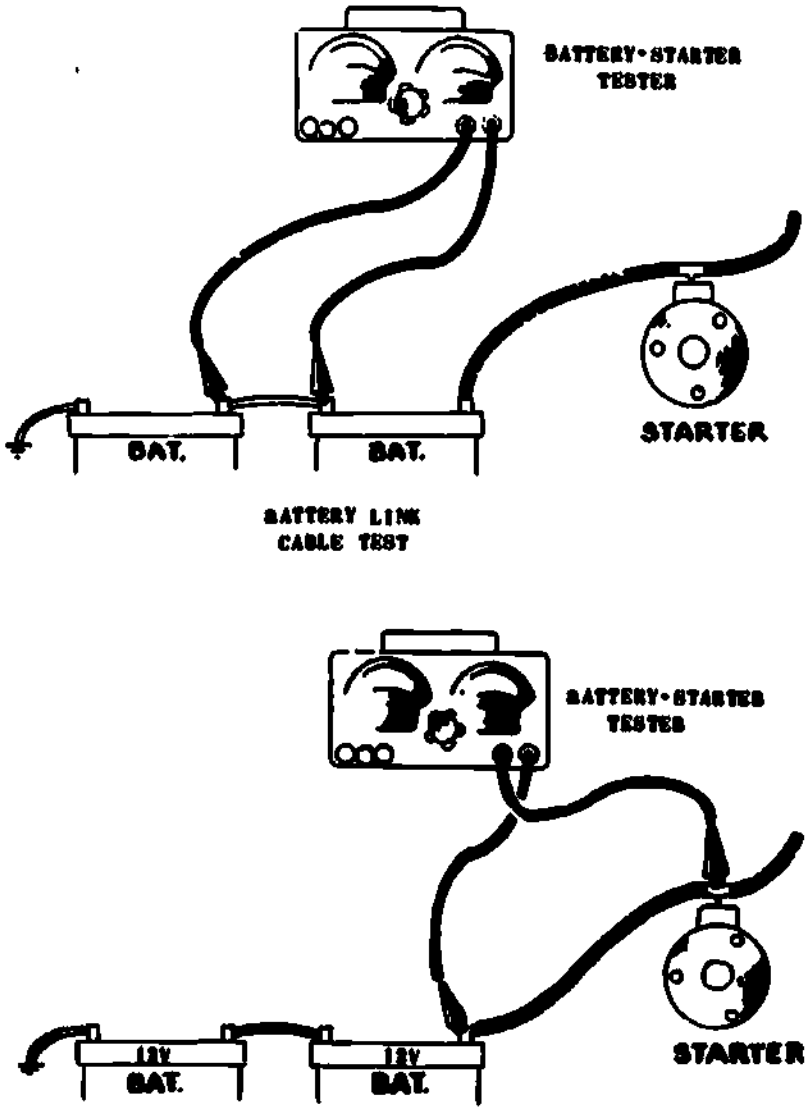


Fig 1-11. Cable test.

Step 1. Turn the voltmeter selector to 5 VOLTS.

Step 2. Connect the voltmeter leads as illustrated. The voltmeter lead must contact the battery post and the connection terminal or from terminal to terminal. Loose or corroded connections will cause a false reading if the leads are connected to the cable clamps.

Step 3. Do NOT allow the voltmeter lead to ground the circuit.

Step 4. With the tester connected, close the starting circuit and obtain the reading. Leave the ignition or the throttle controls in the off or stopped position when making the test. The test requires the starting motor to be under load.

(c) Ground circuit test (fig 1-12). This test is made in the same manner as the cable test except that a reading above .2 volt is excessive. Excessive readings may be due to poor connections or defective parts within the starting motor. A poor connection between the engine and the vehicle frame will cause an excessive reading if the battery ground strap is connected to the vehicle frame. Excessive voltage loss indicates resistance in the circuit which will interfere with the operation of the entire electrical system.

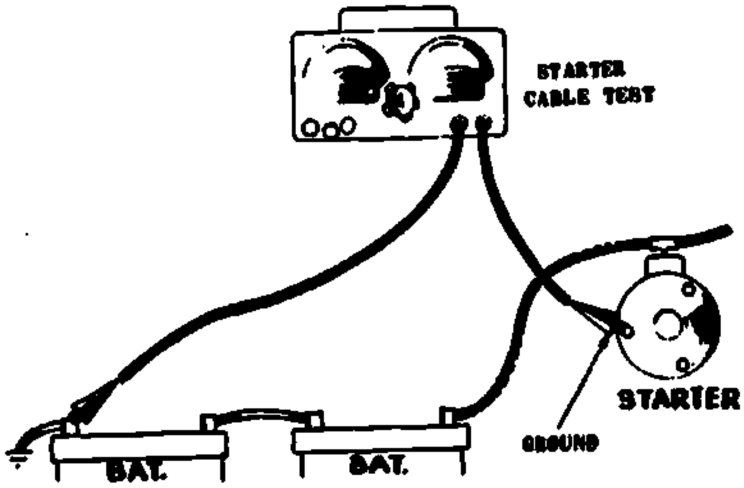


Fig 1-12. Ground circuit test.

(3) Volts-ampere tester (fig 1-13). The volts-ampere tester looks like the battery starter tester and care must be taken to be sure the correct set is being used. Both sets have a scale for volt readings and a scale for the ampere readings. The volts-ampere tester is used for testing the starting motor amperage draw and charging circuit and primary circuit resistance.

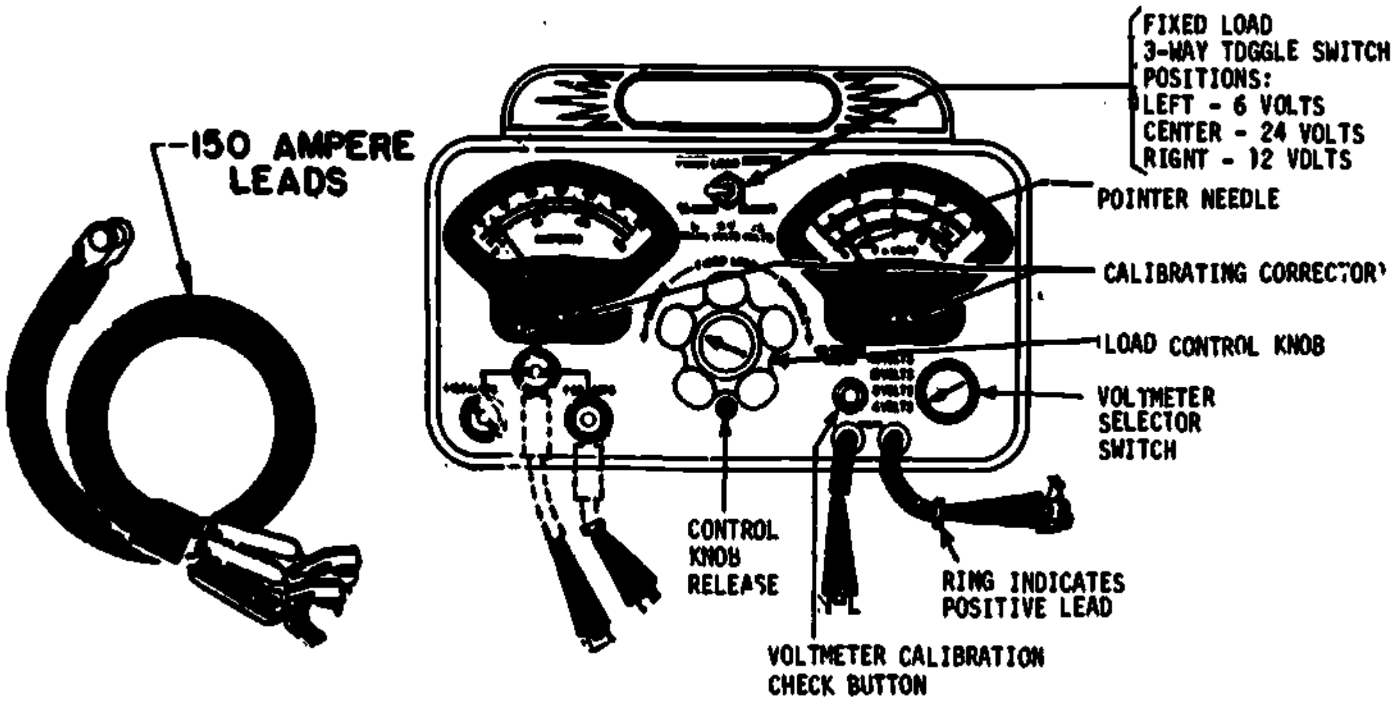


Fig 1-13. Volts-ampere tester.

(a) Starting motor amperage draw test (fig 1-14). The purpose of the test is to determine the amperage draw of the starting motor. The engine must be at normal operating temperature so that the cranking load will be normal. Note in the illustration that the tester leads are connected so that if the tester controls are turned to a certain position there will be a direct short across the battery.

Note: These procedures are for a 24-volt system.

Step 1. Turn the load control knob to FIXED LOAD. Leave the fixed-load switch at 24 VOLTS and turn the voltmeter selector to 40 VOLTS.

Step 2. Connect the test leads as illustrated in figure 1-14.

Step 3. With the ignition switch off or the throttle in the stopped position, engage starter and note the exact reading on the voltmeter.

Step 4. Disengage the starter, then turn the load control knob clockwise until the voltmeter reads exactly the same as with the starting motor operating.

Step 5. Read the tester ammeter for the starting motor amperage draw.

Step 6. Turn the load control to FIXED LOAD before disconnecting leads. DO NOT turn counterclockwise.

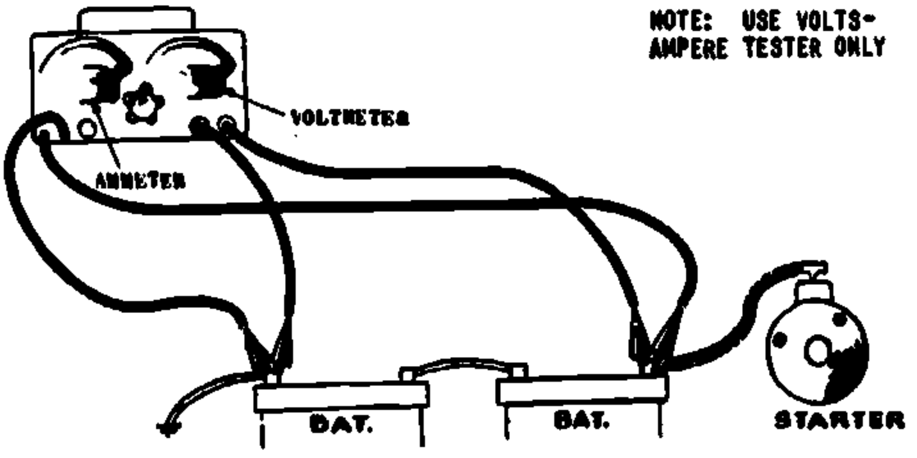


Fig 1-14. Starting motor amperage draw test.

(b) Charging system tests.

1. Test preparations. Inspect the entire charging system for loose or corroded connections. Check the generator drive belts for proper adjustment. If all connections are clean and tight and the belts are adjusted, install the adapters and controls of the adapter kit.

Step 1. With the engine stopped and all electrical loads switched off, disconnect the battery lead from the regulator and install adapter as shown (fig 1-15).

Step 2. Turn the load control knob to DIRECT and connect the 75-ampere ammeter leads as illustrated.

Step 3. Install the generator testing control on the generator.

Step 4. Turn the toggle switch on the generator testing control to FIELD CONTROL and turn the field control to OPEN.

Step 5. There are other leads of the volts-ampere tester that will require connecting, but these will be discussed under each test.

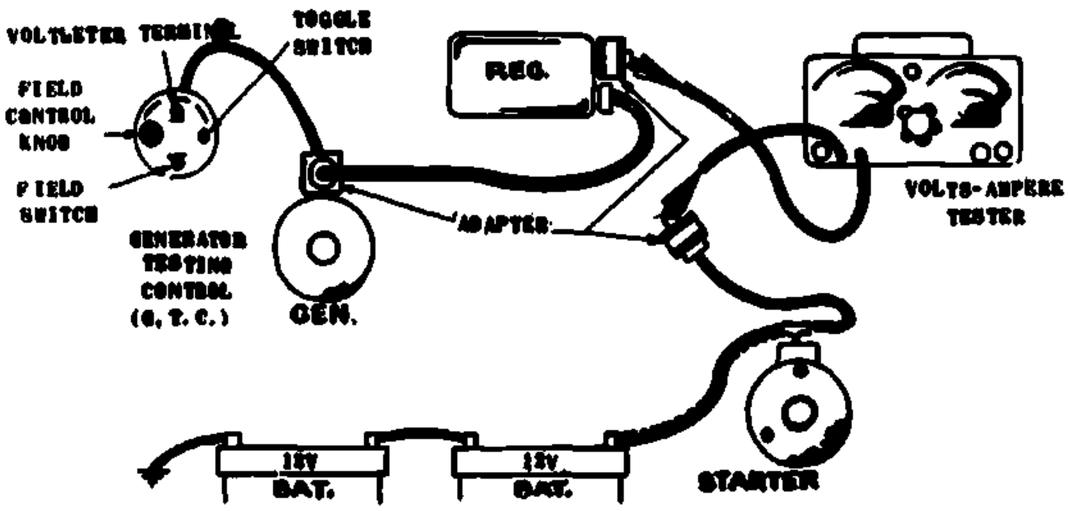


Fig 1-15. Charging circuit test connection preparations.

2. <u>Insulated circuit resistance test</u> (fig 1-16). Excessive resistance in the charging circuit will cause undercharging of the batteries and an abnormal load on the generator and generator regulator.

Step 1. With the load control knob on DIRECT, turn the voltmeter selector to 4 VOLTS and connect the voltmeter leads between the voltmeter terminal of the generator testing control and the battery as illustrated. (NOTE: The meter will read off-scale to the left.)

Step 2. Start the engine and run it at approximately 1,000 rpm.

Step 3. Turn the field control knob of the generator testing control to obtain a reading of 10 amperes on the volts-ampere tester. A voltmeter reading of 4 or more volts, when no reading can be obtained on the ammeter, indicates that the generator regulator cutout relay is not closing or that the charging circuit is open at another point. Check the system again for loose connections and broken conductors. Check position of tester controls. If no charging rate is obtained and the voltage will not rise above zero, the generator is probably defective.

Step 4. With the test ammeter reading exactly 10 amperes, the voltmeter should not exceed .5 volt. A reading above .5 volt indicates excessive resistance.

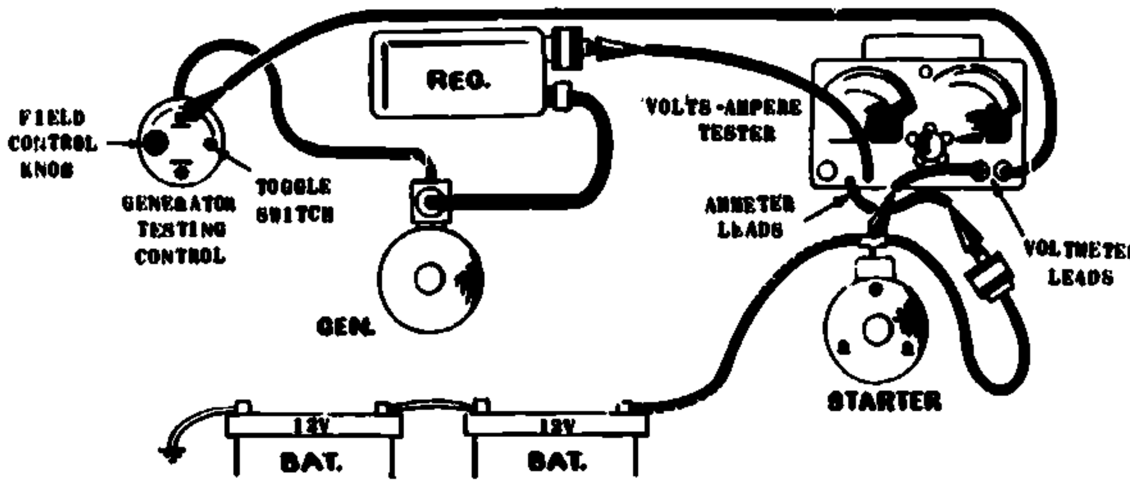


Fig 1-16. Insulated charging circuit resistance test.

3. <u>Locating circuit resistance</u> (fig 1-17). The procedures for locating charging circuit resistance are used only if the insulated circuit readings indicate there is excessive resistance. If the previous readings are within specified limits, there is no need to perform these tests.

Step 1. With the volts-ampere tester set the same as for the insulated circuit test, the charging rate te adjusted to exactly 10 amperes.

Step 2. Use the voltmeter leads connected as outlined below and illustrated in figure 1-17 to check the resistance in the various parts of the circuit.

Voltmeter test leads connected to	1 and 2	maximum reading	.3 volt
" " " " "	2 and 3	" "	.2
" " " " "	4 and 5	" "	.1
" " " " "	6 and 7	" "	.1

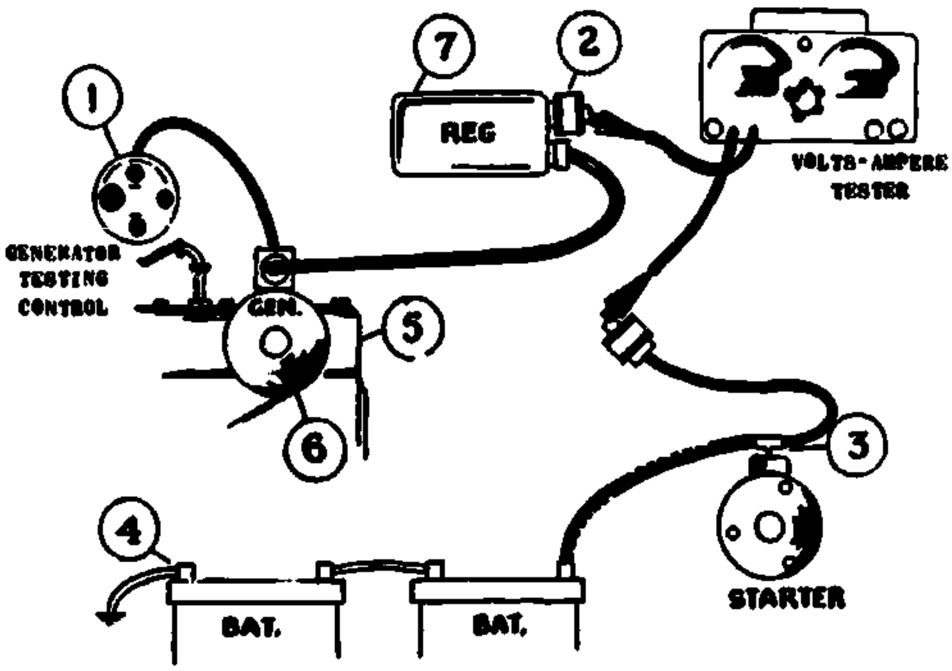


Fig 1-17. Locating charging system resistance.

4. Ground circuit resistance test (fig 1-18). The insulated circuit may show satisfactory test readings, but a restriction in the ground circuit will keep the system from operating properly. Direct current (d_c) must return to its source and the ground circuit te the path normally used for returning. The charging circuit and the regulator circuit can be tested by the following procedures.

Step 1. After completing the insulated circuit resistance test, keep the tester controls the same and the generator operating at exactly 10 amperes. Connect one voltmeter lead to a ground on the generator and the other lead to a good engine ground. The voltmeter reading should not exceed .1 volt.

Step 2. Continue the 10-ampere reading and move the voltmeter lead from the engine ground to the regulator base. The voltmeter reading should not exceed .1 volt.

Step 3. If higher readings are noted, locate the problem by connecting the voltmeter across each wire and connection. The highest reading on the voltmeter will be obtained when it is connected across the point of high resistance. The resistance may be due to a loose, corroded, or dirty connection.

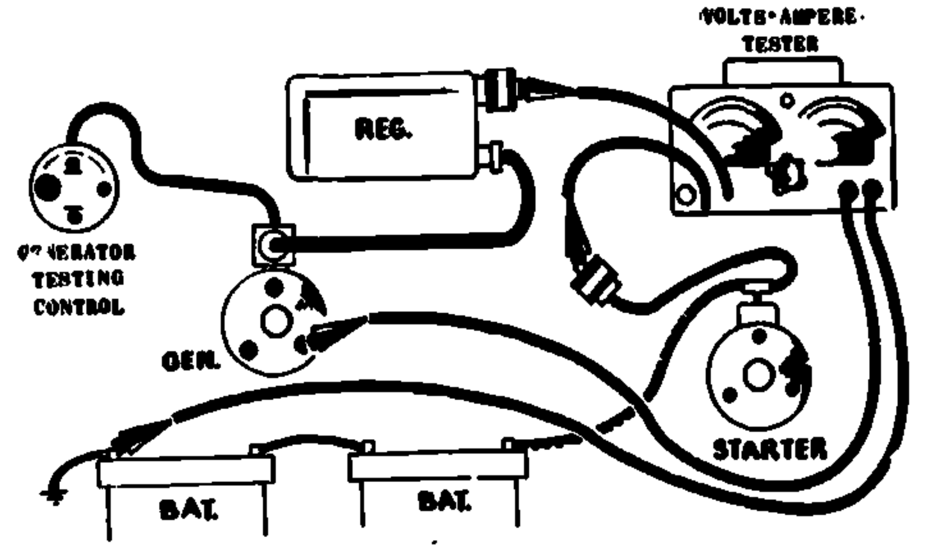


Fig 1-18. Ground circuit resistance test.

5. Output test (fig 1-19). This is a load test to check generator output and drive belt slippage. The generator is operated at its rated capacity and the engine rpm is observed. The rated output should be obtained at or below specified engine rpm. When making this test be careful not to exceed generator output as indicated on the data plate or in the TM.

Step 1. Connect the volts-ampere tester and the generator testing control as illustrated and set the control knob of the tester in DIRECT. Set the toggle switch of the generator testing control in FIELD CONTROL and the field control in the IN position.

Step 2. Set the engine rpm at the specified rpm (approx 1, 000) and slowly turn the field control toward the OUT position while watching the tester ammeter. The reading should rise evenly and steady. If the generator does not produce the rated output at the specified rpm, it should be removed.

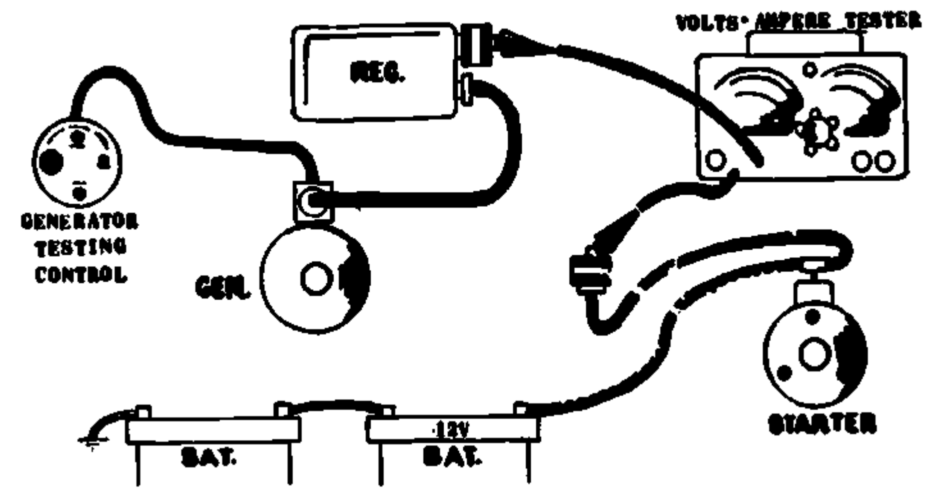


Fig 1-19. Generator output test connections.

6. Cutout relay test (fig 1-20). The cutout relay is a part of the regulator assembly which opens and closes the circuit between the generator and the battery. When the generator is producing enought current to overcome the battery voltage, the cutout relay closes and allows the current to flow to the battery. This relay will open the circuit when the generator is not producing enough current and prevent the flow of electricity from the battery to the generator. The component parts of the regulator are tested after the generator and charging circuits have been tested and are operating satisfactorily.

Step 1. Connect the volts-ampere tester and the generator testing control as illustrated. Set the volts-ampere tester load control knob on DIRECT and the voltmeter selector switch at 40 VOLTS. Set the generator testing control toggle switch in the FIELD CONTROL position and the field control in the OPEN position.

Step 2. Increase the engine speed to 1,000 rpm and slowly turn the field control out so that the voltmeter reading builds up a fraction at a time. Check the tester ammeter after each increase in voltage. The closing voltage of the cutout relay is the highest voltmeter reading that can be obtained before the ammeter pointer moves.

Step 3. After the closing voltage has been determined, turn the field control clockwise until the ammeter indicates approximately 10 amperes charge. Then slowly turn the field control to the IN position while watching the ammeter. The opening amperage of the cutout relay will be the greatest discharge reading obtained before the pointer drops to zero.

Step 4. The cutout relay is closed by current flowing through the winding, and opened by spring tension. The satisfactory closing range of the cutout relay is 25 to 27 volts for a 24-volt charging system. Only in emergencies will organizational maintenance personnel attempt to repair or adjust the cutout relay.

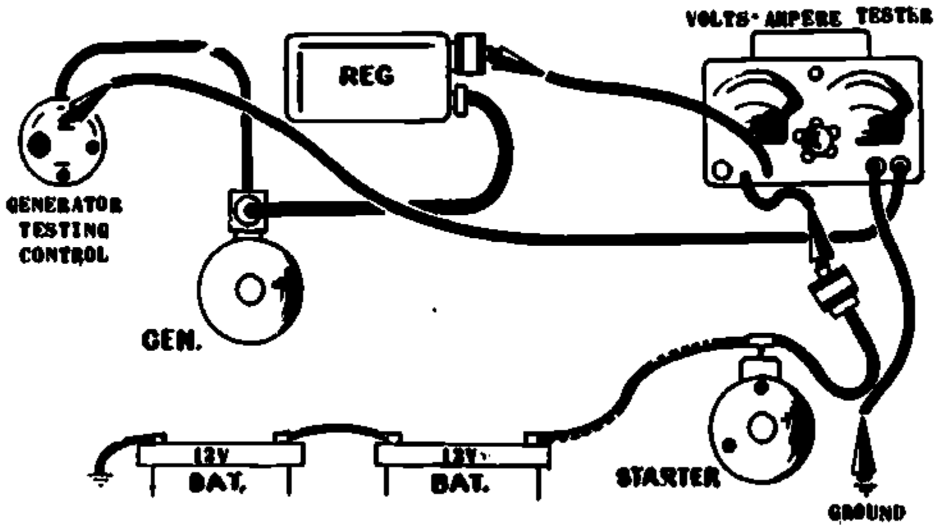


Fig 1-20. Cutout relay test.

7. Voltage regulator test (fig 1-21). The voltage regulator limits the voltage of the charging system and protects the lights and accessories from high voltage.

Step 1. After completing the cutout relay test, turn the generator testing control toggle switch to REGULATED and the field control to OPEN. Turn the control knob of the volts-ampere tester to FIXED LOAD and the selecter switch to 24 VOLTS.

Step 2. Remove the ammeter test lead from the regulator to battery wire and connect the voltmeter test leads to the regulator battery terminal and to ground.

Step 3. Increase the engine speed to 2,000 rpm. Switch the generator testing control toggle switch to FIELD CONTROL and then back to REGULATED to cycle the regulator. The reading on the voltmeter now indicates the setting of the voltage regulator.

Step 4. If the reading obtained is unsatisfactory, replace the regulator assembly.

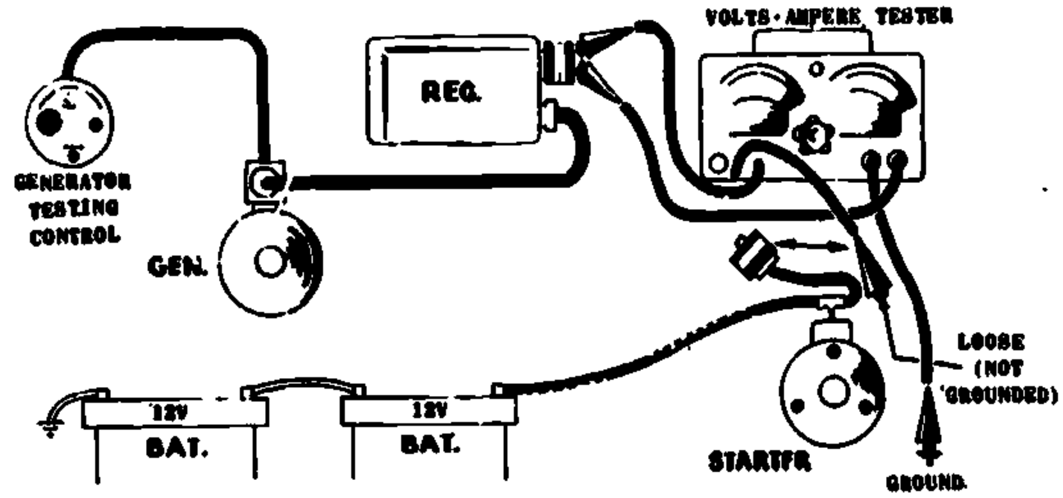


Fig 1-21. Voltage regulator test.

8. Current regulator test (fig 1-22). Current flow creates heat; for example, current flowing through the conductor in a light bulb causes it to become white-hot and produce light. It is possible for the generator to build up sufficient current to melt the metal in it, therefore the current must be controlled to prevent damage. The current regulator prevents the generator from exceeding its safe output when the battery is in low state of charge or when the electrical load exceeds the maximum safe output.

Step 1. After completing the voltage regulator test, lock the local control knob of the volts-ampere tester in the FIXED LOAD position and turn the fixed-load switch to 24 VOLTS. Place the generator testing control toggle switch in the REGULATED position.

Step 2. Connect one ammeter and one voltmeter test lead to a good ground and one ammeter and one voltmeter test lead to the regulator battery terminal. Set the engine speed at approximately 2,000 rpm.

Step 3. Turn the load control knob of the volts-ampere tester to VARIABLE and adjust until the voltmeter reads 25 volts. The ammeter reading now indicates the setting of the current regulator. Check appropriate TM for manufacturer's specifications.

Step 4. If unsatisfactory readings are obtained, replace the regulator assembly.

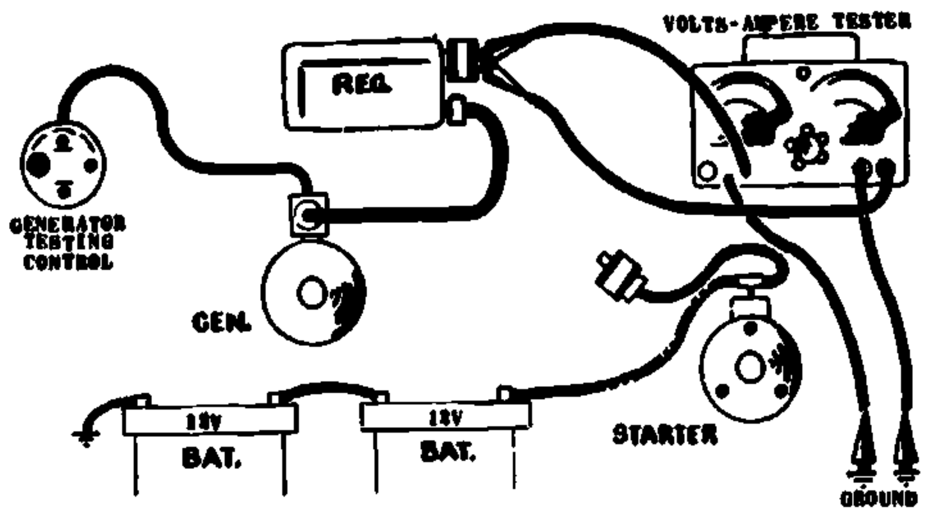


Fig 1-22. Current regulator test.

9. Ignition primary circuit resistance test (fig 1-23). Hard starting and misfiring can be caused by excessive resistance in the ignition primary circuit. Remember that resistance is affected by the type of material used, the size of the conductors, corrosion, and dirty or loose connections. Although there can be other causes of hard starting and misfiring, testing the resistance of the circuit during scheduled maintenance is a worthwhile time investment.

Step 1. Turn the volts-ampere tester voltmeter selector to 4 VOLTS.

Step 2. Connect the adapters, if needed, and the voltmeter test leads between the battery and the battery side of the ignition coil. Place the clips in such a manner that they will not touch ground and short-circuit the primary circuit.

Step 3. Turn the ignition on, crank the engine slowly until the points close. Note the voltmeter reading. The highest reading will be obtained when the points are fully closed. The reading should not exceed .2 volt.

Step 4. A high reading indicates excessive resistance. The circuit should be checked across each conductor and connection to locate the highest voltmeter reading and the location of the resistance.

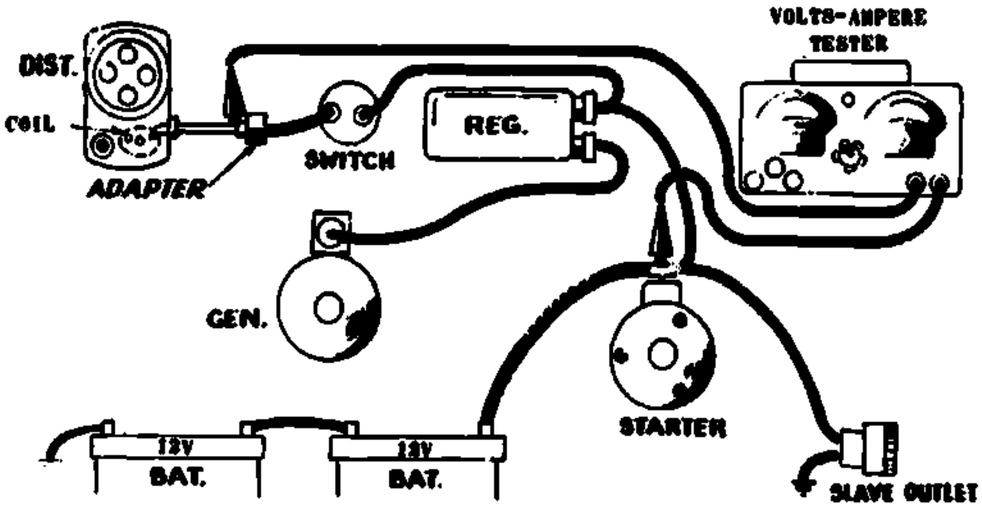


Fig 1-23. Primary circuit resistance test connections.

(4) Dwell-tach tester (fig 1-24). The dwell-tach tester is used to measure the dwell angle and the rpm of an engine that has a spark ignition. One lead (normally red) is connected to the primary ignition circuit at the closest place to the contact points and the other lead is connected to ground. Some testers have only one meter for reading both dwell angle and rpm. Other testers, such as the Sun Dwell-Tach (fig 1-24), have a meter for reading dwell angle and a meter for reading rpm. The testers that use batteries have a control for calibrating the tester before each use. If the tester cannot be calibrated, the batteries should be replaced. Testers without an internal power source are usually calibrated by turning a screw at the pivot point of the pointer needle. The adapter kit is used with the testers on magnetos and distributors with shielded systems.

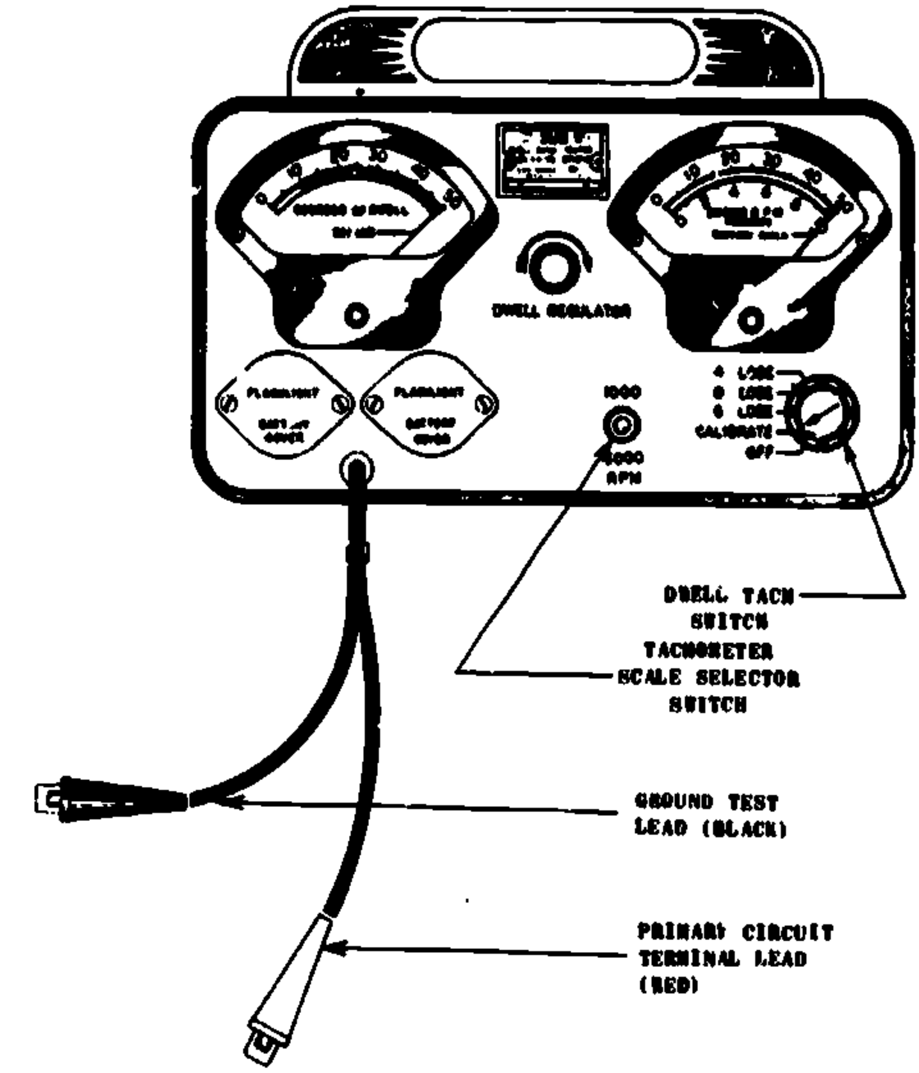


Fig 1-24. Dwell-tach tester (Sun).

(a) Distributor circuit resistance test (fig 1-25). Testers with an internal power source can be used to test the resistance of the primary circuit in the distributor. Resistance of the circuit is made prior to taking a dwell angle reading because excessive resistance will give an incorrect reading. NOTE: Resistance of a magneto ignition system cannot be checked with the dwell-tach tester.

Step 1. Calibrate the dwell-tach tester by turning the dwell-tach switch to CALIBRATE and the dwell regulator so that the pointer rests on the set line of the dwell angle scale. Then connect the red test lead to the primary circuit of the distributor terminal and the black lead to a good ground.

Step 2. With the ignition switch in the ON position, turn the engine slowly until the points close. When the points are fully closed, the highest reading on the dwell angle scale will be indicated. This reading should be inside the bar on the right end of the scale; a reading outside the bar indicates high resistance in the distributor ground circuit.

Step 3. If the reading indicates that there is high resistance in the circuit, check the points, distributor plate, and distributor housing. Remember that the size of any conductor used will also affect the resistance.

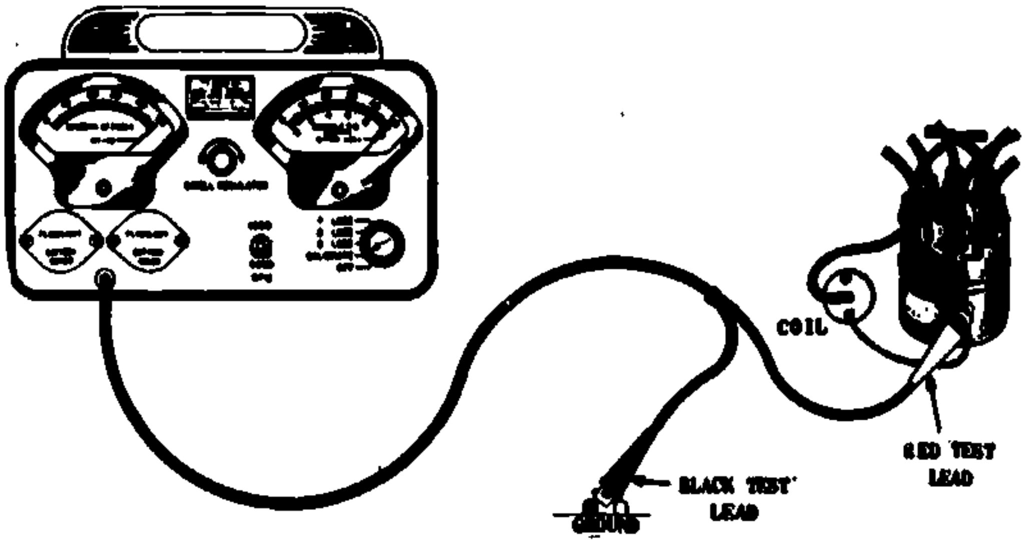


Fig 1-25. Distributor circuit resistance test.

(b) Engine idle rpm test (fig 1-25). The engine rpm should be checked to insure that it is within manufacturer's specifications. High and low idle rpm can be tested with the dwell-tach tester when making governor and carburetor adjustments.

Step 1. Calibrate the dwell-tach tester and turn the dwell-tack switch to the proper cam lobe position. The number of cam lobes usually is the same as the number of cylinders, however some magneto ignition systems can have less than the number of cylinders. When the number of cylinders and the number of lobes are different, check the manufacturer's recommendations for testing engine rpm. Set the tachometer scale selector switch to 5000 RPM.

Step 2. Connect the black tester lead to a good ground and the red tester lead to the primary circuit of the ignition system.

Step 3. Crank the engine and note the reading on the tachometer scale for engine rpm. If the rpm is less than 1,000, set tachometer scale selector to 1,000 rpm position. Adjust the components necessary to change engine rpm to specifications.

(c) Contact point dwell test. Figure 1-26 illustrates some of the fallacies of using a feeler gage to adjust contact points. Measuring the dwell angle (fig 1-27) is the most accurate method of adjusting the contact points in a spark ignition system. Degrees of dwell, dwell angle, and cam angle are terms used to refer to the number of degrees that a distributor cam will turn while the points are closed. Dwell angle will affect ignition timing and coil output. If the points stay closed too long, ignition will be late; if the points open too soon, the coil will not produce the spark required. When making the dwell angle test, the engine rpm should be varied from idle to 2,000 or maximum governed rpm and the variation of the dwell noted.

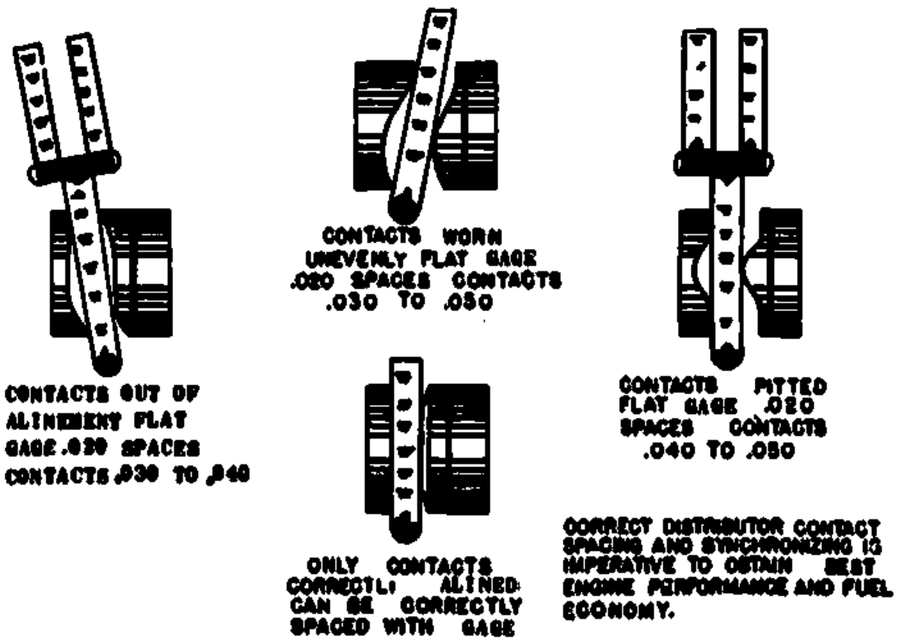


Fig 1-26. Setting contact points with a feeler gage.

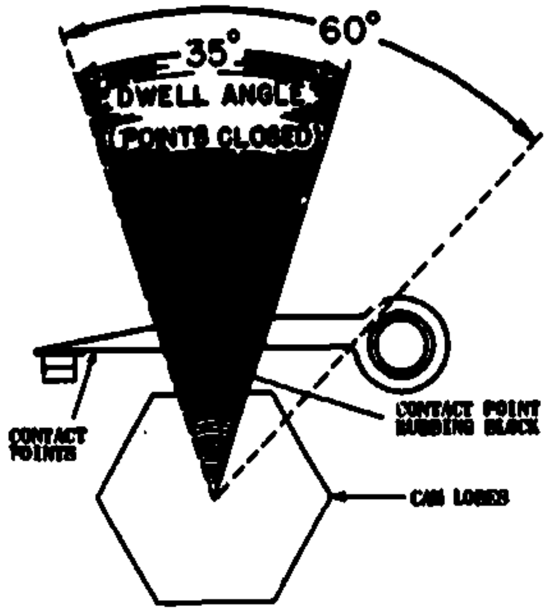


Fig 1-27. Dwell angle.

Step 1. Calibrate the tester and turn the selector switch to the correct lobe position. Connect the test leads (fig 1-28) and start the engine.

Step 2. Adjust the contact points to obtain the specified dwell angle. To obtain the dwell angle while making the adjustment, remove distributor cap and rotor. Turn on ignition switch. Adjust points to correct dwell angle while engine is turned by starting motor.

Step 3. Variations in the dwell angle reading can be caused by high resistance, mechanical wear, and loose connections.

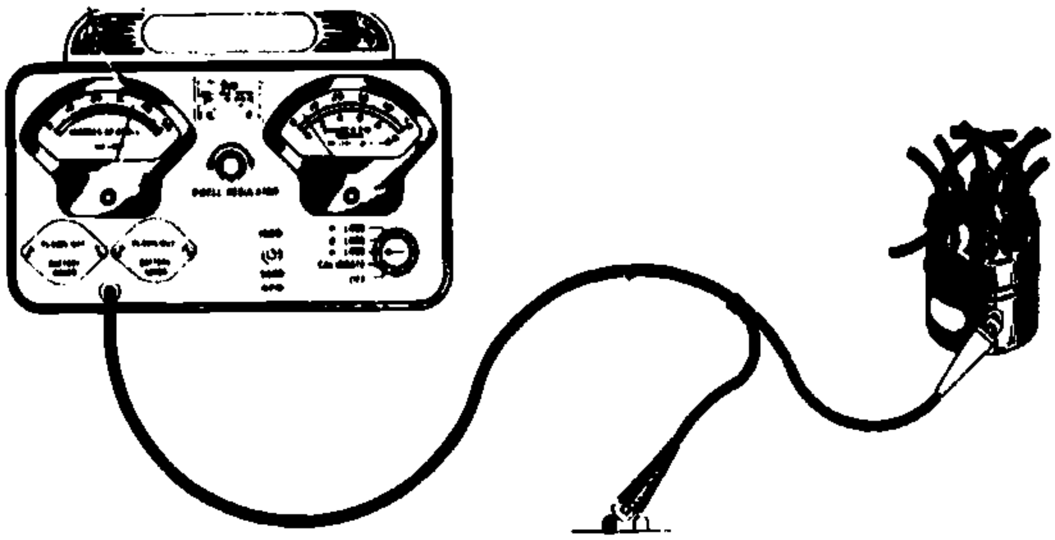


Fig 1-28. Connections for testing dwell angle.

(5) Timing light. Ignition of the fuel-air mixture must occur at the proper time for the engine to operate properly. A timing light is used to check and adjust the timing of the ignition in a spark ignition system. The timing light is connected to the No. 1 spark plug high-tension lead and to the spark plug. Locate the timing mark (usually on the crankshaft pulley or the flywheel). With the engine running, the light should come on when the timing mark is in the correct position. If the power-type timing light is used, connect the high-tension lead to No. 1 spark plug (leave distributor-to-plug high-tension lead connected) and connect the low-voltage leads to the battery. Crank the engine and check the timing.

Note: It is advisable to ground the secondary wire of the ignition coil to prevent high tension current from traveling over spark plug wires, etc. during adjustments.

UNITED STATES MARINE CORPS
MARINE CORPS INSTITUTE, MARINE BARRACKS
BOX 1775
WASHINGTON, D.C. 20013

ENGINEER EQUIPMENT MECHANIC

Lesson 1

Test Equipment

STUDY ASSIGNMENT: MCI 13.41c, Engineer Equipment Mechanic, chap 1.

LESSON OBJECTIVE: Successful completion of this lesson, combined with on-the-job training using the principles presented, will enable you to diagnose fuel and electrical problems using the test equipment available in the Marine Corps.

WRITTEN ASSIGNMENT:

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

Value: 1 point each

1. What device is used to measure the engine rpm?

   a. Torque wrench
   b. Tachometer
   c. Compression gage
   d. Speedometer

2. When a compression test is made, what problem will NOT be indicated by a low-compression reading?

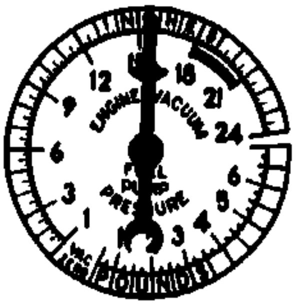
   a. Bad valves or valve adjustment
   b. Worn rings
   c. Cracked head or bad head gasket
   d. Cracked intake manifold

Note: Items 3-6 are illustrations of four different readings of the vacuum gage and fuel pump pressure tester. You are to identify the condition indicated (a-e) by the respective gage readings.

   a. Loss of power on one or more cylinders causes steady pulsation.
   b. Improper carburetor adjustment causes slow oscillation.
   c. Loss of power affecting all cylinders
   d. Normal vacuum reading
   e. Loss of power due to restricted exhaust system

3.

4.



5.

6.

7. Unit injectors and nozzles are tested with a

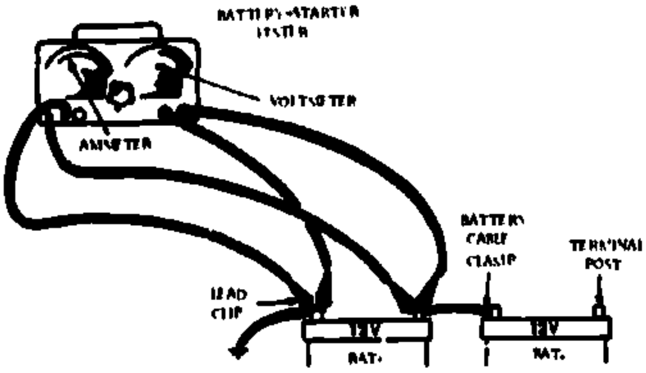
   a. fuel pump pressure test set.
   b. diesel engine compression test set.
   c. diesel fuel system test set.
   d. compression gage.

8. A visual inspection of the battery and preliminary tests fail to locate the electrical problems. Which test would be taken prior to the capacity test?

   a. Generator voltage test
   b. Specific gravity test
   c. Voltage regulator voltage test
   d. Voltage regulator amperage test

9. The diagram shows the hookup for a _______ test.

   a. ground circuit
   b. link cable
   c. cable
   d. capacity



10. When making a cable test, excessive resistance is indicated when the reading exceeds ________ volt.

   a. .1
   b. .2
   c. .3
   d. .4

11. When conducting a cranking motor ground circuit test, a high voltage reading may be caused by

   a. excess resistance.
   b. poor connection.
   c. low resistance.
   d. voltage loss.

12. Which test(s) can be made with the volts-ampere tester?

   a. Battery capacity
   b. Starter ground circuit and cable resistance
   c. Cam angle and engine rpm
   d. Charging circuit resistance and starter motor amparage draw

13. When using the volts-ampere tester on the charging circuit, what is indicated by a reading of 4 or more volts on the voltmeter when no reading can be obtained on the ammeter?

   a. Open circuit in charging system
   b. Closed circuit in charging system
   c. Grounded circuit in charging system
   d. Battery capacity is low.

14. When conducting a charging system ground circuit resistance test, a voltmeter reading in excess of .1 volt would indicate

   a. excessive resistance.
   b. insufficient resistance.
   c. increased engine load.
   d. increased starting motor spin.

15. When conducting a cutout relay test, the closing voltage of the cutout relay is the highest voltmeter reading obtained

    a. before the pointer drops back to zero.
    b. after the pointer drops back to zero.
    c. after the ammeter pointer moves.
    d. before the ammeter pointer moves.

16. Excessive resistance in the ignition primary circuits maybe indicated by

    a. slow oscillation.
    b. steady pulsation.
    c. hard starting and misfiring.
    d. slow cranking speed.

17. What device is used to check the timing of the ignition in a spark ignition system?

    a. Dwell-tach tester
    b. Vacuum gage
    c. Timing light
    d. Low voltage circuit tester

18. What device is used to measure dwell angle and the rpm of a spark ignition engine?

    a. Low voltage circuit tester
    b. Dwell-tach tester
    c. Vacuum gage
    d. Tachometer

Total Points: 18

* * *

Chapter 2

ENGINE DIAGNOSIS AND REPAIR

The objective of this chapter is to enable the student to identify the procedures necessary to diagnose and correct malfunctions of some of the common models of:

1. gasoline engines,
2. diesel engines,
3. engine cooling systems.

The malfunctions will not be listed in the order of most frequent occurrences. These troubleshooting charts and tips are to be used as a training aid only. For more specific information on specific items of equipment, check the TM for that specific item of equipment.

2-1. INTRODUCTION

As an engineer equipment mechanic, you are required to maintain, diagnose malfunctions of, and repair gasoline and diesel engines. Some items of equipment such as bridging boat, pumps, chain saws, and small generators are powered by gasoline engines. Most of the larger items of engineer equipment such as crawler-tractors, crane-shovels, and large generators are powered by diesel engines. Both gasoline and diesel engines come in various sizes, models, and makes, but use either the 2- or 4-stroke-cycle principle of operation. They are produced by many manufacturers; however, the most common diesel engine being used by the Marine Corps is produced by Detroit Diesel, a division of General Motors Corporation. These diesel engines operate on the 2-stroke-cycle principle and are the 71 series. Units authorized to perform maintenance are provided with the necessary tools and equipment required to maintain, troubleshoot and repair engines within the echelon authorized. Experienced personnel are the other requirement. Diagnosing is the art or act of recognizing a problem from the symptoms, and a troubleshooter is one who can locate the causes of a problem from these symptoms. You can readily see that you will need experience, knowledge, and the proper equipment to perform this requirement.

2-2. GASOLINE ENGINES

a. Introduction. The gasoline engines used by the Marine Corps can be either 2- or 4-stroke-cycle; single- or multiple-cylinder; battery or magneto spark ignition; in-line, V, or other-type cylinder arrangement. There are very few gasoline engines used with more than four cylinders. The nomenclature of engine parts and components can be learned from books, but the theory, principles, and functions are learned by reading, observing, and doing; both knowledge and experience will be needed to diagnose and repair gasoline engines. If you know the theory, principles, and functions, you will be able to follow the sequence of events to locate engine problems. You can trace each action and locate and eliminate a malfunction because you know which part or component must function at the proper time in relation to other parts or components.

b. Diagnosing malfunctions. Once an engine develops trouble, you are responsible for locating the cause of the malfunction and restoring the engine to the original performance standards. The operator can tell you how it acts, but you must rely upon your knowledge, experience, tools and equipment to locate the problem and correct it. You must listen to the engine and the explanation by the operator and then determine which part, component, or system is causing the problem. An engine malfunction can be caused by one defective part or a combination of defective parts or systems. Consider and check all possibilites when diagnosing engine malfunctions. For example, there is no need to change all the spark plugs on an engine with a misfiring cylinder if all it needs is a replacement for a defective spark plug high-tension lead. However, do not overlook the possibility that both the high-tension lead and the spark plug may be defective. The following paragraphs will discuss some of the malfunctions of gasoline engines and the methods used to locate them.

(1) Engine fails to turn.

(a) The first and easiest part of diagnosing is to determine how the engine is cranked: battery starter or hand-cranked with pull rope or crank. Visually check for any obvious defects. After checking and eliminating each problem, try cranking.

(b) If engine is hand-cranked, check for a dragging or defective component.

1. Check the pull-rope assembly (if enclosed) to be sure it is operating properly.

2. Check the attachments that are required to turn with the engine. Disengage the engine clutch or remove the belts used to drive attachments.

3. Try rotating the engine opposite the normal cranking direction. This can indicate internal damages. Then, listen for unusual noises when turned in the normal cranking direction. Some causes of internal seizure are water in the cylinder, overheated parts, or damaged or broken parts.

(c) If the engine is battery-cranked, after checking the following items, make the checks listed above for hand-cranked engines.

1. Battery cablo connections. Be sure they are clean and tight.

2. Starting circuit. Be sure the conductors are of the proper size, not broken, nor frayed and shorted, and are clean and tight.

3. Battery condition. Be sure the battery has sufficient charge to crank the engine. Check the specific gravity of the electrolyte to determine the state of charge.

4. Defective cranking motor. You will need test equipment to check the cranking motor. The electrical parts can be defective or the drive parts can cause it to be inoperative. A loose starter can cause malfunction, but this should have been noted during the visual check and the electrical starting circuit check. Other cranking motor problems will be discussed later in the course.

(2) Engine turns, but fails to start. Make the following checks after performing the before-operation service.

(a) Incorrect cranking speed. This should be the first check made since it is the easiest one. There are several possible causes for slow cranking speeds and there could be a combination of causes.

1. Engine oil. For engines with an oil reservoir (oil in the crankcase), the oil viscosity may be too heavy for the temperature. The 2-stroke-cycle gasoline engines normally have the engine oil mixed with fuel and would not be affected by viscosity.

2. Starting circuit. Hand-cranked engines may have some part of the engine or attachment binding or causing a drag. This can also be true for engines with an electric starter; the battery, cable, and starting motor conditions are checked first unless visual inspection showed signs of dragging components or attachments.

3. Internal damage. Overheating and scored or damaged internal parts will also cause the engine to crank slow and hard. This will normally disappear after cooling, except in extreme cases, but may cause unusual noises thereafter. Sudden overloads or backfire can bend parts or cause other damages which will cause slow cranking speeds.

(b) Correct cranking speed. If the engine cranks at normal cranking speed, but fails to start, it probably has one or more defective systems or components. An engine will usually start if it has gas and air, the air-fuel mixture is compressed, and a spark is provided at the proper time. However, it is possible to have too much gasoline for the amount of air and a spark that is too weak to ignite the normal air-fuel mixture.

1. System checks. Before making any detailed checks, you can usually eliminate some probable causes for failure by checking the following.

a. Fuel supply. Be sure the engine has an adequate supply of fuel. Some fuel tanks are constructed to prevent draining the tank completely; they will show some fuel, but not an adequate supply. If the engine is equipped with a fuel strainer, check to be sure that the fuel is not restricted nor contaminated with water or other foreign matter. Remove the air cleaner and see if fuel is being drawn through the carburetor venturi. Excessive amounts of gasoline indicate that the mixture is too rich.

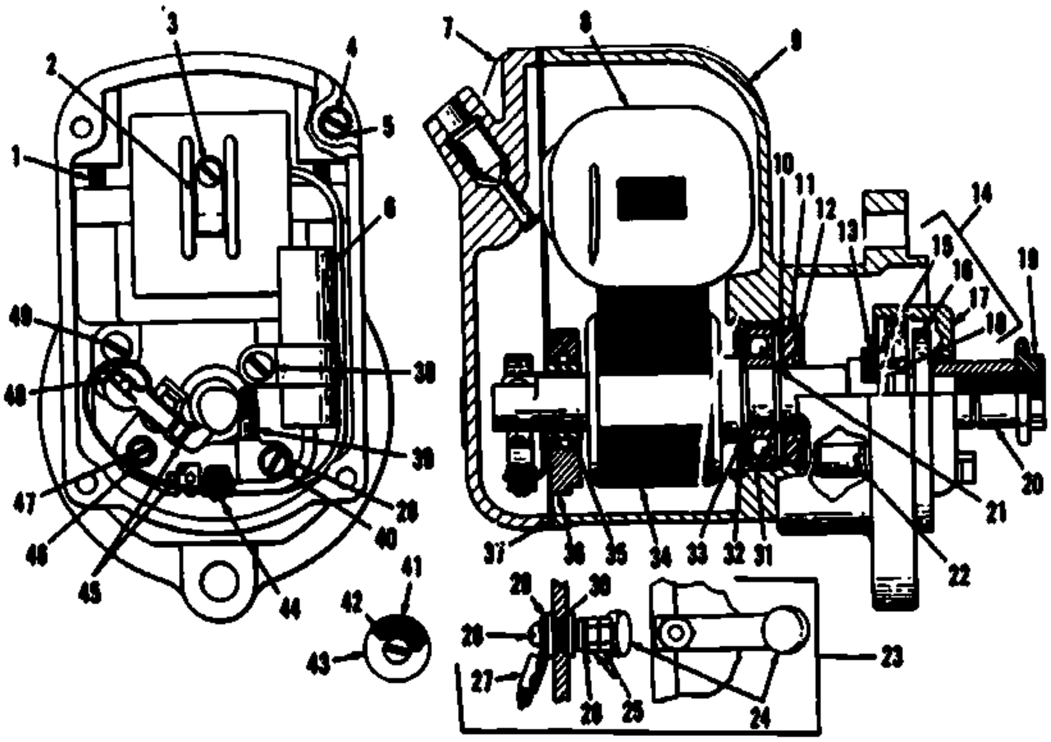
b. Ignition. Make a quick check of the ignition by removing one spark plug high-tension lead from a spark plug and while cranking the engine hold it about 1/8 in. away from the base of the spark plug or any other good ground. The ignition system should produce a blue spark about the diameter of a small pencil lead. If there is a good spark, remove the spark plug and see if it will jump the spark plug gap while holding the base of the spark plug against the engine for a good ground. When making these tests, use insulated pliers or another type of insulation to prevent electrical shock.

2. Components check. If a rapid check of the systems fails to locate the problem, a detailed check of the components and parts is required.

a. Carburetor. Check the operation of the choke and throttle butterfly. Both should operate freely without looseness. With the shutoff valve turned on, observe the carburetor to be sure the float circuit does not allow too much gasoline in the chamber. A gravity feed system will allow the gasoline to run through the carburetor without engine cranking if the float does not stop the flow. The float circuit may also restrict the flow and prevent sufficient gas from entering. Check the screws used to adjust the mixture and make an initial adjustment if necessary. Check for leaks between the carburetor and the cylinder. On the 2-stroke cycle, a leak will prevent the mixture being pressurized and forced into the cylinder, and on the 4-stroke cycle, a leak will allow additional air to enter and change the ratio of the air-fuel mixture.

b. Battery-distributor ignition. The first check should be for moisture in the distributor, distributor cap, or anywhere on the high-tension side of the system which could cause the system to fail. Check the condition and adjustment of the contact points. If necessary, test the coil and condenser. If all parts are good and properly installed and adjusted, start at the battery and trace the flow of electricity through the ignition circuit. Make a test at each junction so that a shorted or broken conductor will not be overlooked. Don't forget to test the ground circuit from the points back to the battery.

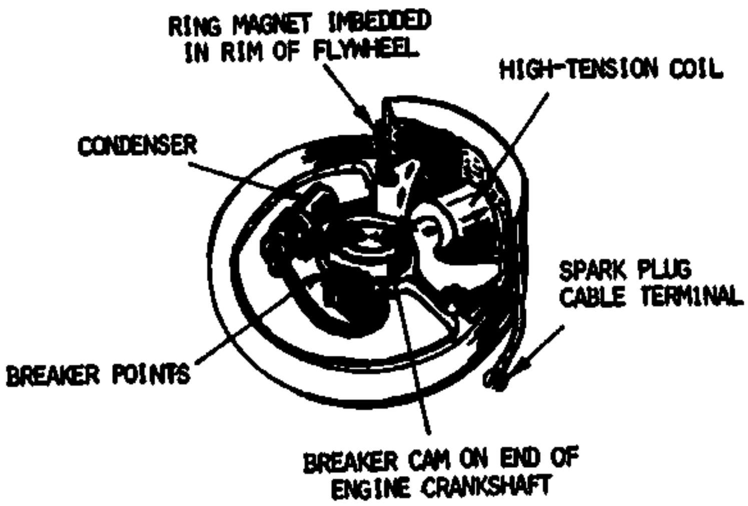
c. Magneto. There are two types of magnetos used on gasoline engines. Some are self-contained and connected to the engine (fig 2-1A) while others are constructed to use a special flywheel as a part of the magneto (fig 2-1B). The self-contained unit has an impulse coupling to increase the speed of the magneto while cranking or operating the engine at low idle speeds. Operation of the impulse can be heard when cranking the engine or when idling very slowly; it makes a snap or tapping sound. If the impulse is not working properly, the magneto will not deliver the spark necessary to ignite the mixture. The flywheel type depends on cranking speed to generate the low voltage to initiate ignition. Moisture will affect the magnetos in the same manner as the battery-distributor ignition. Also check the condition and adjustment of the contact points. Test the coil and condenser and check the strength of the magnet. Some of the self-contained magnetos have a gear-driven rotor and the internal parts of the magneto require timing as well as timing the magneto to the engine. For those magnetos behind the flywheel, the high-tension lead is soldered to the coil. This particular magneto is properly timed when the correct flywheel is properly installed and the point setting is correct. An exception to this is the military standard gasoline engine.



1 Screw	11 Seal	21 Clip	31 Bearing	41 Screen
2 Bracket	12 Washer	22 Pin	32 Ring	42 Screw
3 Screw	13 Spring	23 Switch	33 Shim	43 Cover
4 Screw	14 Coupling assy	24 Lever	34 Rotor	44 Screw
5 Washer	15 Hub assy	25 Nut	35 Bearing	45 Contact set
6 Capacitor	16 Spring	26 Washer	36 Support	46 Washer
7 Cap	17 Shell	27 Lead	37 Gasket	47 Screw
8 Coil	18 Key	28 Screw	38 Screw	48 Clip
9 Housing	19 Nut	29 Washer	39 Wick	49 Screw
10 Washer	20 Bushing	30 Bushing	40 Screw	

A

Section view of self-contained Fairbanks Morse magneto.



B

Section view of flywheel-type magneto.

Fig 2-1. Section view of magnetos.

d. Spark plugs. If visual inspection of the igniton system indicates that it is functioning properly, if there was a spark at the spark plug high-tension lead, and if there is gasoline in the carburetor, removal of the spark plugs should be the next step in diagnosis and troubleshooting. Clean, gap, and test the spark plugs and take a compression reading while the plugs are removed. Visual inspection of the spark plugs will also give some indication of the condition of the internal parts. Spark plugs which are loaded with dark oily carbon indicate that the engine is using oil or that the 2-stroke cycle fuel-oil mixture contains too much or the wrong type of oil. Overheated spark plugs usually have blisters or scale formations around the insulator, and the electrodes are badly burned.

e. Internal engine parts. The compression test will indicate the general condition of the valves and piston rings. Low compression that shows a rise after adding oil indicates defective rings. Low compression on two adjacent cylinders indicates a defective head gasket. If there is no change in the low readings after adding oil, defective valves are indicated. However, you should remember that the 2-stroke-cycle engines may or may not have valves; also that an engine can have compression that is satisfactory for cranking and still be unsatisfactory for power or economy of operation. Higher than normal compression readings indicate carbon deposits.

(3) High oil consumption. By the time an operator becomes concerned about high oil consumption, there are many other problems with the engine. But when an item is in for some component or attachment repair you should check it for possible high oil consumption. Like other mechanical problems, high oil consumption can be caused by many things or a combination of things. Some of the more common causes are discussed below.

(a) Leaks. One of the easiest causes of high oil consumption to locate is external leaks. Visually check all gaskets and seals. Dust and dirt will normally collect at these points, but if it is very wet after use, further investigation is required. Check all around valve cover and oil pan. Check the places where shafts extend from the engine. Check the oil-pressure gage, lines, filters, and breathers. Do not confuse oil that is dripping from the clutch compartment with transmission oil. This oil must be checked by feel and by smell to determine if it is coming from the rear engine oil seal or the front transmission seal. In some cases the clutch cover may require removal before a decision can be made, When there is doubt as to the source of the oil leak, clean the area thoroughly and run the engine long enough to start the oil leaking again.

(b) Crankcase ventilators. Some engine crankcases are ventilated through the carburetor. It is possible for oil to be drawn into the combustion chamber with the air from the crankcase and burned. The system can be checked by removing the line between the crankcase and the intake manifold or the carburetor, and checking for oil.

(c) Internal defects. The compression check discussed earlier can detect some of the high oil consumption causes, but not all of them. A quick check of the exhaust will help determine if the oil is being burned with the gas, leaking from the gaskets, or being blown by the exhaust valve guides. A dark sooty exhaust indicates that the engine oil consumption is from internal causes. If the soot is shiny and wet looking the oil is probably being blown by the exhaust valve guides without passing through the combustion chamber. Excessive oil use from internal sources may be oil passing worn or sticking rings, worn cylinder bores, worn valves or valve guides, or a defective head gasket. Oil can show in the liquid cooling system, which indicates a defective head gasket.

(4) Overheating.

(a) Air-cooled engines. Most overheating problems encountered with air-cooled engines are caused by restricted air passages and overloading. Dirt, leaves, and other debris lodge between the cooling fins and the shroud, and block the cooling air. This will also cause hot spots if only a part of the system is restricted. Other causes for overheating are low oil level, low idling for long periods, and high speeds or overloading. Incorrect carburetor adjustment, retarded ignition, and excessive carbon deposits within the combustion chamber will also cause overheating.

(b) Liquid-cooled. An insufficient amount of coolant in the system is the primary cause for overheating. Chemicals added to the water, rust from the engine parts, and debris added to the cooling system will build up and restrict the normal flow of the coolant through the system. Dirt, leaves, and other debris close or restrict the air passages through the radiator core and prevent proper cooling. Before making further checks, be sure there is a sufficient quantity of the proper oil in the engine. Deteriorated radiator hose, especially on the suction side, will sometimes collapse and restrict the flow of the coolant. Some liquid cooling systems are pressurized to increase the boiling point temperature. A leak that prevents a buildup of pressure will cause overheating. Incorrect fuel, improper carburetor adjustment, and exhaust restrictions will also cause overheating.

(5) Unusual noise. Noises are the hardest of all engine problems to diagnose because there are so many different parts inside and outside the engine that are possible causes. Although noise is the hardest to diagnose, it will sometimes accompany some other symptom. For example, an engine that is pinging will often have a loss of power, slightly higher temperature, and sometimes be hard to start. A compression check will probably indicate carbon buildup, or a check of the ignition timing will show that it is advanced. To determine the cause first determine what type of noise the engine is making: knocking, rattling, clicking, pinging, etc. Then locate the place where the noise can be heard the loudest. A stethoscope is the best instrument for locating the sounds, but a welding rod or a piece of wood will serve the purpose. Place your thumb tightly over the end of the rod or wood and then put your thumb in your ear and move the opposite end of the stick or rod about the engine to locate where the sounds seem the loudest. After the sound has been pinpointed, you can determine which part is causing the problem.

(a) Knocking. Most engine knocking is caused by worn internal parts. A dull thud or knock when the engine is loaded indicates loose main bearings. A metallic knock that is loudest when the engine is idling at about 2,000 rpm indicates loose rod bearings. Piston pin knock and rod knock are difficult to tell apart, but the piston pin produces a double knock which is usually heard when the engine is idling. In addition to loose-fitting parts, low or improper viscosity oil will sometimes cause a knock. Since oil film reduces friction between the metal parts and acts as a cushion to prevent knocking, if the oil film is too thin or insufficient, the two parts hit and produce the noise. A main bearing knock will be heard loudest near the crankshaft along the crankcase where the main bearing is located. Connecting rod noise will probably be heard loudest in the lower part of the crankcase; piston pin knock along the upper part near the particular cylinder. When you short out the spark plug for that cylinder, the main and connecting rod bearing knock will be reduced or disappear; but it will cause a piston pin to knock more severely. Some of the small engines use ball and roller bearings which may also produce a grinding noise. Bent parts can also cause knocking noises. Loose main or rod bearings are also associated with low oil pressure, but some parts that are not pressure-lubricated may be loose. In such a case, the engine would knock but have a good oil pressure. Other knocking noises can be caused by the gear train, flywheel, crankshaft pulley, camshaft, fuel pump, and water pump.

(b) Clicking. A rapid clicking noise that is continuous, but more pronounced when accelerated under load is probably caused by excessive valve lash. Clicking under load when accelerated is normal for most engines, but the noise should disappear as the engine gains speed and during normal idle. If the noise does not disappear, check the valve lash and the engine timing. Carbon deposits in a cylinder will also cause a preignition ping.

(c) Miscellaneous noises. A squeaking noise is often heard when an engine is accelerated rapidly. A loose or worn fan belt will slip and cause squeaking. If the belt is still serviceable, check the adjustment; if proper adjustment does not stop the squeak, rub the belt lightly in two or three places with a bar of soap. Dry or defective water pump bearings will cause a squeaking noise. Some pumps have lube fittings so that grease can be added; others have plugs or no way to lubricate and require replacement. Squeaking or grinding noises can also be caused by the timing gears or at any place where two metals rub together. Most squeaking or grinding noises are caused by lack of lubricant, maladjustment, or defective parts.

(6) Low oil pressure. The most frequent cause for low oil pressure is lack of oil or improper viscosity oil for the temperature. However, the proper grade of oil can become diluted with fuel leaking from the fuel pump or by the pistons of a flooded engine. If an engine used in extremely dusty areas does not have its oil and filter changed frequently, low oil pressure may develop because of a clogged system. A defective oil-pressure gage will sometimes show a low reading even though the oil pressure is good; worn parts, such as main, connecting rod, or camshaft bearings, that are pressure-lubricated, will allow the oil to bypass and cause low pressure. A defective oil pump or pressure relief valve should be suspected if all other parts appear to be satisfactory or are not worn excessively. The best remedy for low oil pressure is to change the oil and filter and be sure the engine is refilled with the proper oil. If the parts require replacement, be sure that all passages are cleaned and that the oil pump and relief valve are functioning properly before reinstallation.

(7) Loss of power. An engine adjusted to operate at low altitudes will not perform as efficently at high altitudes. Since most Marine Corps bases and camps are located close to sea level, you should consider the altitude when hearing a complaint about loss of power. To correct the problem, a change in ignition timing and carburetor adjustment may be required. The most common cause for loss of power is misfiring, usually caused by one or more of the following: fouled spark plugs, defective contact points, incorrect ignition timing, contaminated or improper fuel, or defective valves. The wrong type of spark plug or a loose one will cause a misfire. The plug may be too hot or looseness may not provide sufficient cooling. The contact points can be dirty, pitted, incorrectly adjusted, or have a weak spring. The valves can be burned, be loose in their guides, or have weak or broken springs.

(8) Defective cranking motor. Before removing the cranking motor, be sure the battery has sufficient power, the conductors are in good condition, the terminals are clean and tight, and the switches are operating properly. If this fails to help then check Table 4-13 Cranking System Troubleshooting.

c. Repair. Once the engine problems have been located and the initial parts requested, the preliminary repair work can begin. The parts or components requiring removal or adjustment to effect repairs should be thoroughly cleaned. Eliminate as many possible causes for abrasives getting into the engine as practical. Steam is a good means of cleaning engines, but it harms the electrical conductors. The heat of the steam causes the insulation to become hard and brittle and the water that penetrates is difficult to dry or remove. An approved cleaning solvent is probably the best cleaner for gasoline engines. Apply a solvent, such as gunk, and allow it to stand for about 15 minutes before washing with water; give the solvent time to penetrate the caked grease but do not allow it to dry. Use solvents with caution and do not apply to a hot engine. After the engine has been cleaned and a space prepared in the shop or where the repairs will be made, the engine or component can be disassembled and repairs started. The smaller engines can be placed on the workbench for easier, faster, and better repairs, but the larger engines are sometimes more difficult to remove than to repair on the machine. Some facilities have engine stands which are used if the engine must be removed.

(1) General procedures. The type of repair necessary will normally determine where it will be done and how much preparation will be required. For example, there is no need to remove the engine in order to repair the magneto unless the magneto is located in such a position that it can't be removed. Remove only those components that require repair or that must be removed to gain access to the part requiring repair. If the engine must be removed and will be test run before reinstallation, remove all the components required for operation. Observe the bolts, gaskets, seals, and parts as they are removed so that they can be reinstalled in the same place. For example, some bolts are longer than others or have different threads and must go back to the same place. The exterior of some parts look the same, but a small passage on the inside could be blocked and cause further damage if installed upside down. When only a component is removed, the area and openings where it was mounted must be protected from weather and dirt; plug the lines and openings and protect the machined surfaces against rust and corrosion. Be careful when using force during disassembly. Some parts or components may have an internal part that could be damaged if not removed before the two pieces are separated.

After the parts have been removed, clean and check them thoroughly for wear, cracks, alinement or original shape, cleanliness, corrosion, and adjustment. Replace all parts when there is doubt about their serviceability and they cannot be repaired. Some components are sealed and should not be disassembled unless repair of the component is within your echelon of maintenance. The component is replaced or referred to the proper echelon for repair. After a sealed unit has been repaired and adjusted, reseal the component. Reassembly is usually the reverse of disassembly, but some parts may require installation before the preceding part can be tightened. Check the nut and bolt torque in the specific TM for the machine. Replace the gaskets during reassembly, but be sure to use a gasket of the correct thickness; in some places a thicker gasket will change the bearing preload and the end thrust of a shaft. Some gaskets are also heat-resistant and must be replaced with a similar type. Waterproof and fungus-proof systems require special attention to insure that they are dry and properly sealed during installation.

(2) Briggs and Stratton. There are several models of this engine, but the discussion will cover sufficient details so that you can study the technical publications for the other engines. All possible problems cannot be foreseen and only a portion of the maintenance is discussed in this text.

(a) Ignition. Some of the items you will find when diagnosing the engine problems are a weak spark, no spark, or fouled spark plug. Do not replace any parts if the engine has another problem that requires repairs until all problems have been diagnosed and a decision to repair has been made.

1. Spark plug. Remove the high-tension lead from the spark plug, then remove the plug. Clean the spark plug with a sandblasting plug cleaner and tester. Be sure that all carbon deposits are removed from the insulator, the shell, and the electrodes. If the plug is burned or unserviceable, replace it with a new one. Before installing either the old or a new plug, check and set the gap as prescribed in the TM (usually .025). Use a new gasket, screw the plug into the hole and tighten it snugly or to the specified torque if given. It must be tight enough to seal the compression, but not so tight that it will distort the plug and change the gap or damage the threads.

2. Flywheel-type magneto. The cause may be due to a malfunction or a defective part within the magneto. Remove the cranking pulley or device and the cowling to expose the engine flywheel. Remove the crankshaft nut and flywheel. Most flywheels have bolt holes so that a puller can be used to remove it. After the flywheel is off, you will see a part of the magnet in the flywheel and the rest of the magnets attached to the engine. The magnets should be tight and strong. They are pressed into or bolted to the flywheel with dowel guides for alining, and are difficult to remove and install. Do not drop or bang the flywheel around; this will loosen the magnet and possibly break some of the fins off the cooling fan. Check the contact points. Replace them if they are pitted, burned, broken, or have a weak or broken spring. They should be alined so that the contact surfaces make full contact. Check the plunger or the rubbing block for wear or binding and the cam surface that forces them open for wear. Check the condition of the electrical conductors and connections. The condenser will seldom go bad, but if there is doubt, replace it. Contact points that are badly pitted indicate a faulty condenser, corroded or loose conductors, or dirt and grease. The coil will seldom be bad, but if it shows signs of insulation cracks due to age or heat, it should be replaced. Both the coil and the condenser can be tested with test equipment. Check the spark plug high-tension lead for insulation cracks, shorts, and continuity. Check the crankshaft for movement, endways or sideways. Movement in excess of that specified in the TM could affect the contact point gap and the magneto operation. If all parts are good or new parts are available, put some lubriplate on the plunger or rubbing block and install. After all parts have been installed, adjust the contact point gap to the specifications listed in the TM (usually .020 in.). Some units also require adjustment between the contact block as illustrated in figure 2-2.

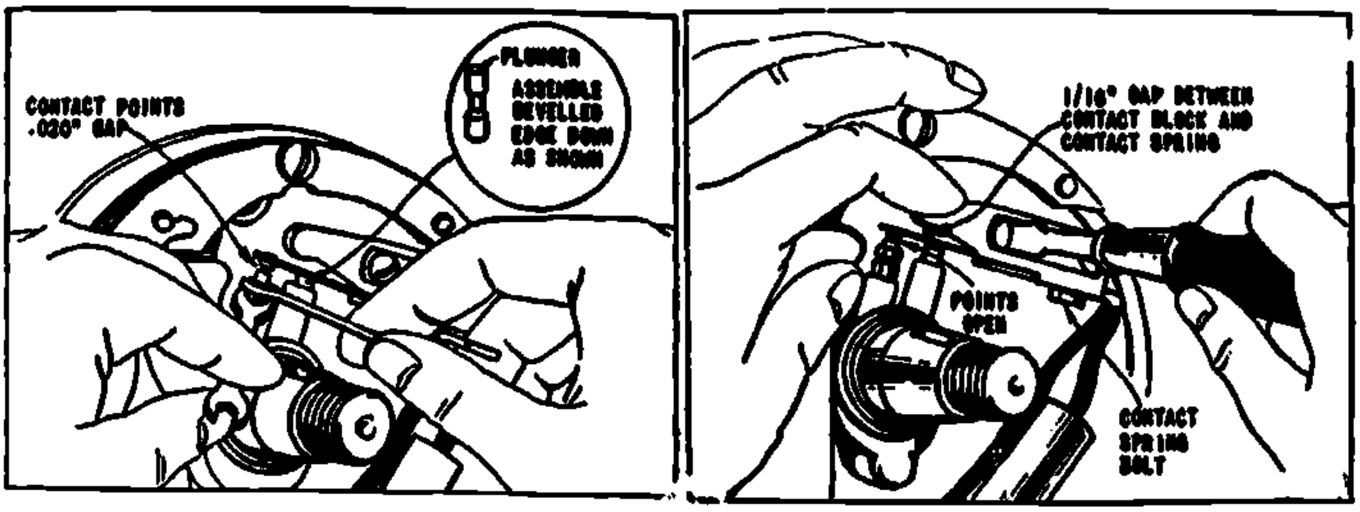


Fig 2-2. Adjusting contact points and contact point spring.

(b) Carburetion. Only a few of the repair facilities for engineer equipment have the tools to disassemble and repair carburetors. It is also difficult to get repair kits. But most problems with carburetion are not in the carburetor. Before removing the carburetor, check the intake manifold gasket, fuel tank and lines, and the air cleaner. Be sure the tank has enough clean fuel. Be sure the air cleaner is not clogged and acting as a choke. If the carburetor has fuel running out after the tank, lines, and air cleaner have been found good, remove the gasoline line connection at the carburetor and blow the debris out of the float needle valve. Once you have stopped the gasoline drip and there are still carburetion problems, check the gaskets between the carburetor and the intake manifold, and the manifold and the cylinder head. If they are satisfactory, readjust the carburetor. The initial setting is made by completely closing the needle valve (fig 2-3) and then backing it out 1 to 1 1/4 turns; turn the idle adjustment screw in and back out 1/2 to 3/4 turn. When closing the adjustment, be sure they are seated, but do not force or the valve will be damaged. If the engine fails to start, replace the carburetor and make the initial adjustments as discussed above. The final adjustment can be made after the engine has warmed up; turn the needle valve in or out until the engine operates smoothly under load. Adjustment of the idle-adjusting screw affects the engine operation during idling periods.

(c) Governor. There are very few small gasoline engine problems that can be traced to the governor. Most problems that appear to be the governor are caused by misfiring spark plugs or incorrect carburetor adjustment. However, binding linkage, worn governor parts, or incorrect adjustment will cause the engine to function improperly. Some governors operate from amount of air flow created by the flywheel while others are gear-driven. In either case the parts should operate freely. The springs should be connected and adjusted properly. Note the notches in the governor lever in figure 2-3. By moving the spring closer to the fulcrum (governor shaft), the governor will become more sensitive. Turn the adjusting nut on the governor rod to adjust the engine rpm. The engine should idle at approximately 1,200 rpm, but check the specific TM for the particular engine. If the governor lever has become loosened or has been removed, reset by loosening the screws in the lever and pushing the lever down. While holding the lever down, turn the governor shaft clockwise to the stop and tighten the screws.

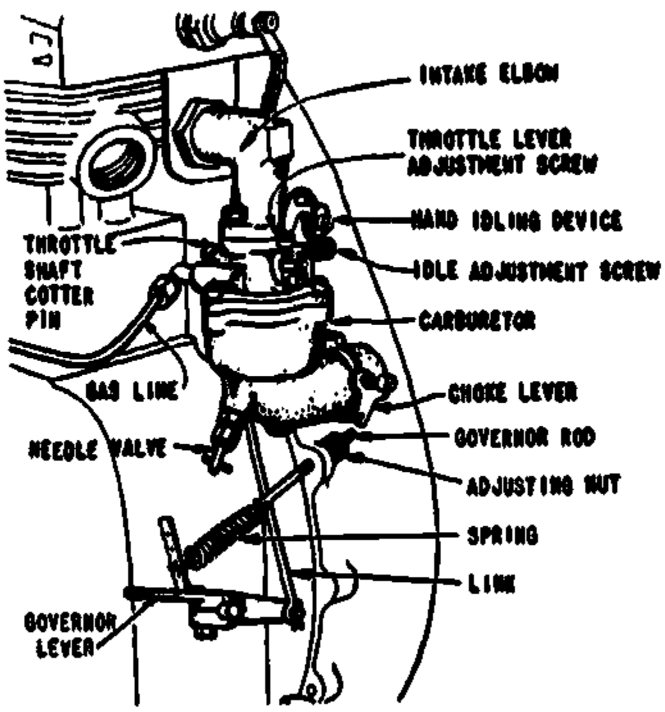


Fig / 2-3. Small gasoline engine carburetor and governor linkage.

(d) Valve mechanism (fig 2-4). Defective valves can cause the engine to misfire, backfire, or fail to start. They can be repaired or replaced with little difficulty by removing the cylinder head, carburetor and intake, and the exhaust; then removing the valves for examination and repair. Clean the carbon and gum deposits from the valves and the valve seats. Check the diameter of the valve stem for wear and the valve face for wear or pits. Check the valve seat for pits and cracks. Check the valve springs for tension and breaks. Use a new valve stem and check the valve guides for wear. Replace those parts which cannot be repaired. If the valve face can be repaired and the stem is good, reface it on the valve-refacing machine. Reface the valve seats and clean thoroughly to remove the valve-grinding compound. Install the parts and adjust by turning the engine until one valve spring is completely compressed and then adjust the other. On some models of the engine, the valves must be removed and the end of the stem ground to obtain more clearance. If the engine is completely disassembled, the cam lobes, camshaft gear, and the spark advance for gear-driven, self-contained magnetos should also be checked.

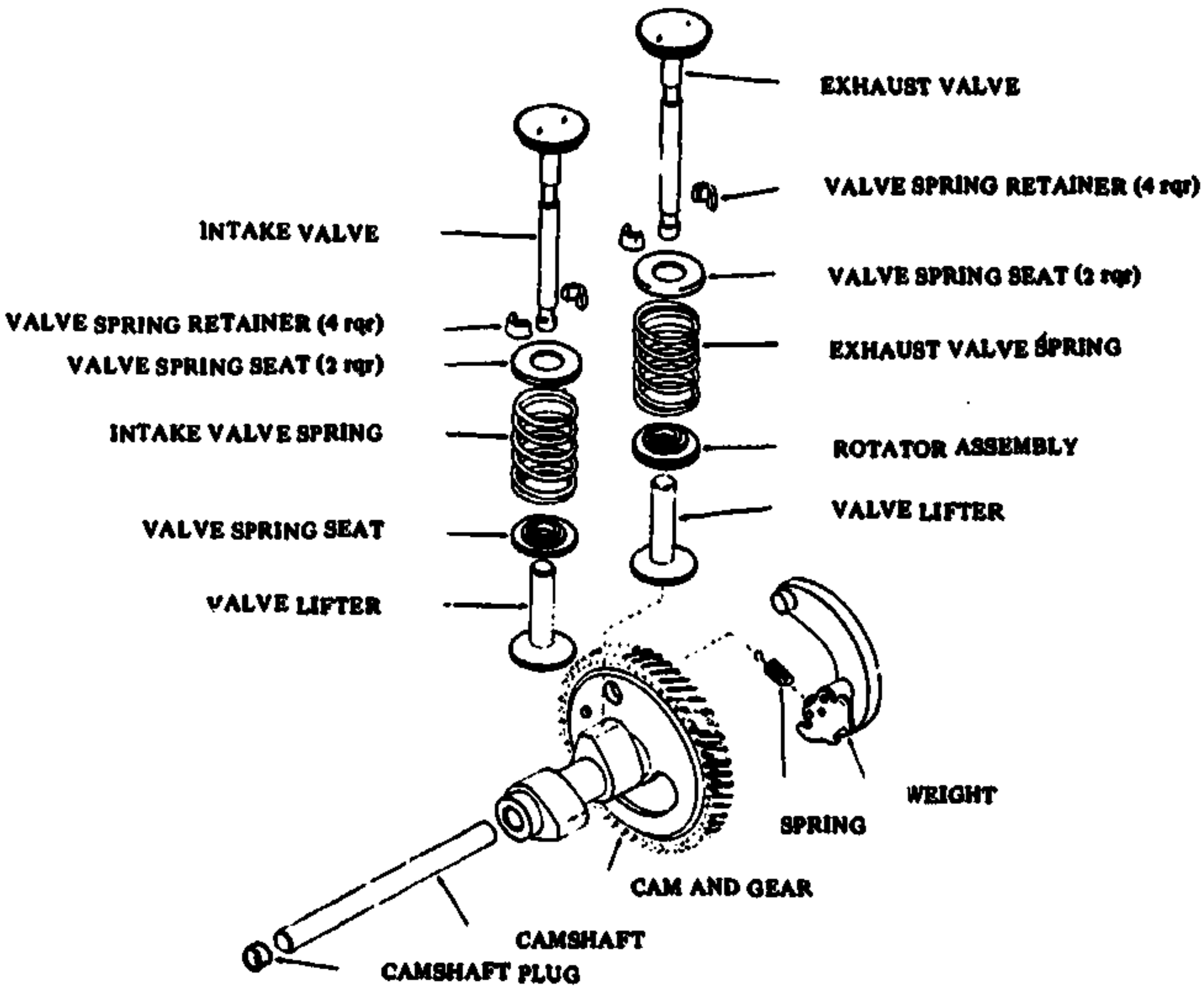


Fig 2-4. Exploded view of valve mechanism.

(e) Crankshaft and related parts. The crankshaft and its related parts are usually removed when major repairs are required. The connecting rod and piston can be removed without disturbing the crankshaft, but it should be checked anyway. Check the end play, main bearing condition (ball bearings), and the crankpin. The end play is adjusted by adding or removing gaskets between the crankcase and the bearing support assembly. The crankshaft can be removed through the hole covered by the bearing support assembly. The bearings are pressed onto the shaft and will require a puller for removal. Check the diameter of the crankpin to see if it is out-of-round or worn. The connecting rod bearing is the poured type that requires replacement of the connecting rod and cap if defective. Install the cap on the rod, torque, and check the diameter of the hole. Before the piston can be pushed through the top, the ridge formed in the cylinder must be removed to prevent breaking the piston rings. Check the cylinder bore and the piston for out-of-round and wear. Check the rings for cleanliness and wear. Remove the rings from the piston, install in the cylinder bore, and check the gap. Check and replace the piston pin if necessary. When installing the piston and rod assembly, stagger the ring gaps around the piston 180° from each other. Install the assembly so that the cam clearance flat is toward the cam gear and the marks on the connecting rod match those on the cap. After the crankshaft and related parts have been installed, turn the crankshaft at least two full revolutions to be certain the connecting rod does not strike anything. Also check the timing marks on the gears to insure proper timing of the engine parts and components.

(3) Wisconsin.

(a) General. Many of the repair procedures for the Wisconsin gasoline engines are generally the same as for the Briggs and Stratton engines, but specifications will be different. Wisconsin also makes larger air-cooled engines. One application of the larger engine is the V-four used on the 350-gpm dispensing and transfer pump of the amphibious assault fuel system. The Wisconsin engines also operate on the 4-stroke-cycle principle and use either the self-contained or flywheel-type magnetos. However, most are equipped with the self-contained magneto.

(b) Controls. The choke control and ignition switch are located on a panel at the flywheel end of the engine. The throttle control, vacuum gage, oil-pressure gage, and tachometer are on the instrument panel. All of the controls and instruments are potential problem areas.

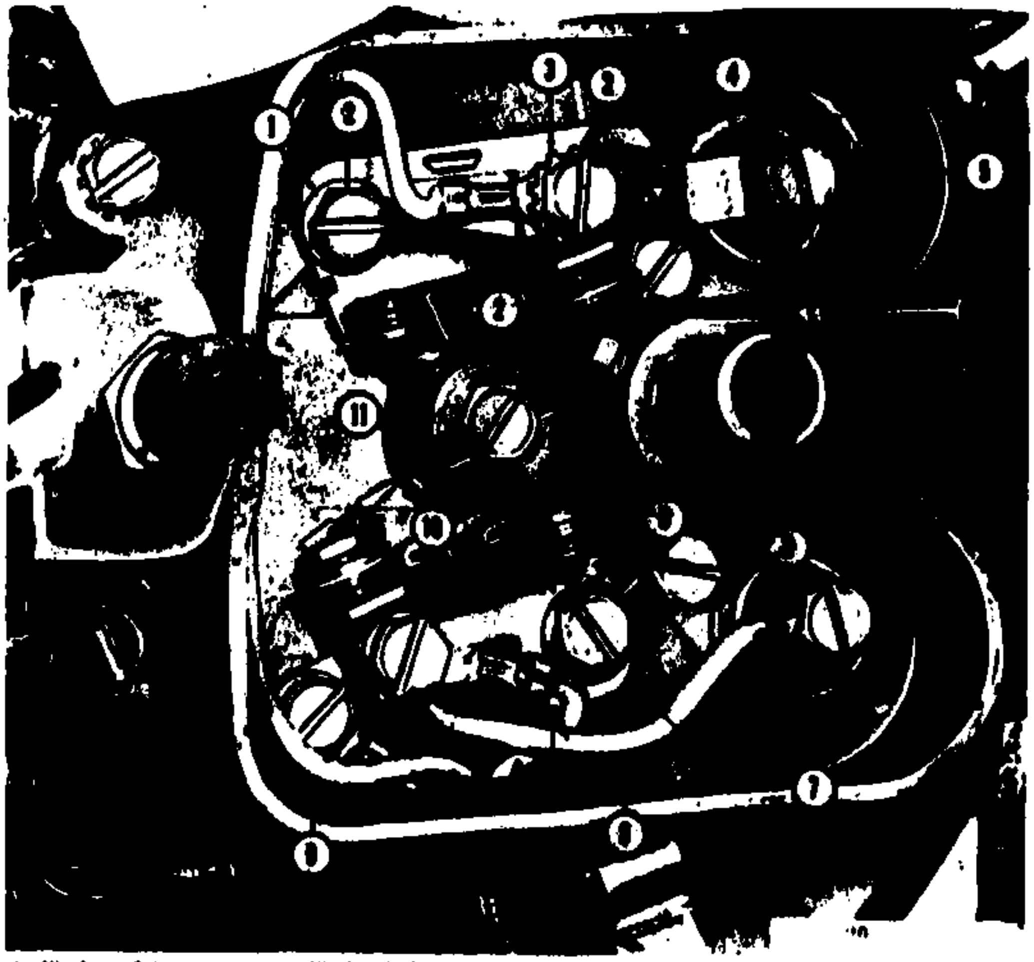
(c) Ignition. The V-four and some of the single-cylinder engines are equipped with self-contained magnetos that are shielded to help prevent radio interference. Moisture probably causes most ignition problems, but the location of the ignition switch on the V-four engine will also cause trouble. The switch closes the circuit to ground out the magneto primary circuit and stop the engine. A defective switch or conductor can ground out the magneto and prevent starting or proper operation. Shielding around the system provides a good ground for any electricity that leaks out of the defective part. It is usually easier to remove the magneto to make repairs than to attempt repairs while it is installed on the engine. The contact points, condenser, coil, conductors and connections, and the mechanical parts should be checked and replaced if necessary. The magneto must be properly timed to the engine when installed. Remove No. 1 spark plug and crank the engine slowly until you can feel compression. Then aline the edge of the marked flywheel vane with the mark on the shroud. Remove the inspection plug and install the magneto so that the marked tooth on it is visible through the inspection hole. If the engine has more than one cylinder, be sure the correct high-tension lead from the magneto is connected to the proper spark plug.

(d) Carburetion. The V-four engine has a fuel pump to supply the carburetor. The pump has a lever which allows the operator to pump gasoline to the carburetor by hand. If the float circuit is not working properly, you can force gasoline into the engine with the lever and flood the engine. A clogged air cleaner will restrict the air passage, reducing the air flow to the engine causing a rich mixture. In addition to the normal gasket and manifold leaks, some engines are equipped with a vacuum gage which can cause trouble if it or the line is defective. Any leaks which allow additional air to enter will change the air-fuel mixture ratio (too much air for the fuel) and cause improper engine operation.

(4) Military standard engines.

(a) General. The 1 1/2- and 3-horsepower (hp) military standard gasoline engines are air-cooled, 4-stroke-cycle, overhead valve, gasoline engines. The 10- and 20-hp engines are the same except that the cylinders are horizontally opposed. The military standard engines have one or more cylinders depending on size. Although these engines were designed and produced to meet military standards, the basic fundamentals and principles of operation are the same as for other 4-stroke-cycle engines. Cranking motors and battery-charging components are standard equipment on the 10- and 20-hp engines and can be installed on the 1 1/2- and 3-hp engines. The military standard engine has a life expectancy of 1,500 hours at the rated full load and speed before major repairs are required (compared with 100 to 500 hours for other air-cooled gasoline engines).

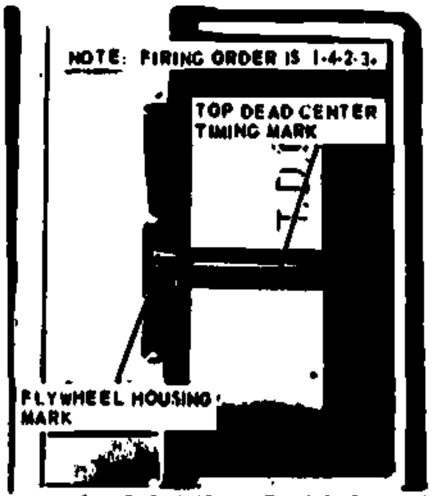
(b) Ignition. The 10- and 20-hp engines use a self-contained magneto which requires the same repairs as other self-contained units. The 1 1/2- and 3-hp engines are equipped with a magneto that is different from the other magnetos explained in this text. One part of the magneto is similar to the flywheel type and the other part is contained in the governor accessory case. The contact points and condenser are in the accessory case while the magnets for generating the primary circuit current and the coil are located behind the flywheel. The spark plug high-tension leads are connected to a terminal block near the coils. Repairs are made easier because the contact points and condenser can be replaced or adjusted without removal of the flywheel. Only the accessory case cover is removed to adjust or replace the contact points. However, moisture can cause more trouble because of a leaky accessory case cover gasket or loose parts. Condensation can also cause enough moisture to ground out the ignition system. All models are equipped with shielded electrical and ignition systems which can cause a grounded circuit. Before attempting to time the ignition of these engines, it is important to know what model engine is being repaired. The 1 1/2- and 3-hp engines are timed by rotating the flywheel counterclockwise until the intake valve closes; stopping when the IGN mark is on line with the pointer. The intake valve on the 2-cylinder engine must be the one nearest the flywheel. With the engine set, rotate the cam (item 11 in, fig 2-5) until the lower points just begin to open. For the 2-cylinder engine, rotate the flywheel another 180° and line up the marks. Then check the upper set of points. Do not rotate the cam to time the upper set of points; adjust the gap until the points just begin to open.



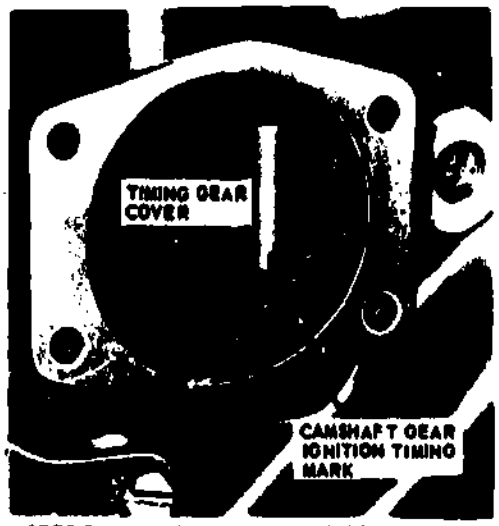
1 Washer, flat, No. 8 (2 rqr)
2 Screw, machine, hex-hd, No. 8 32 x 5/16 in. (11 rqr)
3 Washer, lock, ET, No. 8 (11 rqr)
4 Connector
5 Accessory case
6 Contact assembly point gap
7 Condenser, 0.225-0.275 μf (2 rqr)
8 Connector
9 Electrical lead (2 rqr)
10 Contact assembly (2 rqr)
11 Ignition cam

Fig 2-5. Two-cylinder engine contact assemblies, adjustment and removal points.

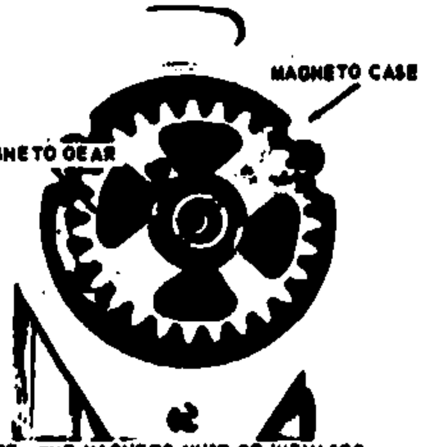
The 10-hp engine is also a 2-cylinder engine, but the timing marks are lined up by removing the No. 1 spark plug and cranking the engine until you feel compression, then alining the flywheel and housing marks. The camshaft and magneto geer marks must also be alined. The flywheel mark will be top dead center (TDC), but for checking with a timing light the mark will be IGN. No. 1 cylinder of the 10- and 20-hp engines is marked on the engine cowling. The 20-hp engine timing (fig 2-6) is basically the same as the 10-hp except that the magneto is rotated so that it will impulse and fire No. 1, then impulse three more times. The camshaft and magneto gear marks are then alined when installing. Ignition of these two engines can be advanced or retarded slightly by loosening the mounting bolts and rotating the magneto.



STEP 1. REMOVE SPARK PLUG FROM NUMBER ONE CYLINDER
STEP 2. INSERT THUMB IN SPARK PLUG HOLE AND TURN PULLEY UNTIL AIR ESCAPING BY THUMB INDICATES NUMBER ONE CYLINDER IS ON COMPRESSION STROKE. CONTINUE TO TURN UNTIL TDC TIMING MARK ALINES WITH FLYWHEEL HOUSING MARK. INSTALL SPARK PLUG.



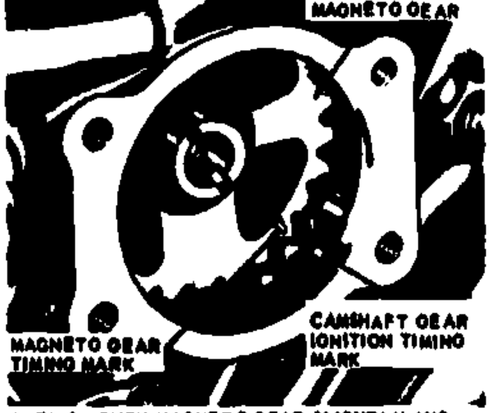
STEP 3. WITH TIMING MARKS ALINED AS DESCRIBED IN STEP 2, THE CAMSHAFT GEAR IGNITION TIMING MARK WILL APPEAR IN OPENING IN TIMING GEAR COVER.



NOTE: THE MAGNETO MUST BE IMPULSED TO DETERMINE NUMBER ONE CABLE.

STEP 4. REMOVE CABLE FROM NUMBER ONE SPARK PLUG AND HOLD END ONE-EIGHTH INCH FROM SHROUD OR MAGNETO CASE. TURN MAGNETO GEAR CLOCKWISE UNTIL MAGNETO IMPULSES AND SPARK OCCURS. IMPULSE MAGNETO THREE ADDITIONAL TIMES.

NOTE: POSITION MAGNETO GASKET ON MAGNETO BEFORE INSTALLATION.



STEP 5. TURN MAGNETO GEAR SLIGHTLY AND POSITION MAGNETO SO THAT MAGNETO GEAR TIMING MARK AND CAMSHAFT GEAR IGNITION TIMING MARK ALINE.

Fig 2-6. Magneto alinement and positioning (model 4A084-II).

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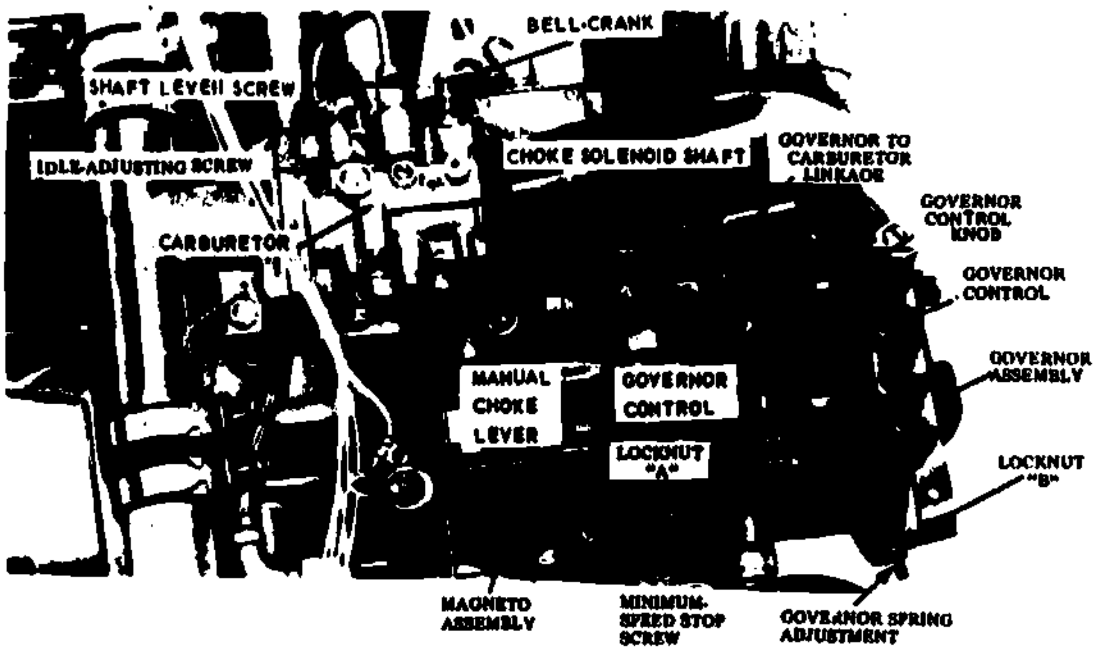
(c) Governor. Maximum rpm of the military standard gasoline engine is controlled by a governor. The speed of the 1 1/2- and 3-hp engines is regulated by shortening or lengthening the control rod that extends from the accessory case up to the carburetor throttle lever. Surging or poor speed regulation is eliminated by turning the carburetor idle adjustment needle. The starting point for adjusting these governors is to disconnect the control rod from the throttle lever and hold the control rod and lever down. Raise the throttle lever 1/16 in. and adjust the length of the control rod so that it can be connected. Note that on some engines the control rod is clamped to the throttle lever and can be extended by loosening the clamp while the other control rods have a clevis that screws in and out to extend or shorten them. Adjustment to the 10- and 20-hp engine governors is more complicated than in the smaller engines. The governor and tachometer are driven by the camshaft gear through the magneto gear. The governor is removed each time the magneto is removed and will require adjustment. There are more linkages and adjustments on the governor of the larger engines. Before the govenor is adjusted, the engine ignition and carburetor must be adjusted and operating properly. The engine must be at operating temperature before making the governor adjustment. The governor adjustment procedures for both the 10- and 20-hp engines are explained in figure 2-7.



<u>Step 1.</u> Loosen locknut "A" and turn minimum-epeed stop screw counterclockwise 4 turns to prevent engine overspeed.

<u>Step 2.</u> Start engine and allow to warm 30 minutes.

<u>Step 3.</u> Loosen governor control knob and place governor control in govern position (toward carburetor). Tighten knob.

<u>Step 4.</u> Apply load and turn minimum-speed stop screw clockwise to obtain engine speed of 3,600 rpm. Tighten locknut "A."

<u>Step 5.</u> Disengage load and check engine speed. If speed does not exceed 3,708 rpm, no further adjustment is necessary. If epeed exceeds 3,708 rpm, perform stepe 6 and 7.

<u>Step 6.</u> Loosen locknut "B" and turn governor spring adjuetment nut clockwiee 4 turns to reduce no-load speed. Tighten locknut "B."

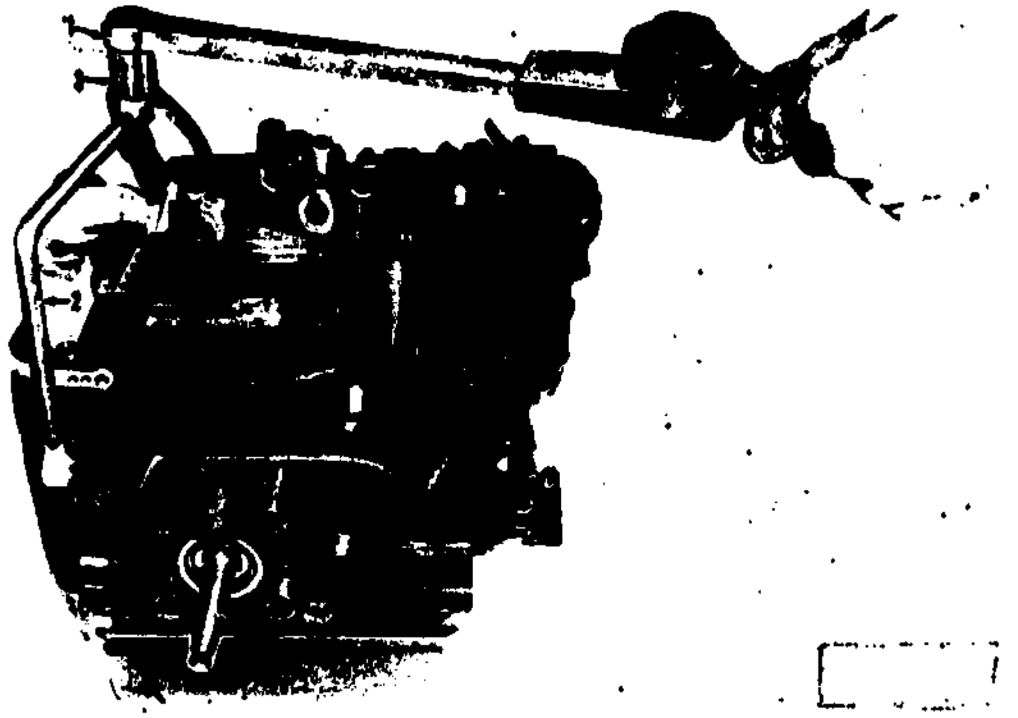
<u>Step 7.</u> Perform steps 4 and 5.

<u>Note:</u> If no-load speed is adjusted too close to load speed, instability or hunting will occur. If instability occurs, adjust governor spring adjustment nut to obtain no-load speed of 3,708 rpm; then perform steps 4 and 5 to obtain stability.

Fig 2-7. Governor adjustments for 10- and 20-hp military standard gasoline engines.

(d) <u>Lubrication system.</u> The 1 1/2- and 3-hp engines are splash-lubricated and rely on the proper amount of the proper grade of oil for lubrication. The 10- and 20-hp engines are pressure-lubricated and use a gear-type oil pump to force the oil through the system. A defective oil pump, clogged system, or lack of oil can cause many problems. The oil pump is similar to other gear-type pumps, but it is located behind the flywheel which must be removed to repair the pump. Some engines are equipped with an emergency shutdown device that operates from the oil pressure. A loss of oil pressure will short out the magneto. These larger engines are also equipped with hydraulic valve tappets which fail to operate properly if the engine oil is too low or becomes contaminated. The oil pump gears are housed in the crankcase of the engine and require replacement parts. The pump is not replaceable as an assembly.

(e) Cylinders and cylinder heads. The military standard gasoline engines are valve-in-head type engines; the valves can be adjusted be removing the rocker covers. The cylinder heads and the cylinders are replaceable, but special tools are required for their removal. Therefore, a valve job cannot be done without the special wrench to remove and install the cylinder head. Figure 2-8 shows the special wrench being used to torque the cylinder heads. If either the cylinder head or the cylinders are removed, replace the gaskets before reinstalling.



1 Torque wrench
2 Cylinder head nut torque wrench adapter
3 Adapter, ½ to ¾ in.

Fig 2-8. Cylinder head nut torque wrench adapters.

d. Troubleshooting. When diagnosing engine malfunctions, consider and check all possibilities. The following charts will cover some of the malfunctions of gasoline and diesel engines, the causes and possible remedies to correct them.

Table 2-1. Troubleshooting Cnart for the Gasoline Engine

Symptom	Probable cause	Corrective action
1. Engine fails to turn		
a. Cranking motor inoperative	1. Corroded or loose terminals (including ground).	1. Clean and tighten. Replace cable if necessary.
	2. Faulty battery.	2. Recharge batteries or replace if necessary
	3. Broken conductors.	3. Replace.

Table 2-1. Troubleshooting Chart for the Gasoline Engine--contd

Symptom	Probable cause	Corrective action
b. Engine oil too heavy for temperature	1. Use of incorrect viscosity oil.	1. Drain and refill with proper grade oil.
c. Internal seizure	1. Broken or damaged parts or fluids in cylinder(s).	1. With clutch disengaged, transmission in neutral, remove spark plugs and attempt to turn engine. Failure to turn indicates damage requiring repair beyond organizational level.
2. <u>Engine turns, but fails to start</u>		
a. Insufficient gasoline to engine	1. Empty gasoline tank.	1. Fill with gasoline.
	2. Gasoline shutoff valve closed.	2. Open shutoff valve.
	3. Gasoline strainer clogged.	3. Clean gasoline strainer.
	4. Water in gasoline.	4. Drain gasoline tank, strainer, and carburetor.
	5. No gasoline at carburetor.	5. Clean gasoline fuel line. Check and correct linkage between carburetor and compression release mechanism.
b. Fuel-air mixture too rich	1. Carburetor choked too much.	1. Push in choke control; wait a few minutes; attempt to start.
	2. Dirty or damaged float needle valve or improper float setting.	2. Replace carburetor.
c. Engine not turning fast enough	1. Batteries low in charge.	1. Recharge or replace batteries.
	2. Loose connection, defective conductors or switches.	2. Clean and tighten connections. Replace conductors or switches.
	3. Defective cranking motor.	3. Test and replace if needed.
d. Faulty ignition system	1. Broken ignition circuit.	1. Check electrical wiring from battery through ignition switch, manifold switch, distributor, and ground. Clean and tighten corroded or loose connections. Replace damaged wiring.
	2. Wet or fouled spark plugs.	2. Remove, clean, gap, reinstall.
	3. Cracked or broken spark plug insulators.	3. Replace.
	4. Defective manifold switch.	4. Repair or replace.
	5. Wet or defective distributor.	5. Clean, dry, and repair as needed.

Table 2-1. Troubleshooting Chart for the Gasoline Engine--contd

Symptom	Probable cause	Corrective action
3. Engine misses and backfires		
a. Water in gasoline	1. Contaminated fuel supply or condensation.	1. Drain gasoline fuel system, clean sediment bowl and strainer, and refill with clean gasoline.
b. Incorrect firing order	1. Improper installation of spark plug leads.	1. Check and correct spark plug high-tension lead installation.
	2. Improper installation of distributor cap.	2. Check and correct installation of distributor cap.
4. Engine does not develop full power--uneven operation		
a. Insufficient air to engine	1. Clogged air intake system.	1. Remove, clean and service air cleaner.
b. Air leaks around intake manifold	1. Loose bolts and nuts.	1. Tighten to proper torque.
	2. Defective gasket.	2. Refer to higher echelon for replacing.
c. Poor fuel	1. Improper grade.	1. Drain and refill with proper grade of fuel.
d. Internal wear or damage	1. Defective valves or pistons.	1. Refer to higher echelon for repair.
5. Excessive oil consumption	1. Oil leaks.	1. Check and repair.
	2. Improper lubricant.	2. Drain and refill with proper grade of oil.
	3. Overheating engine.	3. Check and correct.
	4. Overfilling.	4. Check proper side of gage and fill only to specified level.
6. Loss of engine oil pressure		
a. Low oil level	1. Normal use or leaks.	1. Determine cause and fill with proper grade of oil.
b. Clogged oil filter elements	1. Operation in dusty conditions and not changed often enough.	1. Change filter elements.
c. Defective oil-pressure indicator or line	1. Broken indicator.	1. Replace.
	2. Crimped or broken line.	2. Replace.

Table 2-1. Troubleshooting Chart for the Gasoline Engine--contd

Symptom	Probable cause	Corrective action
7. <u>Engine noises</u>		
a. Sharp rap at idle	1. Loose piston pin.	1. Locate faulty pin by short-circuiting spark plugs or venting nozzles until noise stops. Refer to higher echelon for repair.
b. Flat slap when increasing speed under load	1. Piston slap.	1. Refer to higher echelon for repair.
c. Metallic knock when idling or slowing down that disappears under load	1. Faulty connecting rod bearing.	1. Refer to higher echelon for repair.
d. Constant knocking	1. Low engine-oil level.	1. Check and fill to proper level.
	2. Overheating.	2. Check coolant and oil level. Refill to correct level.
e. Constant rapid clicking	1. Incorrect valve adjustment.	1. Adjust to specified clearance.
f. Combustion knock	1. Improper engine temperature.	1. Keep temperature at operating level.
	2. Poor fuel or water in fuel.	2. Drain and refill with proper grade of clean fuel.

2-3. DIESEL ENGINES

a. <u>Introduction.</u> Diesel engines are used in many items of construction engineer equipment. There are many makes, models, and sizes, each designed to perform a specific job. The diesel engine principles of operation are similar to those of the gasoline engine; however, the diesel engine is usually heavier than the gasoline engine of equal horsepower. The main difference between the two engines is the method of ignition. The diesel engine uses heat of compression to ignite the fuel. Another difference in most, but not all, engines is the method of getting the fuel into the combustion chamber. The diesel engine uses a fuel injection system while most gasoline engines use a carburetor. On the intake stroke, the diesel engine draws in air only. The air is then compressed enough to raise the temperature sufficiently to ignite the fuel when it is injected. The fuel injection system meters the fuel, injects it into the cylinder at the proper time for ignition, and atomizes it. Swirling motion of the compressed air, and heat help vaporize the fuel and mix it with the air for burning. The Detroit diesel (often called the Jimmy) is the most widely used diesel engine in the Marine Corps. It is a 2-stroke-cycle, water-cooled engine made in many different sizes with V or in-line cylinder arrangements. Although other makes of diesel engines are used by the Marine Corps, only the Detroit diesel is discussed in this paragraph.

b. Diagnosis.

(1) Introduction. You diagnose problems on the diesel engine about the same as you do on the gasoline engine. It is a matter of locating the problem and isolating it so that repairs can be made. Although the engines are similar, cleanliness within the diesel is more important than on the gasoline engine. Dirt in the fuel system of a gasoline engine does not affect its operation as much as dirt in a diesel fuel system. Loss of compression on the diesel engine is more noticeable than on the gasoline engine.

(2) Diagnosing malfunctions. Diesel engine malfunctions can be caused by one part or a combination of defective parts, components, and systems. All possible causes must be checked when you diagnose malfunctions. If the malfunction is not caused by a part directly related to the problem, look for defective parts or components in another system which may affect the area where the problem is located. For example, the engine is losing power and has an excess of white smoke. The cause can be low compression caused by worn cylinder parts or bad valves. It could also be caused by a restriction in the air intake system or improper fuel. It could also be a defective or improperly adjusted fuel injection system. The following paragraphs will discuss some of the malfunctions and methods used to locate their cause. The TM contains a list of problems, their possible causes, and the remedies. Before attempting to diagnose malfunctions in an engine, perform all the before-operation services and checks.

(a) Engine fails to turn. The diesal engines used by the Marine Corps are cranked by an electric cranking motor. There are several places that are potential problem areas, but a quick check of the battery terminals and connections is the most logical place to start. Be sure they are clean and tight and the battery has sufficient charge. Then trace the path of the current flow and check for loose, corroded, or broken connections, including the ground circuit. If all parts are clean, tight, and in good repair, the problem could be in the starter switch, solenoid, cranking motor, or it could be internal seizure of the engine. Try turning the engine backwards while listening for unusual noises. If it turns back easily, try rotating it by hand in the normal running direction. If the engine rotates freely in both directions, the problem is most likely in the cranking motor which requires test equipment to check. If it rotates back but not forward, water in a cylinder could be the problem. This water could leak by a defective head gasket, through a crack in the cylinder head, or by a defective injector tube. Failure to turn in either direction could be caused by a defective attached component or other damaged parts within the engine.

(b) Engine turns but fails to start. A diesel engine must have an adequate supply of air compressed to a sufficiently high compression pressure, the proper amount of fuel injected at the right time, and the proper cranking speed before it will start. Failure to meet any of these requirements will result in a failure to start or abnormal operation. The cranking speed is easily detected, so most problems encountered will be caused by lack of air or fuel. Some of the engines are equipped with safety devices which automatically shut the fuel or air off if the engine reaches a danger point during operation. They are usually electrically operated sending units mounted where they can be actuated by excess heat, low oil pressure, overspeed of the engine, and some by a malfunction of the driven component. They serve as switches to control a solenoid which stops the flow of fuel or restricts the air. These devices are connected by electrical conductors which cause most problems of hard starting. The conductors short out, ground out, or break, causing the parts to malfunction. Slow cranking speed is usually caused by low battery output. If the batteries are good, check the connections and cranking motor. Improper oil for the temperature will also cause slow cranking speed. In cold temperatures, cold-weather starting aids are provided to assist in cranking the engine. Failure of the system to function properly will result in failure to start or hard starting. Whether the starting aid is the fluid type or the air heater type, it must function properly and be used correctly to perform its functions. Binding or broken linkage or other defects in the governor can shut the fuel off and prevent the engine from starting. In extreme case, bad valves or worn cylinder parts will prevent the engine from starting by failing to compress the air to the high compression required for ignition.

(c) Uneven running or frequent stalling. The diesel engine will often start, but fail to continue to run. This is especially true when the engine is cold. The governor, governor linkage, and throttle linkage must be correctly adjusted and operating properly to permit setting the speed at an rpm at which the engine will run until it reaches operating temperature (160° to 185° F). Improper adjustments will cause the governor to hunt (run the engine rpm up and down) until the engine finally stalls. In cold temperatures the starting aid may be required to keep the engine running until it reaches a temperature where assistance is no longer needed. If the engine is equipped with a safety device that is actuated by low oil pressure, a switch that will stop it from functioning must be used until the engine builds up sufficient oil pressure (takes about 30-seconds). Improper operation or malfunction of the device will cause the engine to be hard to start or to stall. Insufficient fuel or faulty injectors will also cause the engine to run unevenly or possibly stall. However, the most common problem encountered in uneven operation is often caused by improper adjustment of the injector timing or rack setting. Low compression pressures can sometimes be overcome to permit starting by use of starting fluids, but after the fluid has burned, the engine will probably stall or run unevenly. Low compression on just a few cylinders will not prevent starting, but will cause uneven operation. Compression pressures should not vary more than 25 psi between cylinders when the engine is operating at 600 rpm. Loss of compression is often caused by a restricted air intake system, improper adjustment of valves, bad valves, or worn or stuck piston rings. Another problem, especially in the Marine Corps, is contaminated fuel. The fuel provided meets the requirements of military specifications, but water and debris get into it while it is in storage or being used to refuel equipment. The water and sediment soon clog the filter or cause the fuel system components to malfunction and in some extreme cases the water is injected into the cylinder. Any of these conditions will cause hard starting, frequent stalling, or uneven operation.

(d) Lack of power. The main cause for lack of power is a restricted air intake system. Dirt that builds up in the breather assembly, too much oil in the air cleaner oil pan, or a closed emergency shutoff will keep the engine from receiving the proper amount of air, causing it to lose power. Contaminated fuel will clog filters and prevent the proper amount of fuel from reaching the cylinder. The fuel will sometimes get hot and expand and prevent the proper amount from being injected. If the engine is getting plenty of fuel and air, it is probably being misused. The operator is overloading the engine. Another cause that rarely occurs is a restricted exhaust. Restricted exhaust problems normally occur when they are modified or when substitute parts are installed. In some cases where the engine has just been repaired, it is possible that the gear train is improperly timed. If the engine had been performing properly and the above checks show nothing, then it needs a tuneup. Of course, worn parts within the engine will prevent proper compression of the air and cause loss of power. Uneven running was discussed in the previous paragraph and will also affect engine power.

(e) Detonation. A cold engine will usually knock when first cranked. The knocking is more noticeable if starting fluid is used to assist in cranking. If the air cleaner oil pan is overfilled or the oil is too light, it can be drawn into the cylinder and cause detonation. Faulty injectors or injector timing will also cause detonation. In extreme cases, carbon deposits that build up in the cylinder will cause higher compression and detonation.

(f) Insufficient or no fuel. The person making the diagnosis has two choices of where to start, and knowing the using unit and the operator's habits will help locate the problem more rapidly. After checking the fuel tank to insure that the item of equipment has not run out of fuel, you should then check for leaks on the suction side of the fuel supply pump. Then check for clogged system. Loose connections between the tank and the fuel pump will allow the pump to get air and fail to supply the fuel. Leaks between the fuel pump and the injectors can be easily detected by observing the fuel that is forced out. This will keep the pump from supplying the fuel at the proper pressure. Either of the above problems can also be caused by faulty installation. Some engines are used where another source of fuel can be connected. If the source is too far away or too low, it will act as a restriction or leak. If the diameter of the line is too small, it will act as a restricted line. There are other problems created by faulty installation which will prevent the proper amount of fuel from being delivered to the cylinder. Improper installation or a defective fuel intake line check valve (fig 2-9) will allow the fuel to drain back to the supply tank or prevent the fuel from flowing. The valve would close and stop the fuel if it was installed backwards. A valve that fails to close would allow the fuel to drain back to the tank. The installation of a substitute for the restricted elbow in the end of the outlet manifold (fig 2-9) would prevent the fuel pump from building up the required pressure to supply the injectors. The last items to check for insufficient or no-fuel problems are the fuel pump and the injector control rack setting. A defective relief valve or worn pump will not deliver the proper amount of fuel at the prescribed pressure. The pump is driven from the rear end of the lower blower rotor. It is possible for the pump to be improperly installed or have a broken shaft and fail to operate. An engine that is receiving the proper amount of fuel should have about 1 gallon per minute flow through the return line with the engine operating at 1,200 rpm. The temperature of the return fuel should not exceed 150° F.

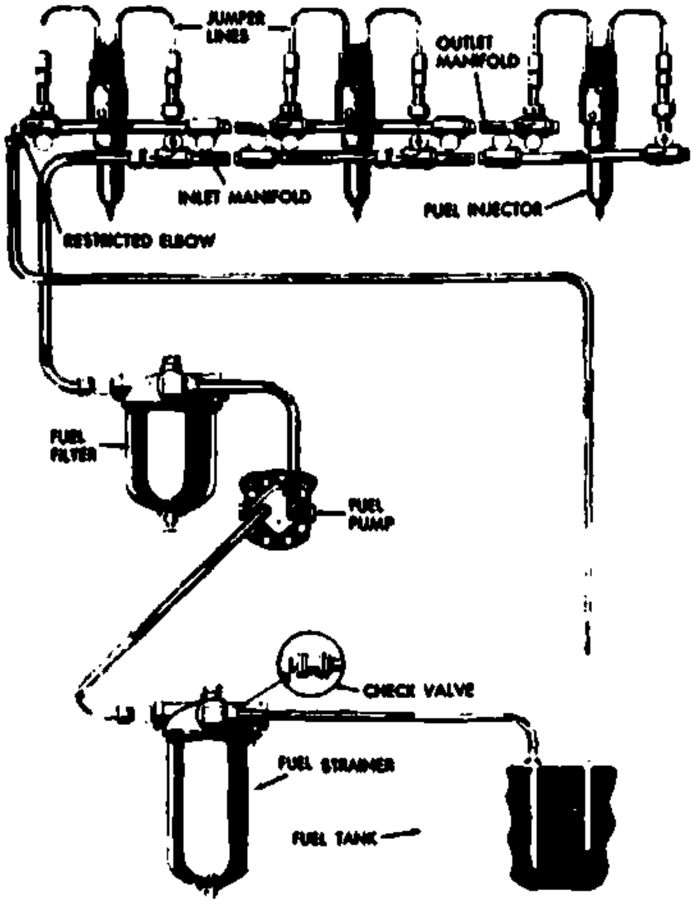


Fig 2-9. Typical fuel system.

(g) Excessive oil consumption. Very seldom is an engine sent to the repair shop for excessive oil consumption. By the time the dispatcher or the equipment chief notices the oil consumption, the operator is complaining of lack of power or other engine problems. Leaks can go for a long period of time before they are noticed unless someone keeps a close watch on the equipment records. Oil that is being burned will show in the exhaust smoke or through lack of power. External leaks are easy to locate and the engine should be checked daily and very closely just after repair for signs of oil leaks. The oil will leak through loose connections, defective lines, and loose or defective gaskets. It can be blown out by high crankcase pressure caused by a restricted crankcase breather or defective cylinder parts. Internal leaks are hard to detect and locate. The oil leaks past the blower seals into the air box or through the oil cooler into the cooling system. Oil which leaks past the blower seals can be dangerous. Oil, which leaks past the blower seals, can be forced through the air box into the cylinder, where it is burned as fuel, causing tho engine to run away. The oil will act as fuel and keep the engine running. If the seal or gasket is completely worn out, the engine can get enough air and oil to continue operating after the fuel and the emergency air shutoff have been placed in the stop position. Lack of oil control at the cylinders can be caused by improperly installed, stuck, broken, or worn oil control rings; by loose piston pin retainers; by scored cylinder liners, pistons, or oil rings; or by incorrect piston alinement caused by worn crankshaft thrust bearings. The piston rings and cylinder can be visually checked for scoring by removing the covers from the air box and turning the engine until the parts can be seen through the inlet ports. Of course, overfilling the crankcase or using the incorrect grade of oil will cause the engine to use an excessive amount of oil.

(h) Excessive crankcase pressure. Pressure above normal is caused by pressure escaping from the cylinder past the piston, cylinder head gasket, and in rare cases the exhaust valve guides or pressure from the blower escaping past the "blower to block gasket" or the end plate. An obstructed breather will also allow the engine heat to build up pressure as it expands. Exhaust back pressure will put extra pressure on the piston rings and gasket and possibly cause excessive crankcase pressure. If there is excessive pressure in the crankcase, the exhaust system should be checked as possibly the start of the trouble. Exhaust back pressure can destroy both the head gasket and the blower gasket. It will also cause heat and strain on the piston and rings which will stick and score.

(i) Low oil pressure. Inexperienced persons think their engine needs an immediate repair if the oil pressure drops, but most of their problems are from using the wrong viscosity oil or from failure to keep the oil level at the correct level. If the engine is full of the correct oil the cause could be poor circulation. This is often caused by the filters or the oil cooler being clogged. Excessive wear on the crankshaft bearings will allow the oil to flow through end back to the oil pan without lubricating the other parts. A defective oil pump will not supply the amount of oil required to keep the pressure up. In rare cases, the pressure control valves fail to function properly and cause low oil pressure. If the engine has just been repaired, the cause is probably missing plugs. Sometimes the engine oil pressure is satisfactory, but a defective gage or lines to the gage cause a false reading of low oil pressure. The lines become clogged, crimped, or otherwise restricted, preventing an accurate reading.

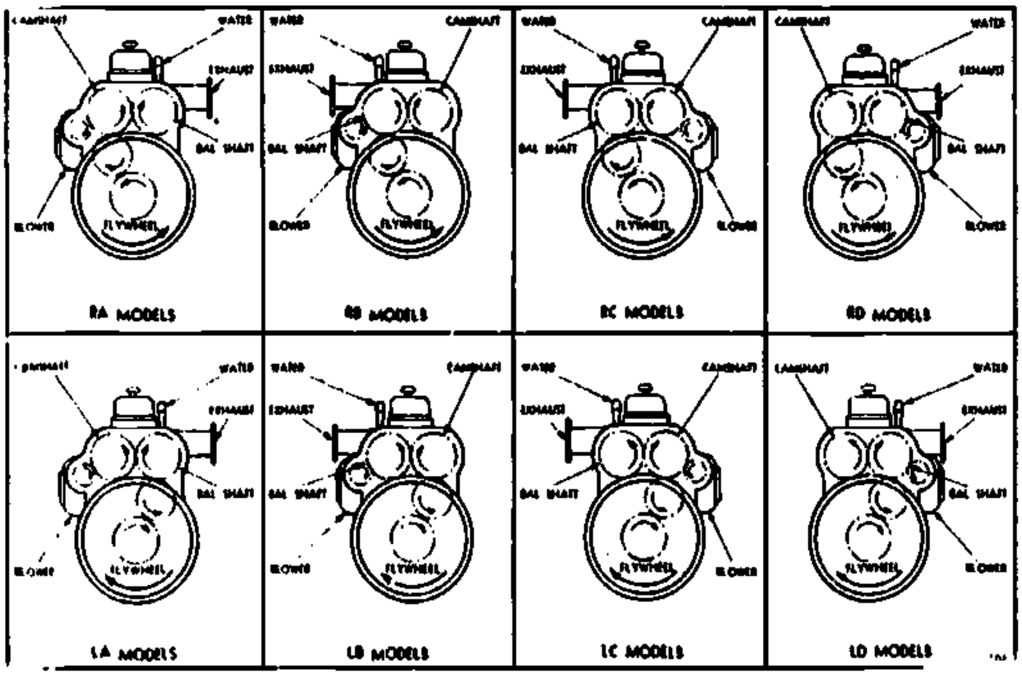
(j) Abnormal engine coolant operating temperature. Coolant temperature plays an important part in engine performance and efficiency. An engine that is too hot causes wear on the internal parts and a loss of power. Overheating is caused by insufficient heat transfer and poor circulation. Most overheating troubles are caused from lack of coolant. Some of the older engines have scale and other deposits that clog the cooling system and prevent circulation. Defective coolant hoses can restrict the flow and cause overheating. A hose that is collapsing is very hard to detect because it normally collapses when the engine is operating at a high rpm. Loose fan belts will slip and not turn the fan at a speed that will draw sufficient air across the radiator to properly cool the water. A defective thermostat can restrict the coolant flow, causing the engine to overheat or fail to close and prevent the engine from reaching the operating temperature. An engine that is operated below the operating temperature will knock and fail to burn all the fuel delivered to the cylinder. In extreme-cold climates a shutter may be required to assist the thermostat. For additional trouble shooting hints check paragraph 24.

(k) Miscellaneous. Diagnosing engine noises and electrical component malfunction is the same as for gasoline engines.

c. Repairs.

(1) General repair procedures. Order the parts required as soon as diagnosis is completed and you have determined which parts can be repaired. The vehicle, especially the engine, should then be cleaned if it was not cleaned before diagnosis. Steam or solvents and water should be used to remove the caked-on grease and dirt. Don't try to clean the engine while it is hot; allow it to cool to reduce fire hazards and to prevent cracking the hot components. The type of repair required, its location on the engine, and the engine application and model will determine whether the engine will need to be removed from the vehicle or if the repairs can be made while it is mounted in the vehicle. This will also help determine what special tools and equipment will be required. If the engine must be removed from the vehicle, be sure that all connections are free before

attempting to lift it. Some components may require removal before the engine can be removed. Some components or parts may require removal for repair even if the engine is not removed. When disassembling, place the parts and components in a safe place to prevent loss or damage. As it is removed, inspect each item for defects, positioning, and peculiarities. For example, the blower assembly will fit on either side of the engine, but it will work properly in only one place. Check its position in relation to the exhaust manifold, water manifold, flywheel, and other external parts and markings (fig 2-10). Check the size, threads, and position of nuts and bolts. Check the location, shape, and size of lines and electrical conductors. If necessary, mark or tag the items. If the parts can be placed in some order, reassembly is usually much faster. After the parts have been removed, clean and inspect them closely for wear, cracks, breaks, alinement, and proper operation. Many items may give satisfactory service, but be worn so badly that they would fail in about 1 day's operation. These are also some of the parts that will be omitted from the initial requisition. After the parts have been inspected and repaired or replaced, reassembly can begin. The parts are usually reassembled in the reverse order of disassembly. However, this is not true in all cases. Use the TM as a guide. Lubricate those parts that need it and torque the nuts and bolts to specification. Make an initial adjustment on those components that require adjusting before attempting to crank the engine.



ALL VIEWS FROM FLYWHEEL END OF ENGINE

Fig 2-10. Rotation and accessory arrangements--3-, 4-, and 6-cylinder in-line engines.

(2) Repairs to systems.

(a) Cooling system. The Detroit diesel cooling system used in Marine Corps engineer equipment is a radiator and fan-type liquid-cooling system. It consists of a radiator, fan, water pump, oil cooler, thermostat, and necessary hoses and pipes. The thermostat is probably the most troublesome part of the system (fig 2-11). It becomes inoperative and requires replacement more frequently than any of the other parts. To replace it, drain the system and remove the upper radiator hose and thermostat housing water outlet. Remove the thermostat, inspect it, and check its operation. It is checked by immersing in hot water; the thermostat should start to open at about 175° F and be fully open at about 185° F, depending on the thermostat setting. The opening temperature is usually stamped on the thermostat. If the thermostat is satisfactory, check the way it was installed and the type used. It should be installed so that the flow of water will assist opening and it should not bind or rub any of the other parts. Some of the thermostats have a small opening so that some of the coolant can circulate through the radiator when the thermostat is closed; do not use a substitute that does not have the opening. Defective thermostats are discarded and replaced. Place a new thermostat in the thermostat housing, replace both gaskets, and install the thermostat housing water outlet. Install the hoses and refill the cooling system. Some engines require the vent on the thermostat housing to be opened when filling. The water pump, which is mounted on the front of the blower and driven by the lower rotor, circulates the water through the engine and the radiator when the thermostat is open. There are no repairs to the water pump itself; leaks between the pump and other parts can be repaired, but the pump assembly requires replacement. Leaks can often be stopped by tightening, but replacement of parts requires draining of the system and removal of the defective parts. To remove the pump, loosen and slide the hose toward the pump, remove the bolts from the outlet flange behind the pump, and the pump mounting bolts from the blower. Withdraw the pump assembly and inspect it and the drive connections. While the pump is off, replace the water slinger on the pump intermediate coupling and replace any defective parts. The slinger is secured to the coupling by an Allen setscrew that screws into the blower shaft. Install new gaskets and packing on the pump assembly and install; be sure the coupling mating lugs are properly alined. The outlet packing is installed between the flange and the engine block; a gasket is also used between the flange and the block. After the pump has been installed, all bolts tightened, and hoses replaced, refill the system with the proper coolant.

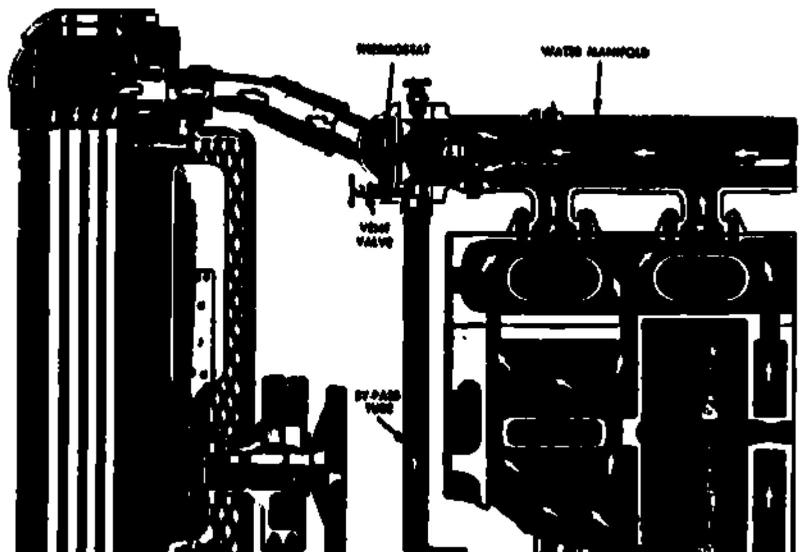


Fig 2-11, Typical cooling system with radiator and fan.

(b) Lubrication system. Figure 2-12 illustrates the flow of oil through a typical series 71 lubricating system. It includes the various components such as the oil pump, oil cooler, bypass and full-flow filters, the pressure regulator valve, and the bypass valve. Most problems with the lubricating system are caused by clogged systems, leaks, and worn or defective parts which usually cause low oil pressure. Some of the problems can be located by attaching an oil-leak detector to the main oil gallery, removing the oil pan, and observing the amount of oil that drips from the pressure-lubricated parts while oil under pressure is being forced through the system. A clogged system will reduce the pressure and slow the flow of oil. Sludge and other debris builds up in the small passage and either reduces the oil flow or stops it completely. The oil passages should be thoroughly cleaned each time the component is removed and when the engine is disassembled. Solvent can be forced through the passages for cleaning and then air to blow out any loose particles. Remember that those particles may lodge at one of the vital parts such as the crankshaft or camshaft bearings. They would then act as an abrasive and destroy the bearing. Defective valves in the system will also cause low oil-pressure readings. The valves usually stick open because of a clogged system, scored and binding valve parts, or weak or broken springs. The valves are usually replaced as a part of another component rather than repaired. Parts that are pressure-lubricated will wear, reducing the amount of restriction on the oil flow. This allows the oil to flow through the path of least resistance and reduces the pressure reading. The system is designed to lubricate properly when the bearing clearance is within specifications and the proper grade of oil is used. If the leak detector forces too much oil by the bearing, measure the shaft and check the clearance between the shaft and the bearing. The clearance can be checked by measuring the shaft and the bearing or by placing a piece of plasti-gage between the bearing and the shaft, and applying torque to the bolts. Remove the plasti-gage and measure it to determine the clearance. Plasti-gage cannot be used on solid bearings such as the camshaft; they must be measured. The bearings are replaced in sets; replace all main bearings, or all connecting rod bearings, or all camshaft bearings, or all balancer shaft bearings. The oil pump, which is mounted on the Nos. 1 and 2 main bearing journal, circulates the oil through the system and very seldom causes trouble. Shims are placed between the mounting base of the pump and the journals to aline the pump and provide the clearance between the pump gear and the crankshaft gear. Any time the pump is removed, mark the shims and keep them in separate shim packs so they can be reinstalled in the same position. The clearance of the gears must be checked after each installation even if the old parts are used. The oil pump assembly is replaced as a unit. The oil pump intake screen should be cleaned each time the oil pan is removed. Some problems are caused by defective indicators, or leaky, crimped, clogged, or defective lines or conductors. Tightening will often stop leaks at a connection. Clogged lines can be blown out. Other defects in lines will require replacement. Electrical test equipment is required to test electrical-type pressure indicators. Electrical connections can be cleaned and tightened. Broken conductors must be repaired or replaced. Short circuits can sometimes be repaired by wrapping with tape. Loose gaskets and worn seals are responsible for most oil leaks. Any loose connection should be tightened to specifications during inspections. The seals must be checked closely during repair to determine if they are serviceable. The seals sometimes dry and become hard or collect abrasives and wear. They are designed to provide a close fit between the soft seal lip and a moving metal part. Except in rare instances, the lip is installed so that it faces the oil, They are pressed into a recess, bolted into a seal retainer, or placed in grooves. The rear oil seal of the series 71 Detroit diesel engine is a 2-piece seal that fits into a groove of the crankcase and the rear bearing cap. The seal can be removed and replaced without removing the crankshaft. Force the old seal out as the crankshaft is rotated and install the new by forcing it into the groove as the crankshaft is rotated. Some of the rear oil seal will require trimming so that the bearing cap will fit properly, but do not trim too much or the seal will not stop the leak. If the mating parts are badly grooved or scored they must be replaced or repaired before the seal will be effective.

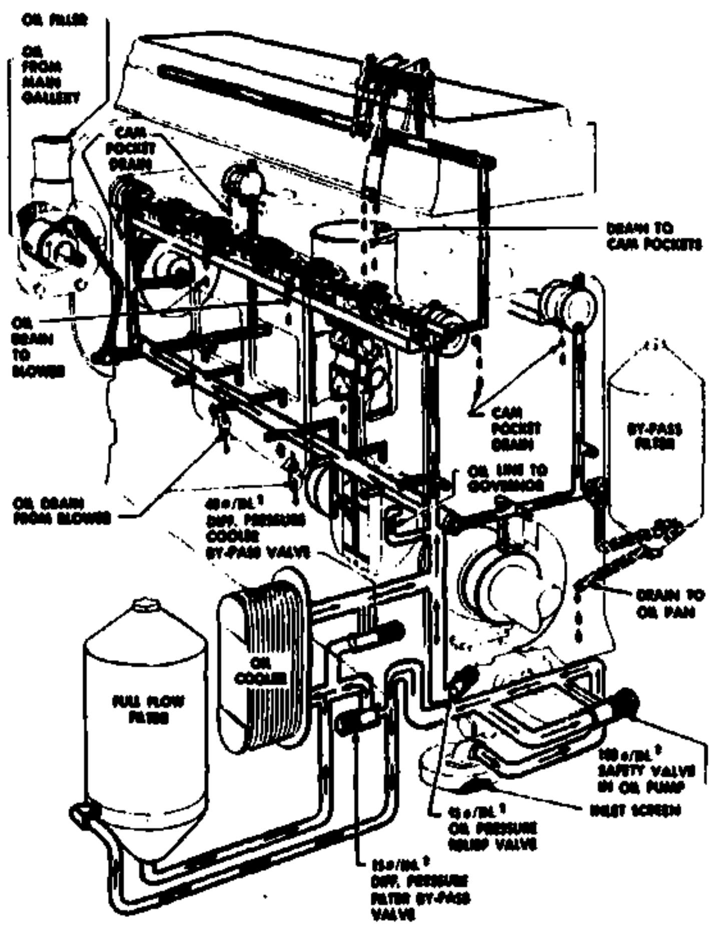
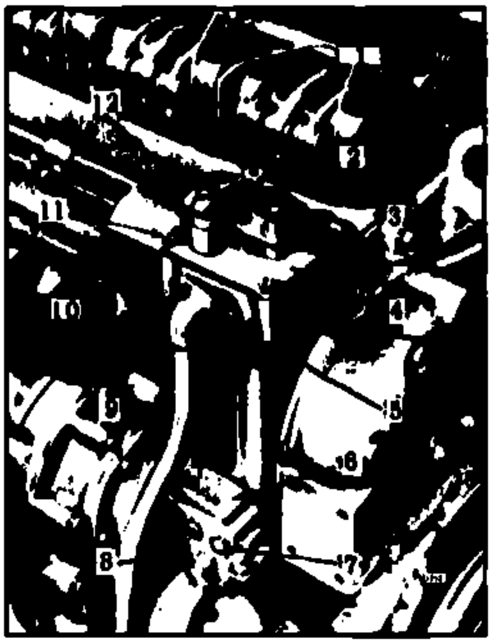


Fig 2-12. A typical series 71 lubricating system.

(c) Air intake system. The importance of an adequate supply of air for the Detroit diesel engine cannot be overemphasized. Many engine problems are caused by lack of air. Most engines are equipped with an oil bath or dry type of air cleaner and a blower or turbocharger. Clean air is drawn in by the blower and compressed to approximately 7 psi in the air box. If any part of the air cleaner or connections becomes clogged or fails to clean the air, the blower will fail to function properly. It cannot draw in a sufficient quantity of air or the dirt that gets through will score the blower rotors and other engine parts. A restriction on the suction side of the blower will put a strain on the blower oil seals. It is possible for the blower to draw the oil through the seals and force it into the engine. Clogged air box drains will cause the blower to create excess pressure which would blow out the blower seals or the handhole cover gaskets. The air cleaner oil pan should be checked daily and the air cleaner assembly thoroughly cleaned, dried, and serviced quarterly. The suction side of the air intake system should be cleaned when the engine requires major repairs. Dirt builds up in the passages and partially restricts the air flow. The air box and drains should be checked quarterly and cleaned if necessary. When the handhole covers are removed, inspect the inlet ports of the cylinder liners; rotate the engine and inspect the piston rings. The blower rotors can be inspected by removing the air inlet housing and rotating the engine. Operation of the emergency shutoff can also be checked. The blower is replaced as a unit rather than repaired. It is usually easier to remove and install the blower, water pump, governor drive, and the fuel pump as a group. The water pump and other components can be removed after the blower is removed from the engine. Before attempting to remove the blower, be sure all bolts and connections have been removed. The blower slides forward and then is lifted away from the engine.

Remember that a new blower must be ordered that will work for the specific engine: correct rotation, mounting, and drive. Replace all gaskets before attaching the driven components and mounting the blower. Install a new seal and clamp over the end of the drive gear. Aline the drive gear and blower drive coupling by rotating the blower and sliding it into place. Be sure all foreign matter has been removed from the blower and all connections are made before cranking or turning the engine or component: stop the engine immediately and investigate the cause of any unusual noises. Check for air leaks at the air box and possible leaks between the air cleaner and the blower.

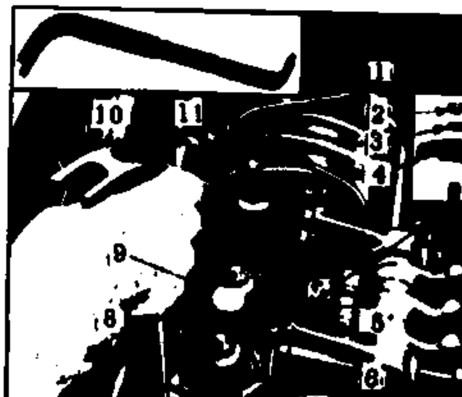
(d) Fuel system and governor. Because the fuel system and governor are so closely related, they are grouped together here. Even though they are separate systems, the governor helps control the amount of fuel that is injected into the engine. The governor is driven by the front of the upper blower rotor. More than one governor is used to control some engines. There are several types of governors used with the Detroit diesel engines and too much space would be required to discuss removal, installation, and adjustment procedures for each. Therefore, it will be necessary for you to refer to the specific TM for governor information. The controls that control it are removed. Figure 2-13 shows how the governor is mounted and attached to the fuel injector control racks; components of the fuel system were shown in figure 2-9.



1. Injector control tube lever
2. Fuel rod
3. Bolt
4. Governor cover
5. Governor control housing
6. Weight housing
7. Bolt
8. Weight housing cover
9. Bolt
10. Breather tube
11. Screw
12. Throttle control lever

Fig 2-13. Typical limiting speed governor mounting.

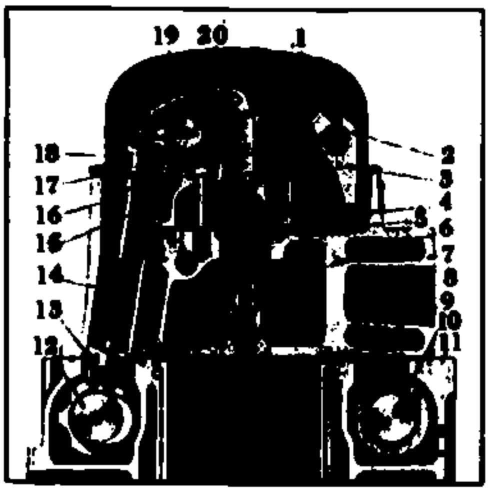
Some vehicles are equipped so that the fuel can be drawn from either a drum or the vehicle fuel tank. Such vehicles are equipped with the necessary connections and a 3-way control valve located between the supply tank and the fuel strainer. The fuel supply pump draws the fuel through the open passage in the valve. A leak at the connections, strainer, or the valve on the suction side of the pump will allow it to draw in air and cause the engine to malfunction. These leaks are hard to detect and may require putting pressure on the fuel on the suction side while the engine is stopped. Do not use too much pressure or the fuel supply pump seals will be damaged. The lip of these seals faces away from the fuel and a leak can be started easily. Leakage of more than one drop per minute is excessive and requires removal of the pump and replacement of the seals. The positive-displacement pump is driven by the blower lower rotor. It is attached to the rear of the blower. A satisfactory pump will deliver 1 gallon of fuel per minute through the fuel-return tube with the engine operating at 1,200 rpm. The relief valve in the pump assists in maintaining 40 to 60 psi in the fuel inlet manifold with the engine operating at 1,800 rpm. Any restrictions in the lines, strainer, filters, or a faulty relief valve will reduce the fuel flow and the pressure. A restricted elbow located in the end of the outlet manifold also helps maintain the pressure. It cannot be replaced by a substitute. The relief valve remains closed until the specified pressure is reached, then it opens and allows the fuel to return to the inlet side of the fuel supply pump. This keeps the pump from building up excessive pressure and destroying itself should the system become clogged. Dirt and water should be drained from the strainer and filter daily by opening the drain valve at the bottom of each housing and allowing about 1/4 pint of fuel to drain. The strainer and filter should be changed every 500 hours when operating under normal conditions. Some of the later model engines are equipped with a gage that shows when they should be changed. The fuel supply pump is replaced as a unit except the relief valve which can be checked and replaced without removal of the pump assembly. The supply pump seals can also be replaced, but removal of the pump is necessary. The fuel lines are disconnected from the pump and the pump disconnected and removed from the blower. Special tools are required to remove and install the seals. The injectors receive their supply from the inlet manifold and permit the excess fuel to flow through to the outlet manifold. They are located under the rocker cover with the valve mechanism between the valves of the 2-valve (two exhaust valves per cylinder) head. They can be repaired, but are replaced as a unit by repair organizations because the facilities, test equipment, special tools, and skilled personnel to perform the repairs are not available. The injectors used in an engine must be the same size; mixing them will cause erratic engine operation. Each injector has its size and type stamped on a tag pressed into its body. The injector can be checked by holding down on the follower, which will cause the engine and injector to function similarly to a shorted spark plug in a gasoline engine. If the injector is good, the operation of the engine will change when the follower is held down so that the injector fails to function; a defective injector will not change the engine operation when the follower is held down. The injector is removed by removing the rocker covers, rocker arms, injector connector (jumper) tubes, and clamp and then prying it up (fig 2-14).



1. Fuel inlet (supply) pipe
2. Stud nut
3. Clamp washer
4. Injector clamp
5. Rocker arm shaft bracket
6. Fuel pipe connector
7. Shaft bracket bolt
8. Shipping cap
9. Injector assy
10. Injector-remover tool J 1227-01
11. Fuel outlet (return) pipe

Fig 2-14. Injector location, removal, and removal tools.

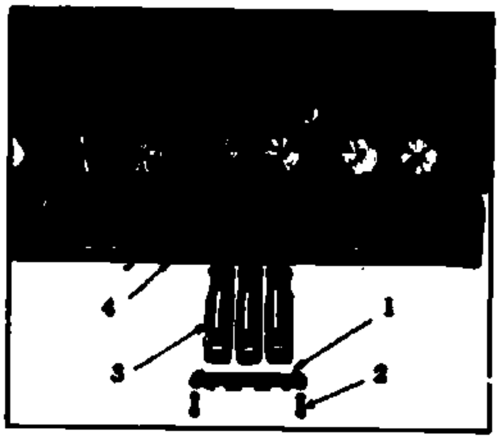
All openings are covered after a tube is disconnected or the injector is removed to keep out foreign matter. After removal, the injector is tested to determine if it is still serviceable. Before installing an injector, be sure the injector hole tube (located in the cylinder head) is clean to permit proper installation and sealing. Be sure the dowel pin hole is clean and will permit the injector to seat properly. Install the injector and clamp, then torque the bolt to specification. Reassemble and adjust the rocker arms; be sure the special bolts are used to hold the rocker brackets or the lubrication system will not function properly. Install the injector connector tubes (fig 2-15). These must be installed with care because any fuel leakage would dilute the engine oil. After the injector unit has been installed and connected, it must be timed, the control rack set, and governor adjustment checked. The timing is adjusted by shortening or lengthening the push rod for the injector rocker. A special tool is set into a recess to check the setting. When making the timing, control rack, and governor settings, follow the procedures outlined in the TM. It is important that the procedures be followed step by step.



1. Injector assembly
2. Injector control tube
3. Rack lever
4. Injector control rack
5. Tube seal ring
6. Injector hole tube
7. Cylinder head
8. Cylinder liner
9. Cylinder head gasket
10. Balancer shaft
11. Cylinder block
12. Camshaft
13. Cam follower
14. Follower spring
15. Injector clamp
16. Push rod
17. Locknut
18. Rocker arm clevis
19. Rocker arm shaft
20. Injector rocker arm

Fig 2-15. Fuel injector mounting.

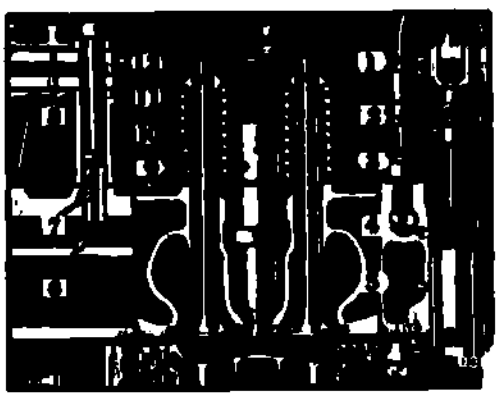
(e) Cylinder block and head. Good judgment and a close inspection will help determine how many parts and components must be removed to correct cylinder block and cylinder head defects. For example, there is no need to remove the engine assembly to repair the cylinder head if there is enough room to remove the assembly. The head is removed to repair or replace valves, gaskets, water nozzles, and other defective cylinder head parts. The cylinder head assembly must be handled with care because of the protruding parts on the top and bottom. The cam followers and the injector tips protrude through the bottom of the cylinder head. The cam followers can be removed from the cylinedr head after the head has been removed from the engine. Figure 2-16 shows these parts for a 2-valve head. After the cylinder head is removed from the engine, the



1. Cam follower guide
2. Cam follower guide bolt
3. Cam follower
4. Cylinder head

Fig 2-16. Cam follower and retainer assembly.

valve parts, valves, and injector parts can be removed, cleaned, inspected, and repaired or replaced as needed. Again it is necessary to check the parts, their position, and location as they are removed. (Note the special bolt that provides lubrication for the valve operating mechanism in figure 2-17.) Check the type of washers and seals or gaskets used as the parts are removed. The water openings in the head can be plugged



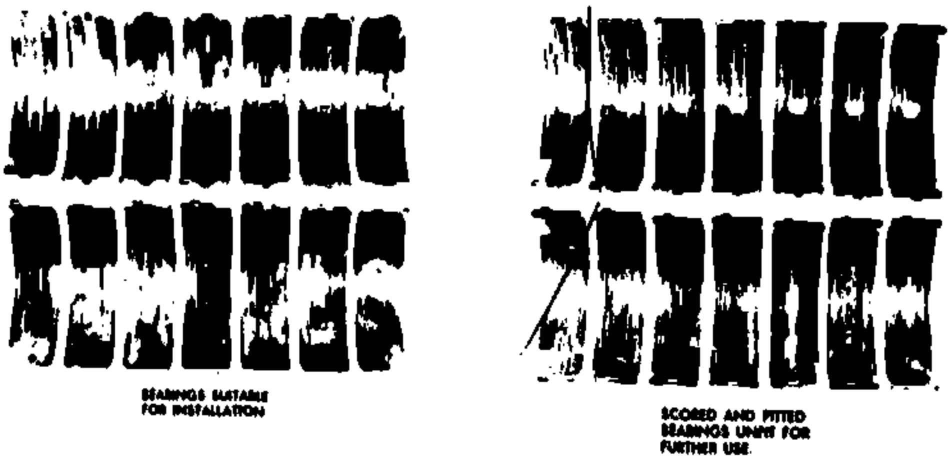
1. Rocker arm
2. Push rod
3. Exhaust valve spring
4. Push rod spring
5. Cam follower
6. Cylinder head oil passage
7. Bracket bolt oil passage
8. Rocker shaft oil passage
9. Exhaust valve
10. Exhaust valve guide
11. Rocker shaft bolt
12. Rocker arm shaft

Fig 2-17. Lubrication of valve operating mechanism.

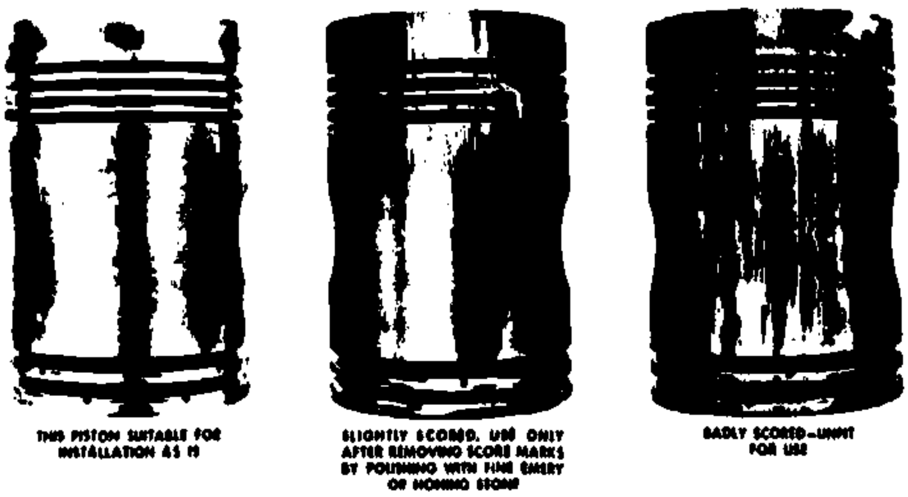
and pressure can be applied to test for leaks. Some leaks can be detected by sight; cracks usually appear at or near the valve seats. After the valve springs are removed, the valve face, stem, seats, guides, and spring tension can be checked and repaired or replaced. Replace those parts which cannot be repaired to specifications listed in the TM. Any repair or replacement of parts within the cylinder block, with few exceptions, requires removal of the engine from the vehicle frame. Since the Detroit diesel engine can be used in a variety of equipment, check the TM for removal procedures.

Repeat warning: Make sure that all connections are free before attempting to remove the engine.

After removal from the vehicle frame, remove the necessary components and place the engine in a suitable position for it to be worked on safely. Good judgment will help determine what parts must be removed. For example, the connecting rod bearings can be replaced by removing the oil pan and rod bearing caps, but removal of all these plus the front end plate, flywheel, rear end plate, oil pump, and main bearing caps is necessary to replace the crankshaft and main bearings. When removing the parts from the cylinder block, pay particular attention to the position and location of the camshaft, balancer shaft and weights, connecting rod and main bearing cap markings, timing marks. crankshaft thrust bearing, and the thrust plates. The piston and connecting rod are removed through the top of the cylinder block. To prevent damage to the piston rings, the carbon and ridge at the top of the cylinder liner are removed before removing the piston. Check the condition of the piston, rings, rod bearings, crankshaft journal, and cylinder liner; measure them to see if they meet specifications. Figure 2-18 illustrates some used parts that are serviceable and unserviceable. The bearings should be kept in sets and with the same connecting rod if they are to be used again. New rings can be installed on serviceable pistons and in serviceable liners if the glaze on the used liner is broken; new and used pistons, piston rings, and liners can be mixed in the Detroit diesel engine. Failure to break the glaze lengthens the time required for the new rings to seat. A hone with 120 grit stone or emery cloth can be used to break the glaze. The honing or sanding operation is performed in such a way as to leave a crisscross pattern the full length of the liner. After breaking the glaze, the liner must be measured again. When replacing the piston rings, it is important that the graves are clean, the rings installed properly and in the correct groove, and that they have the specified clearance and ring gap. Some piston rings are marked with letters denoting top while others have chamfered edges or other marks which must face in the proper direction. In the military, it is advisable to replace the rings on all pistons and other unserviceable parts whenever one requires replacement, if time permits. If only one ring on a piston is defective, all rings on that piston must be replaced even if the other pistons are not removed. The pistons and liners can be replaced individually if replacement parts are the same type as the others. All new and repaired parts are cleaned, dried, and lubricated (except as noted) before assembling and installing. A special puller is used to remove and install the liners. The liners are chilled for 2 hours (in dry ice preferably) and the engine block heated in a tank of 180° F water for 20 minutes prior to liner installation. The chilling and heating operation is timed so that the block is removed from the water just prior to installation of the liner. No lubrication is used when installing the liners in the block; they are cleaned and dried. It may be necessary to lightly tap the liner in a block using the same tool that was used to remove it. Handle the chilled liners with care as cold parts are easily cracked or broken. To measure the crankshaft main bearing journals and replace the main bearings, the crankshaft must be removed. The main bearings are replaced as a set with the grooved part of the shells installed in the upper part of the block. Note the position and location of the crankshaft thrust bearing. Before starting reassembly, be sure that all oil and water passage plugs are tight. Reassembly is reverse of disassembly. When reassembling, install the parts in their proper location and position them properly. Use new gaskets where gaskets are required. Check



A. Comparison of main bearings.



B. Comparison of pistons.

Fig 2-18. Serviceable and unserviceable engine parts.

the fit of new and repaired parts and torque all bolts to specifications. Be sure that all locking devices are the correct type and size, and are installed properly. For example, don't try to use a star lockwasher where a spring-type lockwasher should be used. Use gasket cement or other gasket sealing material only on those gaskets specified in the TM. The clearance and sealing of some of the Detroit diesel engine parts is critical and use of the compounds is important.

(f) Tuneup and run-in. All engines, new or rebuilt, should be run-in and adjusted prior to releasing them for field operations. This insures that the engine is properly adjusted for the type application and gives the new parts time to seat properly before being subjected to heavy loads. The TM also specifies that certain nuts and bolts be retorqued after a specified number of operating hours. Some torque specifications require the engine to be at operating temperature. By running the engine in a test stand or in the vehicle while in the shop, it can be observed and broken in under controlled conditions. After the engine has been run-in, adjusted, and inspected, a quarterly service and inspection is performed. The engine is then ready for release to the using unit.

d. Troubleshooting and diagnosis charts. The charts below do not list the symptoms and causes in the order of most frequent occurrence. When troubleshooting a diesel engine, keep an open mind and consider all possibilities. Listen closely to the complaint given by the operator; study the reported symptoms, locate the cause and correct it. The equipment operator should accurately report the trouble symptoms to the administrative unit. The administrative unit then takes prompt action in scheduling repairs.

Table 2-2. Troubleshooting Chart for the Diesel Engine

Symptom	Probable cause	Corrective action
1. Engine fails to turn		
a. Cranking motor inoperative	1. Master switch off.	1. Turn on and make sure it is functioning properly.
	2. Start switch off.	2. Turn on and make sure it is functioning properly.
	3. Transmission controls not in neutral,	3. Place controls in neutral and attempt to crank.
	4. Corroded or loose terminals.	4. Check, clean, and tighten.
	5. Broken conductors.	5. Replace.
	6. Battery output low.	6. Recharge or replace battery(ies).
b. Engine oil too heavy for temperature	1. Incorrect viscosity oil.	1. Drain and refill with proper-grade oil.
c. Internal seizure	1. Broken or damaged parts or fluids in cylinders.	1. With clutch disengaged, transmission in neutral, attempt to turn engine. Failure to turn indicates damage requiring repair beyond organizational level.

Table 2-2. Troubleshooting Chart for the Diesel Engine--contd

Symptom	Probable cause	Corrective action
2. Engine turns but fails to start		
a. Low engine cranking speed	1. Battery output low	1. Check, clean, and tighten cable connections. Recharge or replace battery(ies).
	2. Improper lubricating oil	2. Drain and refill with proper-grade oil.
	3. Defective cranking motor.	3. Check and replace if needed.
b. Sufficient cranking speed	1. Emergency shutdown closed.	1. Push in emergency knob on instrument panel. Open air shutdown at the engine.
	2. No fuel or incorrect fuel.	2. Check fuel level and fill with correct fuel if required. Drain off water and residue at fuel tank, fuel filter, and fuel strainer.
	3. Air in fuel system or fuel lines restricted,	3. Perform a fuel test by disconnecting the return line at the fuel tank and, if there is sufficient fuel, check the fuel lines for leaks or kinks and repair. Replace fuel filter elements if needed and fill the strainer about 2/3 full of clean fuel. If flow is still unsatisfactory, the fuel pump should be changed by field maintenance.
	4. Improperly timed injection pump.	4. Retime injection pump to engine.
	5. Injection nozzles not functioning properly.	5. Use clean fuel. Vent system. Replace nozzles if needed.
c. Insufficient engine power	1. Clogged air cleaner and intake.	1. Check, clean, and service.
	2. Exhaust back pressure.	2. Check and correct.
	3. Insufficient fuel.	3. Perform fuel flow test.
	4. Incorrect engine adjustment.	4. Adjust exhaust valve clearance. Adjust injector timing.
3. Engine does not develop full power--uneven operation		
a. Insufficient air to engine	1. Clogged air intake system.	1. Remove, clean, and service air cleaner.
b. Air leaks around intake	1. Loose bolts and nuts.	1. Tighten to proper torque.
	2. Defective gasket.	2. Refer to field maintenance for replacing.

Table 2-2. Troubleshooting Chart for the Diesel Engine--contd

Symptom	Probable cause	Corrective action
c. Poor fuel	1. Improper grade.	1. Drain and refill with proper grade of fuel.
d. Air in fuel system	1. Leaks in fuel system.	1. Repair leaks; vent fuel system.
e. Internal wear or damage	1. Defective valves or pistons.	1. Refer to field maintenance for repair.
4. Engine noises		
a. Sharp rap at idle	1. Loose piston pin.	1. Locate faulty pin by short-circuiting spark plugs or venting nozzles until noise stops. Refer to field maintenance for repairs.
b. Flat slap when increasing speed under load	1. Piston slap.	1. Refer to field maintenance for repair.
c. Metallic knock when idling or slowing down that disappears under load	1. Faulty connecting rod bearing.	1. Refer to field maintenance for repair.
d. Constant knocking	1. Low engine-oil level. 2. Overheating.	1. Check and fill to proper level. 2. Check coolant and oil level. Refill to correct level.
e. Constant rapid clicking	1. Incorrect valve adjustment.	1. Adjust to specified clearance.
f. Combustion knock	1. Improper engine temperature. 2. Poor fuel or water in fuel. 3. Incorrect injection timing. 4. Defective injection nozzle.	1. Keep temperature at operating range. 2. Drain and refill with proper grade of clean fuel. 3. Retime injection pump to engine. 4. Replace nozzle.
5. Low engine oil pressure	1. Insufficient oil. 2. Incorrect oil. 3. Defective pressure gage and lines. 4. Poor circulation.	1. Fill to correct level. 2. Drain and refill with proper grade oil. 3. Check pressure gage and lines; replace if needed. 4. Replace engine-oil filter elements.

Table 2-2. Troubleshooting Chart for the Diesel Engine--contd

Symptom	Probable cause	Corrective action
6. Loss of engine oil pressure		
a. Low oil level	1. Normal use or leaks.	1. Determine cause and fill with proper grade of oil.
b. Clogged oil filter elements	1. Operation in dusty conditions and not changed often enough.	1. Change filter elements.
c. Defective oil-pressure indicator or line	1. Broken indicator. 2. Crimped or broken line.	1. Replace. 2. Replace.
7. Excessive engine oil consumption		
a.	1. Operating on excessive slopes. 2. Overfilling crankcase.	1. Restrict slope operations to recommended limits. 2. Fill to specified level. Drain to correct level if overfull.
b. External leaks	1. Loose, cracked, or damaged parts. 2. Excessive crankcase pressure.	1. Check, tighten, and/or replace the defective parts around the oil pan, valve covers, filters, and hoses. 2. Refer to field maintenance if repairs are required. Clean air box drains.
c. Internal leaks	1. Defective gaskets or oil cooler.	1. Check radiator for signs of oil. Refer to field maintenance if repairs are required.

2-4. COOLING SYSTEMS

a. General. Problems with the engine cooling system can be reduced to one problem, overheating. Troubleshooting for correction of overheating should not be confined strictly to the cooling system as other vehicle components can also cause this condition. See table 2-3 for troubleshooting procedures. The most common cause of engine overheating is shortage of coolant. There are many causes of overheating that are easily confused with coolant shortage, since this condition always follows overheating after the coolant begins to boil violently. As a practical guide, all overheating can be divided into three general types based on the following conditions preceding overheating: coolant shortage from overflow loss, coolant shortage from leakage, and no coolant shortage. Determine which of these three conditions existed before boiling occurred. All causes of overheating finally result in violent boiling and coolant overflow loss. Therefore, it is not safe to assume that coolant shortage was the original cause of overheating, merely because the coolant level is low when the overheating is discovered. To determine for sure whether the overheating is due to shortage of coolant and not something else, the test must begin with the coolant at the correct height in the radiator and the coolant temperature must be well below the boiling point. Then run the engine until it overheats. During the time the engine is being run, it can be determined if leakage or overflow loss occurs before the coolant boils. In the following paragraphs we will cover some of the problems in the cooling system.

b. Preliminary diagnosis. The preliminary troubleshooting is done with the engine running--vehicle stationary. Check the coolant level frequently to see if it rises or drops noticeably before the boiling temperature is reached. At the same time, watch the engine temperature gage to keep track of the rise in coolant temperature. The type of overheating is determined by observing whether coolant shortage from overflow loss or leakage takes place before boiling. It is also a good idea to inspect the entire cooling system during this stage as a broken fan belt, for example, could cause overheating, but would be relatively simple to remedy.

c. Preliminary road test. Since the preliminary diagnosis is made with the vehicle standing without any load on the engine, its usefulness is limited. A road test which duplicates operating conditions is often required to determine the type of overheating.

Table 2-3. Overheating and Overcooling Diagnosis Procedure

Diagnosis	Condition	Corrective action
a. Preliminary.	1. Coolant level.	1. Check coolant level. Refill if necessary.
	2. Defective pressure cap, gasket, and seat.	2. Replace defective parts.
	3. Faulty fan and water pump belt.	3. Adjust or replace as required.
	4. Incorrect oil level.	4. Examine dip stick for low or unusually high oil level. If too high, check for internal leaks.
	5. Frozen coolant.	5. Thaw cooling system according to procedure outlined in vehicle TM.
	6. Clogged radiator and air passages.	6. Clean and straighten fins. Feel radiator core for cold spots that would indicate clogging. Refer to higher echelon.
	7. Collapsed upper and lower hoses.	7. Replace as necessary.
	8. Coolant foaming.	8. Replace coolant and repeat test.
	9. Coolant level rise or drop.	9. Watch radiator filler neck; if abnormal rise is noted, follow overflow loss diagnosis procedure. If abnormal drop is noted, follow leakage diagnosis procedure.
	10. High level coolant boiling.	10. Follow diagnosis procedure for overheating not preceded by coolant shortage.
b. Overflow loss.	1. Pressure cap, gasket, and seat.	1. Test pressure. Clean seat. Replace gasket.
	2. Upper radiator tank baffle loose.	2. If baffle is loose, refer to higher echelon.
	3. Leaks above coolant level.	3. Locate and correct leaks.
	4. Defective upper and lower radiator hoses.	4. Remove and examine, replace if necessary.
	5. Removed thermostat.	5. Reinstall thermostat.
	6. Loose or worn water pump drive belt.	6. Tighten or replace.

Table 2-3. Overheating and Overcooling Diagnosis Procedure--contd

Diagnosis	Condition	Corrective action
b. Overflow loss	7. Combustion gas leakage.	7. Correct as outlined in equipment TM.
	8. Faulty thermostat valve operation.	8. Replace thermostat if valve is defective.
	9. Clogged coolant passages.	9. Remove cylinder head and inspect for clogged water transfer holes, nozzles, and other passages. Determine if correct head gasket was used and properly installed. Correct any troubles found.
c. External leakage	1. Leaking hoses, pipes, or connections.	1. Tighten or replace.
	2. Leaking radiator core, seams, tanks, and joints.	2. Replace radiator.
	3. Leaking water pump shaft and housing.	3. Repack seal or replace pump.
	4. Leaking thermostat housing.	4. Replace gasket.
	5. Leaking cylinder head joint.	5. Tighten or replace gasket.
	6. Leaking cylinder head bolts or studs.	6. Tighten or remove and seal threads or replace.
	7. Leaking core hole plugs or drain cocks.	7. Tighten or remove and seal threads or replace.
	8. Cracks in engine block or head casting.	8. Replace head or engine.
d. Internal leakage	1. Internal water jacket leakage.	1. Remove cylinder head, check head gasket, head, and block gasket surfaces, cylinder bores, combustion chamber, and water jacket for evidence of leaks, blowby coolant obstructions, and any other defects. Note whether gasket was properly installed.
e. Overheating-no coolant shortage	1. Obstructions and faulty conditions.	1. Clean passages, brush guards, shutters, and air inlet screens. Straighten radiator air baffles, fins, and fan shroud.
	2. Worn or faulty fan blades, fan shaft, and bearing.	2. Check blades for pitch and tightness. Check shaft and bearing for wear and end play. Repair or replace as necessary.
	3. Faulty ignition timing, centrifugal and vacuum spark advance.	3. Adjust ignition timing.
	4. Faulty exhaust system.	4. Check exhaust system for back pressure. Replace defective part or refer to higher echelon.

Table 2-3. Overheating and Overcooling Diagnosis Procedure--contd

Diagnosis	Condition	Corrective action
e. Overheating-no coolant shortage	5. Loose water pump drive belt.	5. Tighten or replace if necessary.
	6. Faulty temperature gage	6. Test and replace if necessary.
	7. Collapsed upper or lower radiator hoses.	7. Replace if necessary.
	8. Faulty thermostat.	8. Test and replace if necessary.
	9. Clogged radiator.	9. Test radiator for clogged condition by observing gravity flow from outlet. Flush if necessary.
	10. Clogged coolant passages.	10. Remove cylinder head and clear clogged water transfer holes, nozzles and other passages.
	11. Faulty valve timing.	11. Adjust timing as required.
f. Overcooling	1. Faulty thermostat.	1. Test thermostat and replace if it is defective.
	2. Faulty temperature gage.	2. Test gage and replace if defective.
	3. Extremely cold weather, underloading, or short operating periods.	3. Partly shield radiator. Operate engine until it is at proper temperature.

d. Special troubleshooting instructions.

(1) Frozen coolant. Frozen coolant may be checked by examining the coolant in the upper radiator tank or by attempting to draw it into a hydrometer or by opening a drain cock. Squeezing the radiator hose is not a dependable test. because the hose may feel hard when cold even though the coolant is not frozen.

(2) Thaw solid freeze-up. If water is allowed to freeze solid in the cooling system, the practical way to thaw it out, without causing further damage to the engine or cooling system, is to allow the vehicle to stand in a warm place or keep the cooling system warm until all the ice is melted. Under no circumstances should operation of the engine be attempted with the coolant frozen solid.

(3) Thaw slush freeze-up. At temperatures below the freezing point of antifreeze solution there is no solid freezing, but a mass of small ice crystals is formed in the solution which may stop circulation through the radiator. The safest way to thaw out a slush freeze-up is to stand the vehicle in a warm place without running the engine, if certain precautions are followed:

Cover radiator and loosen pressure cap until it reaches VENT position.

With vehicle standing. run the engine as slowly as possible.

Watch the temperature gage closely and stop the engine whenever the gage indicates that coolant temperature is approaching the boiling point.

Do not attempt to drive the vehicle until the entire radiator core feels warm.

UNITED STATES MARINE CORPS
MARINE CORPS INSTITUTE, MARINE BARRACKS
BOX 1775
WASHINGTON, D.C. 20013

ENGINEER EQUIPMENT MECHANIC

Lesson 2

Engine Diagnosis and Repair

STUDY ASSIGNMENT: MCI 13.41c, Engineer Equipment Mechanic, chap 2.

LESSON OBJECTIVE: Successful completion of this lesson, combined with on-the-job training using the principles presented, will enable you to diagnose gasoline and diesel engine problems and perform the necessary repairs.

WRITTEN ASSIGNMENT:

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

Value: 1 point each

1. The act of recognizing a problem from the symptoms is known as

   a. diagnosing.
   b. troubleshooting.
   c. adjusting.
   d. repairing.

2. How can the operator assist you in diagnosing engine malfunctions?

   a. By performing the daily maintenance
   b. By providing the equipment specifications
   c. By providing the necessary tools and equipment for repairs
   d. By explaining the action of the engine

3. If a battery-cranked engine fails to crank, what check do you make first?

   a. Method of cranking
   b. Battery cable connections
   c. Starting circuit
   d. Defective attachment

4. Which will NOT affect starting of a gasoline engine that is being cranked at the proper speed?

   a. Air-fuel mixture
   b. Spark across the spark plug air gap
   c. Compression of the air-fuel mixture
   d. Amount of oil in lubrication system

5. Removing a high-tension lead and checking the spark as the engine is cranked will NOT indicate

   a. spark plug condition.
   b. that the coil is functioning.
   c. that the contact points are functioning.
   d. that the magneto is functioning.

6. When the gasoline engine is cranking at the proper speed and there is no spark at the high-tension lead, what is the first check to be made?

a. Battery
b. Coil
c. Conductors
d. Moisture

7. The spark plugs in a gasoline engine that is using an excessive amount of oil will have

a. blisters on the porcelain.
b. scales on the porcelain.
c. an excess of dark oily carbon.
d. badly burned electrodes.

8. What is NOT indicated by a low-compression reading?

a. Carbon deposits
b. Defective valves
c. Defective rings
d. Defective head gaskets

9. What is the first check made to locate the cause of high oil consumption?

a. Compression test
b. Visual inspection for leaks
c. Crankcase ventilators
d. Spark plug condition

10. Overheating of a liquid-cooled gasoline engine is usually caused by insufficient engine oil, insufficient coolant and

a. improper fuel.
b. high RPM's.
c. overloading.
d. small passages.

11. Which engine problem is the hardest to diagnose?

a. Overheating
b. Noises
c. Ignition failure
d. High oil consumption

12. A dull thud or knock heard when the engine is loaded indicates

a. loose main bearings.
b. worn wristpin bearings.
c. loose compression rings.
d. excess valve lash.

13. An engine with a metallic knock that is loudest when the engine is idling at about 2,000 rpm probably has worn

a. connecting rod bearings.
b. main bearings.
c. timing gears.
d. valve guides.

14. Which knocking noise will be more severe when a spark plug is shorted out?

a. Main bearing
b. Connecting rod bearing
c. Piston pin
d. Valve tappet

15. Which knocking noise will disappear or be reduced when a spark plug is shorted out?

a. Piston pin
b. Valve tappet
c. Flywheel
d. Main and connecting rod bearing

16. What is the first check to make if a squeaking noise is heard when an engine is accelerated rapidly?

a. Water pump
b. Fan belts
c. Gear train
d. Generator

17. Low oil pressure, combined with a knocking noise, would probably indicate a

a. worn main bearing.
b. clogged oil filter,
c. defective oil pump.
d. defective relief valve.

18. In a gasoline engine, what is the most common cause of loss of power?

a. Misfiring cylinders
b. Worn main bearings
c. Worn rod bearings
d. Worn piston pins

19. If there is doubt about the serviceability of a sealed component, what should be done?

a. Disassemble and repair it.
b. Replace it or refer to the proper echelon for repair.
c. Reinstall the unit as is.
d. Clean, adjust, reseal, and install.

20. What could happen if a spark plug is overtightened?

a. The spark plug would be distorted.
b. A perfect seal for compression would be provided.
c. The engine would produce more power.
d. It would prevent exhaust gases from escaping.

21. On the Briggs and Stratton gasoline engine, the crankshaft end play is adjusted by

a. adding or removing gaskets.
b. adding or removing shims.
c. using undersize or oversize thrust bearings.
d. using the adjusting nut on the crankshaft,

22. Which services should be performed before attempting to diagnose the diesel engine?

a. Before-operation
b. After-operation
c. Weekly
d. Quarterly

23. If a diesel engine will turn backwards, but not in the normal direction, the trouble is probably

a. a defective head gasket.
b. water in the cylinder.
c. seized main bearings.
d. defective electric starting circuits.

24. What would be indicated when a Detroit diesel engine is operating at 1,200 rpm and about one gallon of fuel per minute is returned thru the return line?

a. Bad fuel pump
b. Insufficient return flow
c. Excess return flow
d. Normal return flow

25. How will the engine respond if two different-size injectors are installed in an engine?

a. It will fail to start.
b. It will be hard to start.
c. It will operate erratically.
d. It will operate normally.

B. Matching: In each of the groups below (items 26 through 40), match the cause in column 2 with the appropriate symptom in column 1. After the corresponding number on the answer sheet, blacken the appropriate box.

Value: 1 point each

Column 1 SYMPTOM	Column 2 CAUSE
Engine fails to turn	
26. Cranking motor inoperative	a. Master switch off b. Poor fuel
27. Engine oil too heavy for temperature	c. Broken or damaged parts d. Emergency shutdown closed
28. Internal seizure	e. Incorrect viscosity oil
Engine turns but fails to start	
29. Low engine cranking speed	a. No fuel or incorrect fuel b. Incorrect engine adjustment
30. Sufficient cranking speed	c. Transmission controls not in neutral d. Battery output low
31. Insufficient engine power	
Engine does not develop full power--uneven operation	
32. Insufficient air to engine	a. Defective intake manifold gasket b. Leaks in fuel system
33. Air leaks around intake	c. Defective valves or pistons d. Clogged air intake system
34. Poor fuel	e. Improper grade fuel
35. Air in fuel system	
36. Internal wear or damage	
Engine noises	
37. Sharp rap at idle	a. Faulty connecting rod bearing b. Incorrect valve adjustment
38. Metallic knock when idling or slowing down that disappears under load	c. Loose piston pin d. Piston slap e. Incorrect injection timing
39. Constant rapid clicking	
40. Combustion knock	

Total Points: 40

* * *

Chapter 3

DIAGNOSIS AND REPAIR OF POWER TRAIN COMPONENTS

Chapter objectives: A student successfully completing this chapter will be able to identify the procedures necessary to diagnose and correct malfunctions of the:

1. clutch.
2. transmission.
3. propeller shaft.
4. differential and final drive.

3-1. GENERAL

The parts and components of a vehicle used to direct the energy produced by the engine to the part doing the work are called the power train. Webster's dictionary defines power train under two words: "power-mechanical or electrical force or energy," and "train-a series of moving pieces, as wheels and pinions, for transmitting and modifying motion." From these definitions, you can see why the energy that flows from the engine to the work is transmitted through what is called the power train; the power must be modified. A device for slowly engaging the power is necessary to prevent excessive loads and shock on the engine components and the vehicle. Devices are needed to change the direction of power flow if one engine is to provide power to propel the vehicle and perform other jobs. Devices are needed to provide different power end speed requirements so that the vehicle can do more than one job economically at one time. A device is needed that will allow stopping one or more operations without interfering with another. These are called clutches, transmissions, propeller shafts, differentials, final drives, brakes, and other special-type systems. Like other vehicle components, they will develop malfunctions that you will be required to locate and repair. Diagnosing malfunctions of and repairing these components is similar to engine diagnosis and repair; follow the flow of power, isolate the problem, and perform the repairs. To properly diagnose the malfunctions and repair some of the components, you will need special tools such as pullers, measuring devices, and test equipment.

3-2. CLUTCHES

An engine has very little torque when operating at slow speeds. Also, more power is required to start moving a vehicle or its machinery than to keep it going once it is in motion. Hence, it is desirable to have a device that will allow the engine speed to be increased before it is required to start moving the vehicle or its components. But, as stated in the preceding paragraph, a sudden connection of the engine to the power train would result in a severe shock and possible damage. Such shock can be avoided by slowing the engine speed and using one of the many types of devices to connect the engine to the power train, thus gradually applying the load. The engine will not be overloaded and there will be no sudden shock. This device is called the clutch. There are mechanical, electrical, and hydraulic clutches available to perform this job. For this portion of the course, only the mechanical clutches will be discussed unless they are combined with another type for a specific application. The mechanical clutches are disk, expanding, contracting, and cone types. They operate on the principle of pressure and friction and can be used anywhere that there is a need to break the power flow in the power train.

a. Engine clutch. The engine clutch is often referred to as the master clutch. It is the main clutch between the source of power and the vehicle components. A vehicle may be equipped with any of the clutches listed above, but the plate disk type is the most popular.

(1) Mobile crane. The carrier (truck) engine clutch (fig 3-1) is of the adjustable, dry disk, push-type construction. It is model 14-ML manufactured by the Lipe-Rollway Corporation. It is a single plate clutch attached to the engine by mating the slots in the flywheel ring with the driving lugs on the pressure plate. The driven disk is splined to the transmission shaft. The driven disk is the part that connects the engine power to the transmission. Spring tension (10, fig 3-1) causes the levers to move and squeeze the driven disk between the pressure plate and the flywheel; the pressure and friction cause it to turn with the flywheel. When the spring is compressed, the pressure is relieved and retractor springs (17, fig 3-1) pull the pressure plate back and allow the driven disk to move away from the flywheel. Maintenance of this clutch, other than lubrication, is performed at the field maintenance level.

1 Engine flywheel
2 Driven disk facing
3 Facing rivets
4 Pressure plate
5 Clutch flywheel ring
6 Adjusting shims
7 Adjusting strap
8 Flywheel ring stud nut
9 Lock washer
10 Pressure spring
11 Spring equalizer ring
12 Clutch release bearing
13 Sleeve
14 Lever locking bal's
15 Adjusting plate
16 Spring retainer pin
17 Retractor spring
18 Pressure levers
19 Fulcrum rings
20 Snap ring
21 Flywheel ring stud
22 Driven disk assembly

Fig 3-1. Sectional view of the 150-T46 truck-mounted crane-shovel carrier engine clutch.

(a) Diagnosis. Most problems with the 150-T46 crane-shovel carrier engine clutch are listed under four headings: slipping, grabbing, rattling, and dragging. Although the clutch will wear from normal use, most problems are caused by improper lubrication and operation. The operator either fails to lubricate or else he overlubricates. He will drive with his foot resting on the clutch pedal and slip the clutch excessively. Slipping will wear the clutch facing and cause heat which will weaken the springs, warp the disk, and damage other clutch parts. In the discussion that follows, notice that certain causes will apply to each problem. For example, oil on the linings can cause slipping, grabbing, and dragging.

1. Slipping. This is probably the cause of most engine clutch problems. The first indication is a change in the distance that the clutch pedal moves to engage and disengage the clutch. The pedal rises up farther than normal before the clutch will engage and move the vehicle. There is also a difference in engine operation; it will maintain sufficient rpm to prevent excessive lugging when applied to loads that would normally cause it to stall or require a lower gear ratio. This does not mean that the clutch will slip so much that the engine will not move the vehicle. There are many causes for a slipping clutch, but overlubrication and improper adjustment are the first things to check. You will notice that these first two causes are listed on equal terms. Knowing who the operators were and their lubrication and operation habits will help in diagnosing the problem and determining the true cause of the problem. If the clutch is slipping because of overlubrication, it will soon wear to the point that an adjustment is required. If the linings are oil-soaked from overlubrication, an adjustment will do very little good or not last very long. However, if there are no signs of excess grease or oil in the clutch compartment, an adjustment may be all that is required. The clutch is adjusted so that there is 1 1/2-in. free movement at the clutch pedal. It requires adjusting when there is 3/4 in. or less free movement of the clutch pedal with the clutch engaged or when the pedal strikes the floor. A weak pressure spring will fail to apply the necessary pressure and will allow the clutch to slip. Worn disk linings also cause clutch slipping. In addition to wearing, the linings sometimes become glazed and slip.

2. Grabbing. There are many things that will cause an engine clutch to grab, but the easiest place to start checking is the control linkage. The linkage must work freely to engage the clutch smoothly. Bent, broken, or corroded parts will cause the linkage to bind. An oil-soaked lining will also cause the clutch to grab. It will slip until sufficient pressure is applied to overcome slipping, then it will grab. Loose engine mountings will allow the engine to rock far enough to cause clutch grabbing. Worn or burred splines and weak or broken retractor springs will prevent free and even movement of the clutch disk and cause it to grab. Weak or broken pressure levers will cause the driven disk to bind on the splines. Cracks or heat checks on the pressure plate or flywheel do not provide the smooth surface required for smooth clutch operation.

3. Dragging. Slipping and grabbing to most people are self-explanatory, but when dragging is mentioned, many different definitions are thought of. Some think of the clutch contacting and rubbing some part of the vehicle. Some think it is one of the parts worn so badly that it is reducing the amount of power delivered to the transmission. But for the purpose of this text, it means the clutch has not completely released and stopped turning even though it is in the disengaged position. The driven disk contacts the flywheel or some other turning object with enough pressure to cause it to turn. It acts as if it has been adjusted too tightly, and improper adjustment is the first thing to check. Oil or grease on the linings can cause them to swell and drag. An accumulation of dirt in the clutch can cause it to keep turning. Damaged splines on the clutch disk or the transmission shaft, and weak or broken retractor springs may hold the clutch disk in contact with the flywheel. Warped parts can force the clutch into the flywheel and cause it to turn. It is also possible for the clutch facing to break and wedge itself or some other material beside the driven disk causing the clutch to drag. The driven disk and all parts that rotate with it must be free of any parts that rotate with the engine. This includes the pilot bearing mounted in the flywheel to support the end of the transmission shaft that the clutch disk is splined to.

4. Rattles. A rattling or knocking noise on any machine is probably one of the most difficult type of problems to diagnose. It is hard to locate just what part of the vehicle is rattling. Even after the rattle has been traced to a specific component, it is still difficult to pinpoint the cause. However, some of the causes for rattles may also cause other problems such as dragging. Weak retractor springs can cause rattles and can also be associated with a dragging clutch. Weak springs will not hold the driven disk firmly and cause both the disk and the springs to rattle. The noise is usually more pronounced when the clutch is disengaged. A loose flywheel ring bolt will allow the clutch to rattle and may be associated with grabbing, slipping, or dragging. The looseness of the flywheel ring allows the clutch assembly to float into and away from the flywheel at random. This in-and-out movement is not always even and can cause other symptoms. The metal-to-metal contact is what causes the rattle. A poorly centered release yoke will also cause rattling. Vibration of the transmission shaft will cause the metal yoke to strike the release bearing, causing a rattle. This may also cause a grinding, squealing, or other noise. The wear caused by a poorly centered release yoke may wear the release bearing which can cause other noises, including a rattle, in extreme cases. Release bearing noise, other than rattle, will be the loudest when the clutch is partially disengaged. The rattle may disappear when the clutch is disengaged. A worn pilot bearing can cause a rattle that will sound as if the rear engine main bearing is worn. The noise will decrease or disappear when the clutch is engaged because, when the clutch is engaged and there is no slipping, the pilot bearing, transmission shaft, and other parts turn with the flywheel as a unit, reducing or eliminating the noise caused by a worn pilot bearing.

(b) Repairs. The transmission and clutch are removed as a unit from the vehicle for repair and replacement of parts. Because the clutch must be removed and special equipment is required for proper adjustment, the repairs and adjustments are performed by field echelon maintenance units. Some rattling problems can be eliminated without removing the assembly. The flywheel ring bolts can be tightened by removing the inspection plate from the top and bottom, and rotating the flywheel as they are tightened. Adjustment of the clutch is accomplished by adding or removing shims

(6, fig 3-1). The adjustment is checked by using a straightedge across the face of the clutch release sleeve and measuring the distance to the machine surface of the clutch flywheel ring. Removing one shim from each of the adjusting bolts will change the distance being measured approximately 3/32 in. The control linkage is adjusted when the pedal strikes the floor or to obtain 1/8-in. clearance between the release sleeve and the release bearing. The clutch is removed by disconnecting the drive shafts and linkage from the transmission and the control linkage from the clutch. Remove the bolts from the flywheel ring and the bolts from the housing attached to the engine. Slide the clutch and transmission to the rear and lower it to the ground. The driven disk can be replaced without further disassembly but, before removing it from the shaft, note that it has a long and a short side. Be sure that the new part is installed properly with the long side facing the right direction. Inspect the flywheel and the pressure plate closely for heat checks, warpage, and cracks. Clean and inspect the other clutch parts for wear, cracks, and tightness. Inspect the pilot and release bearing for serviceability. Check the transmission shaft splines for burrs and rust. After the assembly has been cleaned, inspected, repaired, and lubricated, it is ready for installation. To assemble and install, reverse the procedures for removal and disassembly. After the clutch has been installed, review the procedures in the TM and adjust to specifications.

(3) Grader. The grader is equipped with a 16-in., single-plate, spring-loaded, Rockford clutch (fig 3-2). It is similar to the Bay City 150-T46 crane-shovel engine clutch. However, the grader clutch control linkage is connected to and activates a clutch brake. The principles of operation are the same: pressure and friction. The clutch is located under the fuel tank between the engine and the upper transmission. The clutch shaft is hollow to permit another shaft to be splined to the engine flywheel and transmit power independent of the engine clutch. The engine clutch controls only the power flow for the propelling power train.

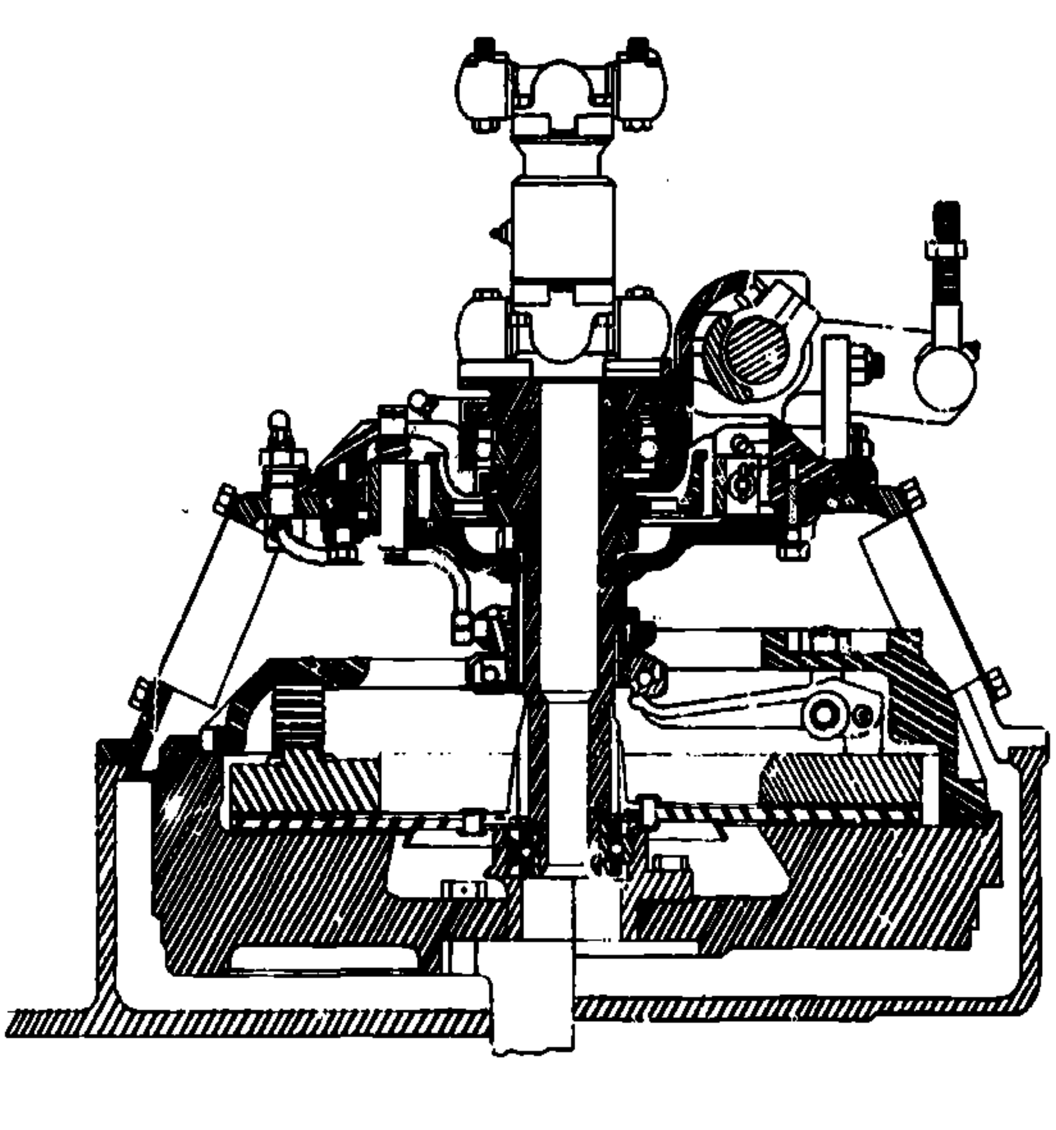


Fig 3-2. Grader clutch assembly.

(a) Diagnosis. Very few problems are encountered with the grader engine clutch. Because of the difficulty in lubricating, the clutch is seldom overlubricated. However, resting the foot on the clutch control pedal while operating does cause more frequent pedal free travel adjustment. Some of the clutch problems encountered are discussed below.

1. Slipping. Overlubrication, oil leaks from other components, and wear are causes of clutch slipping. Free pedal travel can be checked easily by using the drilled holes on the clutch pedal. If the free travel is correct when the transmission lever is in neutral or reverse, but insufficient when in a forward gear, the cause is probably loose bolts in the front power unit support clamp. A clutch that has overheated will have weak springs or a warped driven disk which can cause slipping or dragging.

2. Grabbing or chattering. Glazed linings or rough driven disk mating surfaces cause grabbing and chattering. Burred or dirty splines also cause grabbing.

3. Noises. Most of the noises coming from the clutch compartment are caused by a defective release or pilot bearing. Pilot bearing noise is reduced when the clutch is engaged.

(b) Repair. The clutch pedal free travel can be adjusted by the organizational mechanic, but internal repairs require removal of the clutch assembly and must be performed by field maintenance units. The free pedal movement decreases as the clutch linings wear and adjustment is required when the upper hole in the pedal is even with the deck plate. It is adjusted by turning the sleeve nut on the control linkage under the deck plate. The adjustment is correct when the lower hole in the clutch pedal is level with the deck plate--with the pedal depressed to remove free travel. The clutch brake control linkage adjustment is also checked and adjusted if necessary when the clutch control linkage adjustment is changed. The engine and the clutch must be removed from the vehicle to repair or replace defective clutch parts. They are removed as a group and then the clutch is removed from the engine. Before attempting to lift the group from the vehicle frame, be sure that all electrical wiring, oil and fuel lines, control linkage, mounting and attaching bolts, and other parts are disconnected or removed. Shims are used at the rear engine mounts and should be tagged and marked to insure reinstallation in the same place. The clutch housing, shaft, and lubrication lines can be removed after the group is removed from the vehicle. To remove the clutch assembly from the flywheel, first install and tighten four holddown setscrews to relieve the spring tension. With the holddown setscrews in position, remove the bolts connecting the backing plate to the flywheel and lift the clutch assembly from the engine. The clutch-driven disk can now be replaced. If there is doubt about the condition of other clutch parts, further disassembly is necessary. First remove the four holddown setscrews, then disassemble the assembly. Clean and check the flywheel and pressure plate for heat checks, cracks, and warpage. Check the springs for discoloration and tension. The free length of an old spring is not as great as that of a new spring, but if the old springs meet tension specifications and are not discolored because of heat, they are satisfactory. Replace all defective parts and begin reassembly. (Note: If one of the 24 springs is replaced, replace them all.) Figure 3-3 illustrates the sequence of reassembly. Lubricate the bearings as they are installed. Install the release lever pin with its head facing the direction of engine rotation. To assemble the backing plate to the pressure plate (10, fig 3-4), tighten the holddown setscrews until the lever eyebolts touch the adjusting nuts, raise the lever, start the nuts and tighten until the levers touch the back plate. Then tighten the holddown setscrews until the pressure plate is raised the specified distance from a flat surface. Finally adjust the levers as specified by turning the adjusting nuts. The specifications are different for a new driven disk than for a used one. Install the driven disk, make sure it faces the right direction, and attach the assembly to the engine flywheel. Before tightening the bolts, aline the driven disk by inserting an old clutch shaft or clutch alining tool. Torque the bolts and remove the holddown setscrews before removing the alining tool. Install the clutch housing and its attached parts. Be sure the lubrication tubes are connected to the proper parts; crossing them can cause one part to receive too much grease and the other not enough. The clutch pedal free travel is adjusted after the engine and clutch have been installed and the linkages connected.

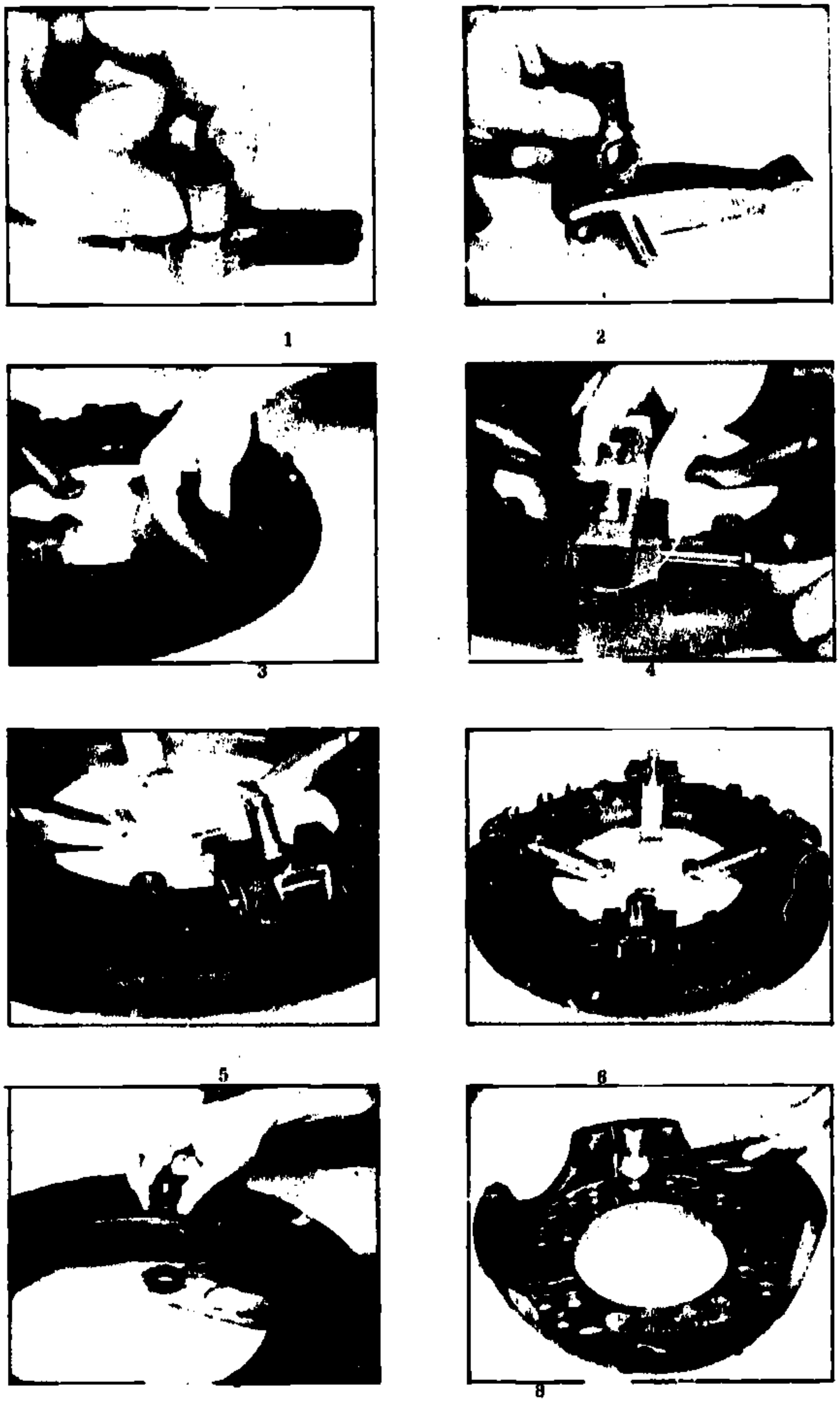
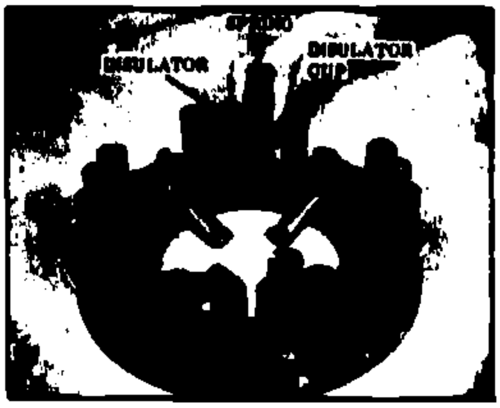
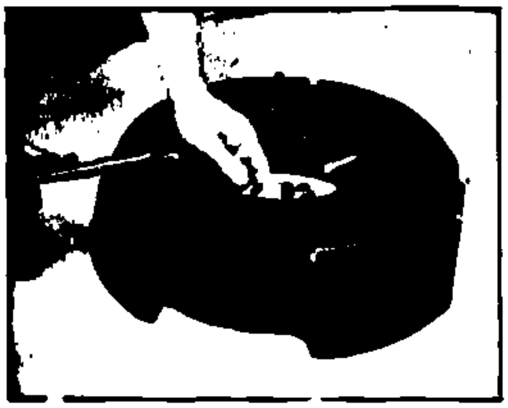


Fig 3-3. Grader clutch assembling sequence.





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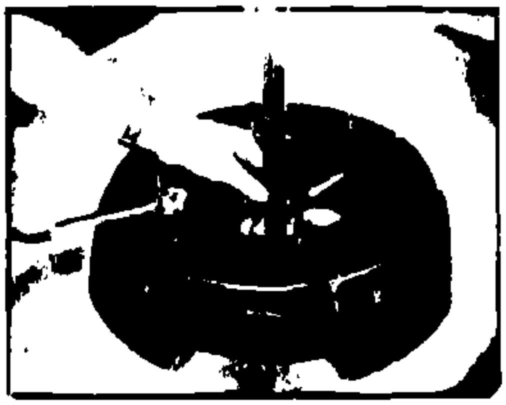

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Fig 3-3--contd

h. Steering clutches. There are many types of steering clutches such as multiple-disk, cone, internal expanding, and external contracting. Some of these clutches are equipped with booster systems which make it easier for the operator to steer tracked vehicles. Some vehicles have the steering clutches (track controls) included as a part of another component such as the Case MC1150 scooploader. It has the clutches in the transmission. Regardless of where they are located or how they operate, they are there to break the flow of power to the tracks so that the tractor can be steered. They can function independently or together: the power can be stopped to one track or to both tracks at the same time.

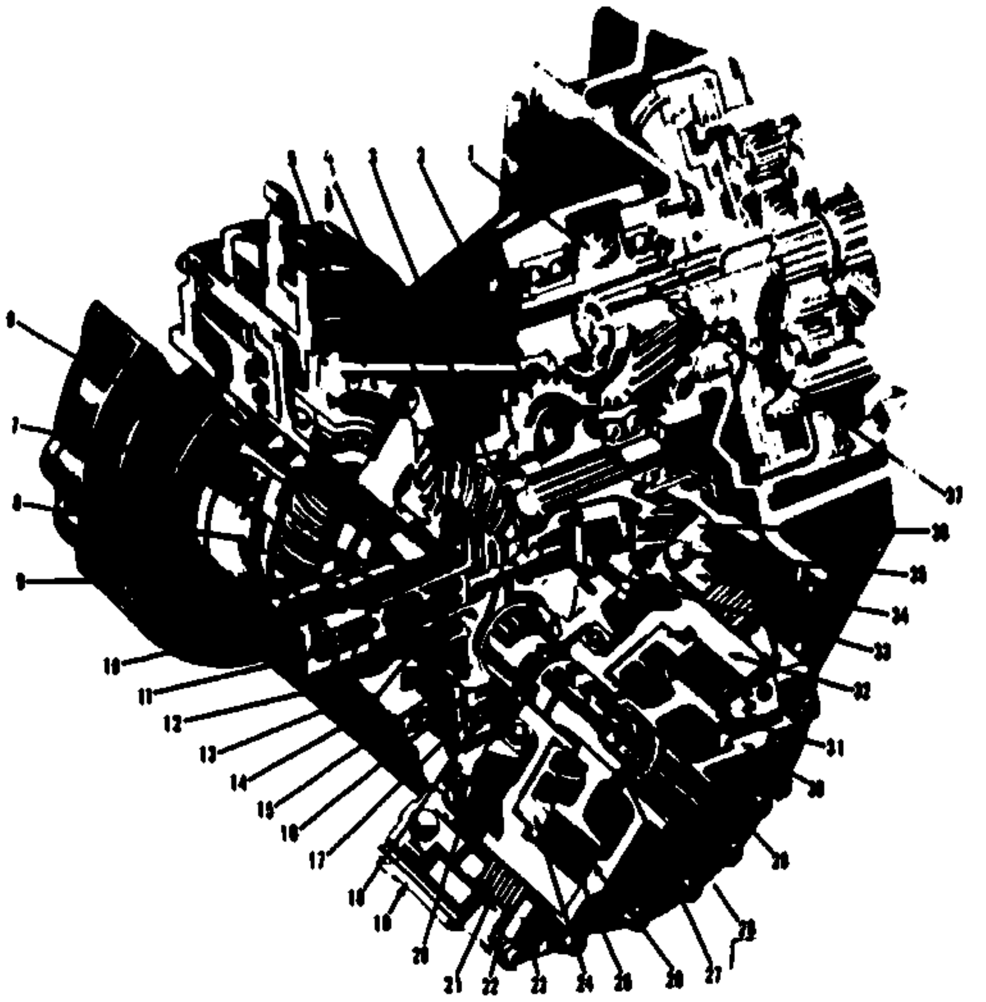
(1) Crawler-tractors.

(a) Case MC1150 scooploader. The mechanical power flow to the tracks is controlled in the transmission. High and low speeds, and forward and reverse for each track are provided by gears and hydraulically controlled multi-disc clutches. Levers connected to hydraulic valves on the transmission allow the operator to manually position spools in the control valves which control a pair of clutches regulating the speed or direction of the right or left track. One track can be directed to travel forward while the other is held in neutral or directed to travel in reverse. The system is called track control system rather than steering clutches and some of the problems encountered are listed as transmission problems. The planetary clutches operate in oil and there are no adjustments to be made.

1. Diagnosis. Since the clutches operate in oil with little wear problems and they cannot be adjusted, most problems will be caused by the hydraulic system. Low drive oil pressure will not fully engage the clutch. This will cause it to slip. Low pressure could be caused by clogged filters, kinked hoses, and leaky connections. However, low oil level will also cause low oil pressure and should be checked first. Defective or maladjusted control linkage will cause improper functioning of the control valves that direct the oil pressure. The last item to check for improper functioning of the track controls is the clutch disk. Although the track controls have been grouped here, check the control valve operation, adjustment, and clutch for the side that is causing trouble.

2. Repair. Proper maintenance by the operator and organizational mechanic will insure that the transmission oil is at the proper level and that the oil filter is not restricting the oil flow. Kinked hoses can be straightened and leaky connections tightened or replaced. If it is necessary to adjust the control linkage, follow the step-by-step procedures outlined in the TM. Check the torque converter inlet relief valve which starts to open at 260 psi and is completely open at 290 psi and the outlet relief valve which starts to open at 20 to 60 psi. Then repair or replace a faulty converter charging pump or pressure relief valve,

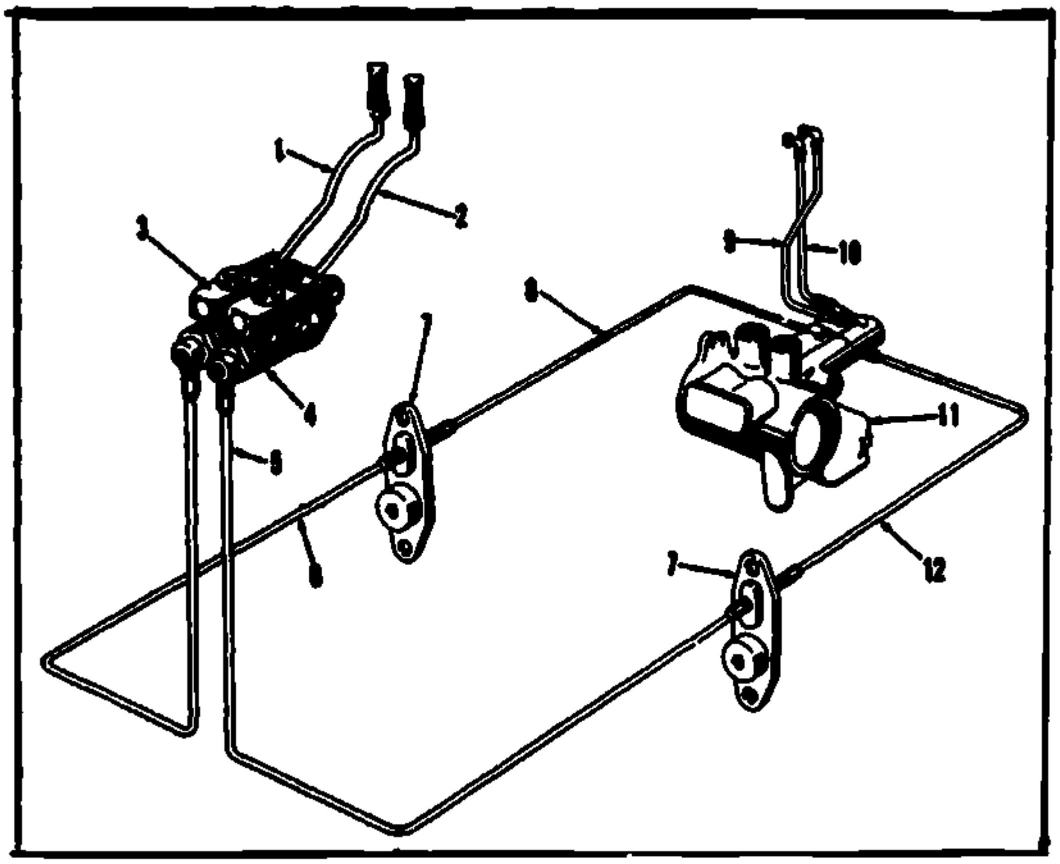
(b) Model 82-30M crawler-tractor, Steering of the Terex 82-30M crawler-tractor is accomplished through steering clutches and brakes located in the reduction gear housing (fig 3-4), The reduction gearing is joined to the transmission and mounted in the drive case. The reduction gearing gives final gear reduction at the transmission and changes the direction of the power flow 90°. It also has footbrakes for holding the tractor, and hydraulically operated steering clutch and brake packs for turning it. A steering clutch and brake pack is located on each side of the reduction gear housing. Each steering clutch pack consists of a piston housing, clutch hub, driving hub, seven friction plates, six reaction plates, a clutch piston, and a brake valve assembly. The friction plates are splined to the clutch hub which is powered by the output shaft from the bevel gear. The reaction plates are splined to the piston housing which transmits the power to the final drive quill shaft. The clutch hub and the piston housing are locked together during normal operation. Transmission operating oil pressure flows through the steering valve and into the area between the clutch piston and the piston housing. This exerts pressure on the friction and reaction plates, locking them together. Pulling back on one of the steering levers applies pressure on the oil (engine oil of 5W viscosity) in one of the master cylinders. The pressure from the master cylinder acts on the piston of a steering control valve located in the reduction gear housing. Movement of the steering control valve cuts off the oil flow to the clutch piston and directs it behind the movable cam ring. This releases the pressure on the clutch pack and applies pressure to engage the brake assembly. The brake assembly can be actuated mechanically or hydraulically. It has four friction and three reaction plates. The disengaging of the clutch pack and engaging of the brake assembly controls the flow of power from the bevel pinion shaft to the final drive quill shaft.



1. Drive gear
2. Driven gear
3. Valve
4. Bevel pinion
5. Reduction gear housing
6. Bevel gear
7. Spring
8. Valve plunger
9. Piston cup
10. Piston cylinder
11. Spring
12. Piston
13. Link
14. Spring retainer
15. Steering valve body
16. Check valve
17. Accumulator valve
18. Valve spring
19. Brake anchor
20. Accumulator plug
21. Reaction plates
22. Friction plates
23. Backing plate
24. Clutch piston
25. Reaction
26. Friction plates
27. Output shaft
28. Bushing
29. Pipe plug
30. Driving hub
31. Clutch hub
32. Piston housing
33. Spring
34. Movable cam ring
35. Brake ball
36. Stationary cam ring
37. Transmission output shaft

Fig 3-4. Cutaway view of the reduction gearing.

1. Diagnosis. Most steering problems are caused by failure of one of the hydraulic systems (fig 3-5 and 3-6). Air in the steering control system acts in the same manner as air in a hydraulic brake system. The master cylinders must be full and the system free of air for them to move the steering control valve as intended. Some of the hydraulic problems may be associated with other transmission problems because the same hydraulic pressure that controls steering controls the clutches in the transmission. Friction and reaction plate wear and brake adjustment also cause steering problems. The two main problems are slipping clutches and dragging brakes; both may be reported as "tractor fails to develop full power." Start looking for the trouble by first checking the master cylinder and transmission fluid levels, then the parking brake adjustment. If these are satisfactory, check the engine for proper operation by making a converter stall test; then make oil pressure checks, following the sequence and procedures outlined in the maintenance manual. Low oil pressure can be caused by clogged strainers and filters, leaking lines, and defective valves, valve springs, or pump. The pump is mounted on and driven by the torque converter. It provides the oil for lubricating and the pressure for operating the transmission and reduction gear components. The last items to check for steering trouble are worn clutch and brake pack parts.



1. R. H [illegible]ng lever
2. L. H. [illegible]g lever
3. R. H. master cylinder
4. L. H. master cylinder
5. L. H. pressure line
6. R. H. pressure line
7. Retainer brackets
8. R. H. pressure hose
9. L. H. bleeder hose
10. R. H. bleeder hose
11. Steering control valve
12. L. H. pressure hose

Fig 3-5. Schematic of steering control system.

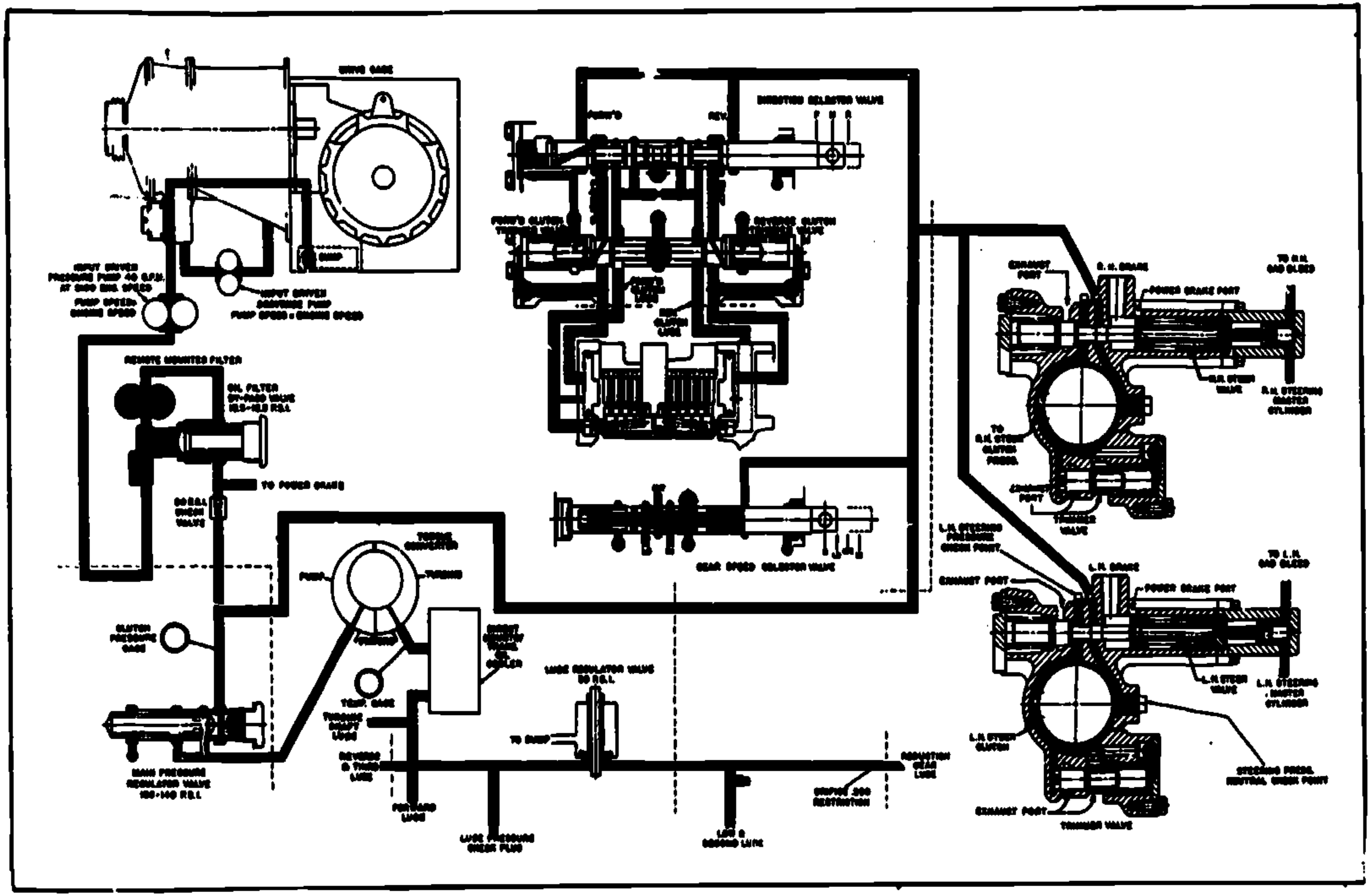


Fig 3-6. Schematic of transmission hydraulic system.

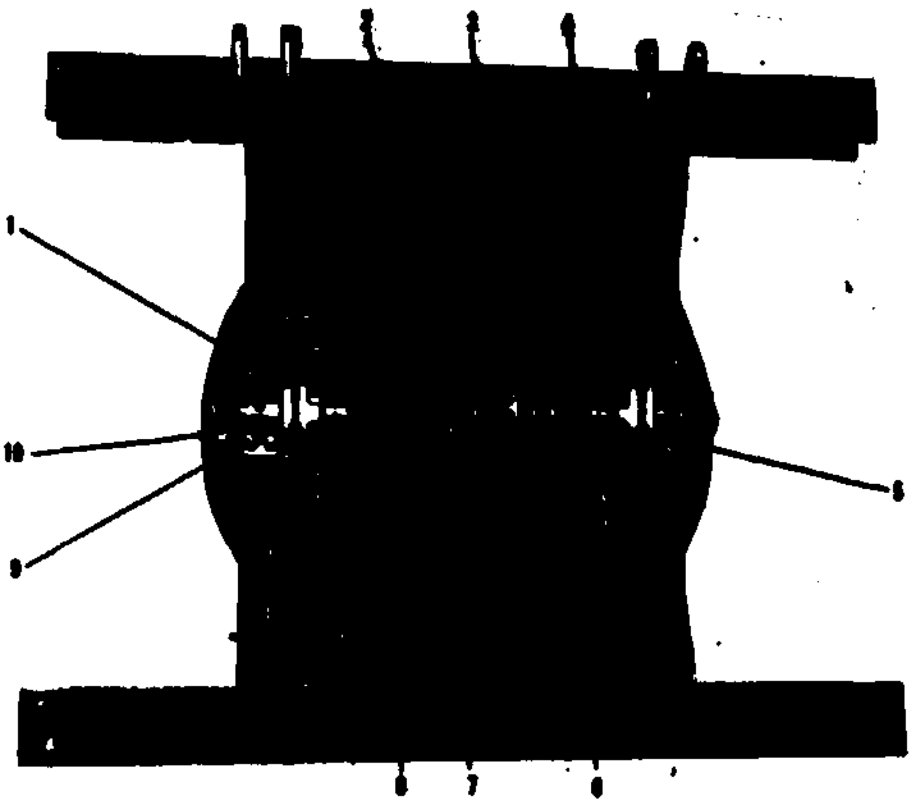
2. Repair. The steering control system can be repaired without removing many parts of the vehicle. Leaky lines are repaired or replaced. The master cylinders are repaired or replaced if defective and the system bled after any repairs are made. To bleed the air from the system, keep the master cylinder filled with 5W engine oil, pull back on the steering levers slowly, and open the bleeder plugs (fig 3-7); close the bleeder plugs before releasing the levers. The transmission hydraulic system is a self-contained system with few external lines. However, there are openings with plugs whic can be removed so that a pressure gage can be installed The valves and regulators are located outside and inside the main components. For example, the main pressure regulator valve is located on top of the converter housing while the steering brake valve is located in the reduction gear housing. Access to some of the valves will require removal of the assembly. The transmission, converter, and reduction gear housing are removed as one assembly, then disassembled as necessary to repair. The steering and parking brakes are adjustable. There are three adjustments necessary to insure that the brake will hold the tractor when the engine is stopped. Remove the inspection cover on the rear of the transmission drive case and check the clutch pack clearance on each side, check the brake effectiveness, and make the brake lever adjustment, if necessary, by turning the adjusting knob.

(2) Crawler crane-shovel. The Marine Corps has two different types of crawler crane-shovels, each with a different type of steering system. The M37 crane-shovel's main steering components are external-contracting brakes, cone-type clutches which serve as a method of engaging the brakes, and a differential. Internal-expanding clutches break the flow of power, and external-contracting brakes hold the drum which steers the 2N crane-shovel. Engaging and disengaging the M37 steering system is by mechanical linkage, while the 2N has a combination air and mechanical linkage. Steering crawler crane-shovels seems complicated to some because the upper machinery can be rotated 360°

(a) M37 crane-shovel. The steering brakes and cone clutches are mounted on the differential propelling shaft assembly in the lower machinery (fig 3-8). The steering brakes are controlled by one lever in the upper machinery with linkage down through the vertical propelling shaft and out to the clutches and brakes. The power flow to the tracks of this vehicle is not broken. However, brakes can be applied which would affect steering. The crane-shovel is equipped with a differential which will allow one shaft to turn while the other is being held. Movement of the steering lever moves the linkage up or down in the vertical propelling shaft. This moves a shaft which is connected to cams mounted on the propelling shafts. Movement of the cams in one direction will force one of the cone clutches into the drum and a spring will force the other cone clutch away from the drum. When the cone clutch contacts the drum, it trys to rotate with the drum and shaft. Connected to the cone clutch is linkage to engage the external-contracting brake. The more the cone turns, the tighter the brake is applied until the drum and shaft are stopped. When the shaft is stopped, the track on that side is stopped and the crane-shovel will turn. Moving the steering lever in the opposite direction will engage the opposite clutch and turn the machine in the opposite direction.

Table 3-1. Troubleshooting M-37 Steering

Complaint: Machine does not steer properly	
1. Worn steering clutch jaws.	1. Adjust clutch jaws to compensate for wear. Replace if necessary.
2. Steering clutch locking.	2. Adjust clutch.
3. Loose or damaged control lever linkage such as bent rods, missing clevis pins, and excessively worn bell crank bushing.	3. Repair or replace missing or damaged parts.
4. Propelling chains t. o loose, causing jerky motion.	4. Adjust propelling chains.

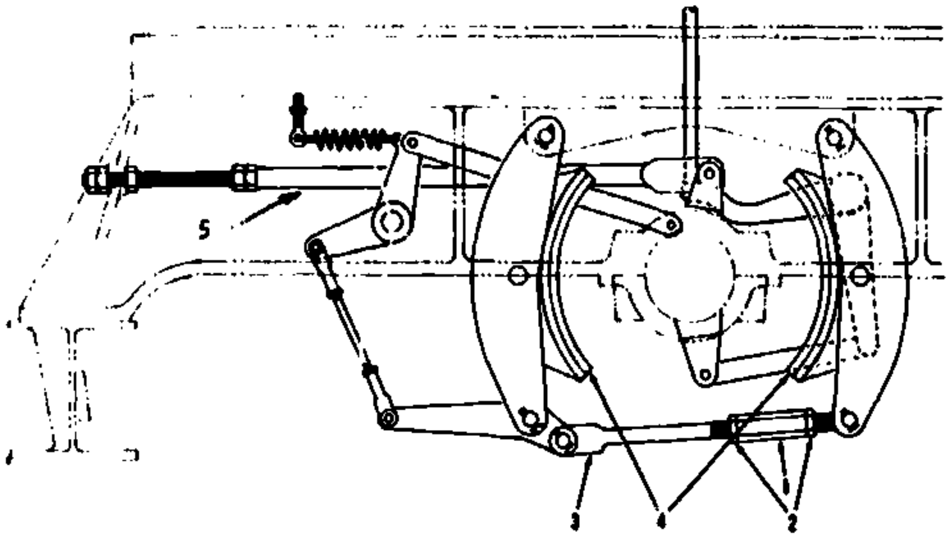


1. Steering brake
2. Center bearing
3. Differential propelling shaft bevel gear
4. Steering brake cone
5. Short shaft
6. Differential assembly
7. Vertical propelling shaft bevel gear
8. Long shaft
9. Bearing
10. Sprocket

Fig 3-7. Bottom view of lower base.

1. Diagnosis. Improper lubrication, dirt and other foreign matter, and defective linkage cause most M37 crane-shovel steering problems. The cone and brake lining must be clean and free of grease or glaze. The shaft must be clean and lubricated so that the cone can move freely. The linkage must be connected and properly adjusted. If the vehicle steers hard or will not steer, check the linkage to be sure it is connected and not binding. Check the cone and brake lining for grease or glaze. Check the cone to be sure it is not binding or sticking and will move freely on the shaft. The last item to check is the adjustment. The above checks and a check of the propelling locks should also be made to determine the cause for failure to release after making a turn. Because of the differential, it is possible for something to block or bind the track and cause the vehicle to act as if the steering is failing to release.

2. Repair. Cleaning the cone clutches can be performed without removing them from the vehicle. Cleaning the brake linings will require removal. Binding linkage can often be corrected by lubrication. If the linkage is broken or binding because of bends, removal and repair or replacement is necessary. Adjustments are made by adjusting rods that extend through the rear of the lower machinery and sleeve nuts on the linkage between the brake shoes (fig 3-8). Note that the heads of the rods are marked with an R and an L which indicate right- or left-hand threads. However, both rods are turned clockwise to tighten the brakes.



1. Sleeve nut
2. Plain nut
3. Brake adjusting rod
4. Brake shoes
5. Clutch adjusting rod

Fig 3-8. M37 Steertng clutch and brake-adjusting points.

(b) 2N crawler crane-shovel. Steering of this crane-shovel is accomplished through air-controlled internal-expanding clutches and external-contracting brakes mounted on the lower traction shaft. Two levers in the upper machinery control four air control valves which direct air to release the clutches and engage the brakes. The clutch is engaged and held in the engaged position by air pressure. The brakes are engaged by spring tension and released by air pressure. This is a safety factor on the vehicle so that if an air leak develops or the system fails, the brakes will automatically engage. Air to operate the clutches and brakes is transmitted from the upper machinery to the lower machinery through the vertical air tubes which extend through the vertical traction shaft. The clutches engage the flow of power from the bevel gear and transmit it to the drum and out to the tracks. The brakes are designed to stop the drum from turning and the track from moving when the clutches are disengaged. Functioning of the clutch and brake on one side will stop the track on that side and turn the vehicle. The clutches can be engaged or disengaged independently or together without damaging the vehicle.

1. Diagnosis. It is more complicated to diagnose the steering problem of the 2N than those of the M37 because the 2N's steering malfunctions may have several possible causes. A slight air leak may allow the brake to drag or fail to fully engage the clutch. Incorrect adjustment will cause slipping, and corroded linkage may keep the clutch engaged. Grease on the linings will cause slipping and glazing. Glazing may cause grabbing, slipping, and hard operation. Failure of the vehicle to travel straight indicates that one clutch is slipping. If the crane-shovel fails to travel with both clutches engaged, make the following checks: system air pressure, track tension and possible binding track, brake adjustment, clutch linings, clutch adjustment, control system air leaks, and clutch and brake operation when the levers are moved. Failure of the vehicle to turn when the correct lever is moved indicates defective valves, defective air cylinder, or incorrect clutch or brake adjustment. If the valves are defective or improperly adjusted, the air will not be directed to disengage the clutch and engage the brake. If the air cylinder is defective it may not release the clutch and engage the brake. If the clutch is too tight it will drag, and if the brake is too loose it will not engage to stop the track.

2. Repair. The clutch and brake linings can be removed, installed, and adjusted without removing the lower traction shaft; only the clutch inspection covers need be removed to expose the clutch and brake assembly. When the brake linings are replaced, disassemble, clean, and inspect the complete assembly. Air leaks can be caused by

defective gaskets, seals, tubing, and loose connections. Loose connections can sometimes be tightened, but replacement is usually necessary to correct defective parts. Check for air leaks by applying soapy water to the suspected part. The air-delivery pressure can be raised or lowered by turning the adjusting screw on the valve. This is the only adjustment that can be made on the air valves. Turning it in raises the pressure.

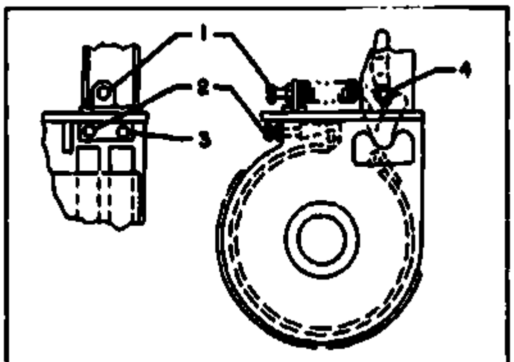
Note: Should the lower traction shaft assembly be removed and disassembled, be sure the drilled air passages are properly alined during reassembly. Failure to aline the passages will prevent installation of all parts and make it necessary to again remove and disassemble the lower traction shaft assembly.

c. Attachment control clutches. These are clutches used to control the power for the attachments and the operating components. They are often referred to as operating clutches except when discussing a specific clutch such as the front drum clutch on a crane-shovel or the right clutch on a double-drum power control unit. Most of these clutches are either external-contracting or internal expanding. However, some machines such as the grader have jaw clutches. On most machines, the operating clutches provided a second break in the power flow; the first break is at the engine (master) clutch.

(1) Double-drum power control unit. This unit uses two external-contracting clutches which hold drums that cause the planetary system to rotate cable drums. It also has two brakes identical to the clutches which stop the cable drums when desired. The clutch and brake bands are interchangeable. Power is flowing to the unit when the engine clutch is engaged. but it cannot operate the cable drums until the control clutches are engaged. These clutches and brakes are partially protected by the housing, shields, and cover plates, but dirt and water can still get in and cause problems.

(a) Diagnosis. Most problems encountered are complaints of dragging or slipping clutches or brakes. In damp climates, the clutches will usually drag for a short time when you first start to use them due to either moisture or rust; moisture causes the linings to swell and drag, and rust makes the drums rough and causes the bands to drag. After the component has operated for awhile, the linings will dry and wear the rust off the drums. Then they may begin to slip because of improper operation or adjustment. Slipping clutches can also be caused by grease on the linings, glazed linings, worn linings, or warped bands. Overheating is another problem that is usually caused by slipping clutches. Bent or binding linkage will prevent proper engaging or releasing and cause slipping and dragging which will overheat the bands. The bands usually warp because they have been overheated.

(b) Repair. Adjustment procedures are usually stamped on a metal tag and attached to the component. The procedures outlined in figure 3-9 pertain to the model 281 cable control unit used with the Terex crawler tractor. The clutch and brake bands are replaced before the linings have worn enough for the rivets to score the drums. Replacement is also necessary if they become warped, glazed, or oil-soaked. They can be removed by loosening the adjustment, removing the shields and covers, removing the pins in the bands, and then lifting the bands out. Glazed or oil-soaked linings can sometimes be cleaned, wire-brushed, and reinstalled. Warping can sometimes be prevented if the operator will stop the equipment, engage the overheated band, and allow it to cool while engaged. After the bands have warped, they must be replaced. Defective linkage should be cleaned, repaired, or replaced as needed. Broken or weak springs must be replaced. Reassemble the bands by reversing the disassembly procedures and adjust as outlined in the TM. Wet and swollen linings can be replaced, readjusted, or caused to slip until dry, then readjusted. Be careful not tooverheat the linings if you use the slipping method. Be sure that the drains are open to prevent water accumulation. Drums which have rusted excessively may require removal of the clutch and brake bands and sanding or turning on a lathe. Light rust can be removed by use. Adjust the bands to prevent dragging, and readjust after the rust has been worn off.



1-Brake spring screw
2-Brake band adj Screw
3-Clutch band adj. screw
4-Bearings

1. Loosen jam nuts and screws (2 & 3).
2. With unit running, screw in the adjustment screw (2) controlling the brake bands until the bearings (4) are centered between levers. This can be checked through the opening in the brackets. The bearings (4) must be centered with this opening.
3. Make certain that the spring is snug, but not tight.
4. Put control lever in operator's compartment in neutral. Adjust the screw (3) controlling the clutch bands until there is a running clearance between the clutch bands and the clutch drums. It will be properly adjusted when 7" to 9" of pull on the operator's control lever will raise the load. Tighten screw jam nut.
5. Pick up the load and place operator's control lever in neutral. If load does not drift down, loosen screw and nut (1) until it just starts to come down. Then tighten the screw and nut until the load stops dropping. If the spring is compressed too much, it will require excessive hand pressure to lower the load.
6. Make certain that all jam nuts are tight.
7. Compensate for wear of band lining with adjusting screw(2 & 3).

Fig 3-9. Model 281 cable control unit adjustment procedures.

(2) M37 crane-shovel. This machine has three types of clutches and brakes used to control the power flow to its attachments: internal-expanding, external-contracting, and jaw clutches. They are engaged three ways: mechanically (through linkage), electrically, and automatically. The front drum is controlled by internal-expanding and external-contracting clutches, and by external-contracting brakes. The hoist drum is controlled by an external-contracting clutch and brake. The dipper trip is controlled by an internal-expanding clutch. The front and hoist drums and dipper trip clutches use a booster control clutch (sometimes called an EZ clutch) to engage the main clutch. The booster control clutch is an external-contracting type clutch that works similarly to a brake. The band tries to stop a control wheel which is free to rotate until contacted by a stop. Linkage between the control wheel and the main clutch will cause the main clutch to engage. When the operator releases the booster control clutch, spring tension will return the control wheel to its normal position and release the main clutch. The dipper trip booster control clutch is engaged by an electric solenoid. The horizontal intermediate shaft is controlled by internal-expanding clutches. They control, through other clutches, raising or lowering the boom, swing, and travel operations. The boom hoist is controlled by a jaw clutch and an external-contracting brake. The

boom hoist brake works automatically and is installed so that movement of the brake-drum against the dragging brake band tends to engage the brake tighter. It and the action of the worm and gear prevent the cable from unwinding unless power through the horizontal intermediate shaft and jaw clutch is applied. Swing operations are controlled by a jaw clutch through the horizontal intermediate shaft clutches and a mechanical lock similar to a jaw clutch. The lock is a partial gear that meshes with the gear teeth in the lower base assembly. The front and hoist drum brakes are external-contracting and are engaged by mechanical linkage from the operating pedal directly to the brake. Operating methods and the functioning of the booster control clutches cause the most difficulty during diagnosis and repair. Figure 3-10 shows the location of some of the clutches.

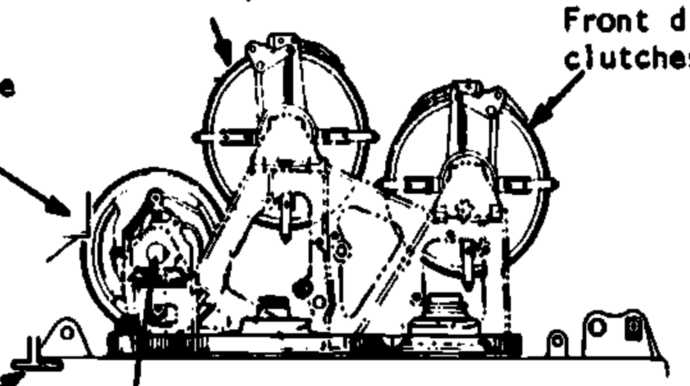


Fig 3-10. Location of M37 crane-shovel clutches.

(a) Diagnosis. The most frequent trouble with operating clutches is their failure to disengage completely or slipping. The M37 crane-shovel clutches are exposed to and absorb moisture from the air. This causes them to swell, drag, and fail to release. Moisture will also cause the drums and linkage to rust. This prevents free movement of the linkage to release the clutches or causes the clutch linings to drag on the rusty drum. Although the linkage is partially protected by the machinery, it is exposed to moisture, dirt, and debris which can cause it to bind. Small objects can also get caught in the gears and bend or break the linkage. Vibration can cause the linkage to come loose. Slipping can be caused by wear of the clutch linings, maladjustment of the linkage and clutch bands, lubricant on the linings or drum, warped bands, and improper operation. Most slipping problems are caused by improper adjustment or lubricant on the linings or drums. Improper adjustment will cause a clutch to drag if too tight or to slip if too loose. Both dragging and slipping will cause a clutch to overheat. This can cause the band to warp and cause drag or slip, even when everything else is correct. The M37 jaw clutches may fail to engage or disengage, but they will not slip. Loose, binding, or improperly adjusted linkage cause most problems with the jaw clutches. Of course, bent linkage will affect the adjustment. If the two mating surfaces make contact but fail to engage, a loud noise will be heard. The brakes and booster control clutches are affected by the same things listed for the clutches.

(b) Repair. Replace the clutch and brake bands before the linings are worn sufficiently for the rivets to score the drums. To remove, loosen the adjusting nuts, remove the pins and springs, and slide the clutch band away from the drum and off the shaft assembly. To install, reverse the procedure. The linkage can be adjusted to position the control levers and pedals, to allow a clutch to be engaged and stay engaged until released by the operator, and to center and prevent clutch band dragging or slipping.

Note: The horizontal intermediate clutches or linkage are NEVER adjusted so they will stay engaged; the operator must always keep pressure on the control lever to keep them engaged. The adjustments are made by loosening locknuts and turning a clevis, sleeve nut, or adjusting screw. The control lever position and booster control clutches are adjusted as desired by the operator as long as the main clutches will fully engage and disengage. The main clutches are adjusted to the TM specifications. The front and hoist drum brakes are adjusted to hold the load when engaged and to allow the drum to rotate freely when completely disengaged. The compression springs are adjusted to keep the band from dragging on the drum when released. Warped bands cannot be repaired and must be removed and replaced. Oil-soaked or glazed linings can sometimes be cleaned, dried, and reused. Bent or broken linkage must be replaced or repaired while using good linkage of the same kind as a pattern. Anytime the adjustment is disturbed, make an initial adjustment before starting the machine, then operate the machine until the bands reach operating temperature, stop the machine, and make the final adjustment.

(3) 2N crane-shovel. The clutches used to control the power flow to the attachments of the 2N crane-shovel are internal-expanding and jaw type. The brakes are external-contracting. The boom hoist is equipped with a ratchet pawl in addition to a brake. The jaw clutches (fig 3-11) are used to shut the power flow from the boom hoist clutches to the retract clutch.

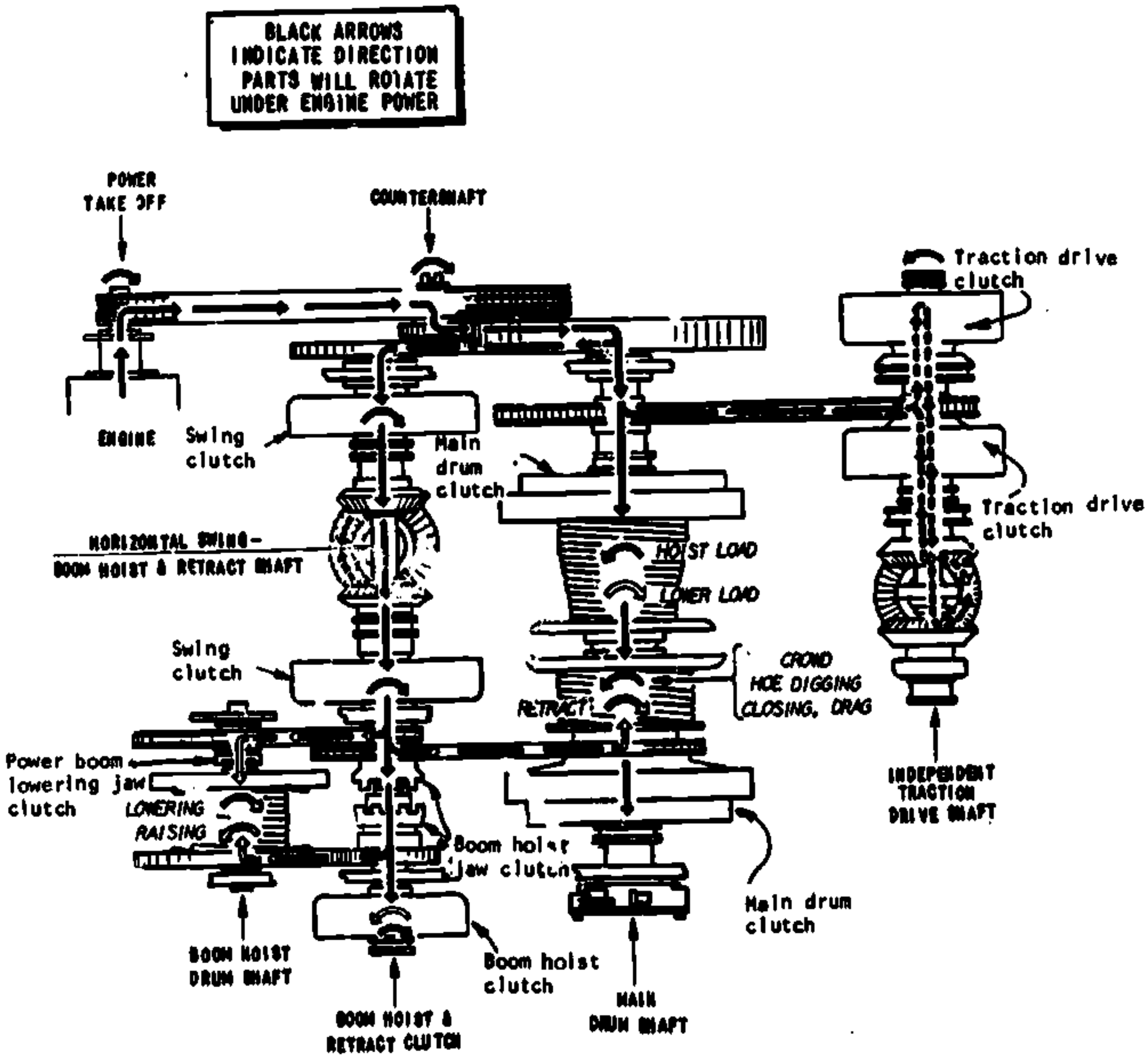


Fig 3-11. 2N crane-shovel power flow and location of clutches.

Figure 3-12A shows a swing clutch and a boom hoist and retract clutch. Notice that both clutches are single-band type and very similar. Most of the other clutches are similar to these; they may be wider, have a thicker lining, or be of larger diameter, yet they function in the same manner. One difference you can note in figure 3-12A is the compensator spring; one is heavier and stronger than the other. One of the methods used to engage and disengage the clutches is illustrated in figure 3-12B. The other operating clutches are controlled by modified versions of the linkage shown. Installation, adjustment, operation, and lubrication affect the proper functioning of the clutches more than anything else. The bands are installed so that the live end (fig 3-12) is connected in the proper place. It should lead the rest of the band in the direction of rotation so that it will aid engagement; it becomes partially self-energized. Clutches on this machine have a small friction surface compared to other makes of crane-shovels. Any slipping or dragging due to improper installation or adjustment will cause excess heat and faster wear. Overlubrication will cause lubricants to get on the drums and linings which can cause slipping. Insufficient lubrication will cause the metal parts to wear faster and will make it harder to maintain the proper clutch adjustment. Overloading or intentionally slipping the clutches will cause them to slip, create excess heat, glaze the linings, and cause abnormal wear on other machine parts. With few exceptions, the 2N crane-shovel clutches are adjusted to prevent toggle backlock (snap-over-center; stay engaged) for safety reasons.

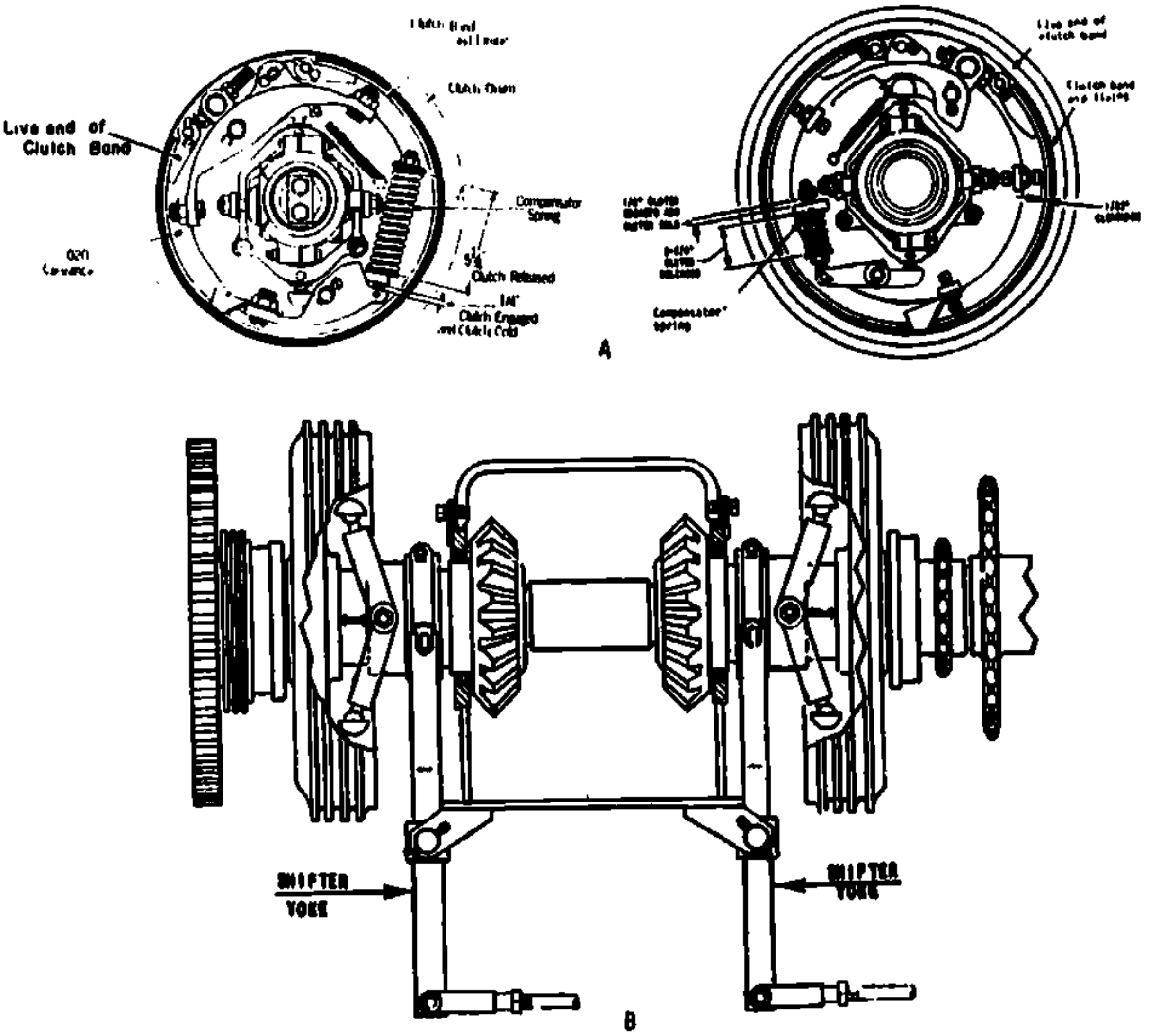


Fig 3-12. 2N crane-shovel clutches and control linkage.

(a) Diagnosis. Locating and determining the cause of 3N crane-shovel operating clutch problems is harder than for the M37 crane-shovel because the upper machinery is more confined. Because of shields and machinery configuration, it is harder to observe the clutches and brakes during operation and to make the necessary checks and measurements when trying to locate the cause of a problem. The complaints are usually the same as those listed for the M37 crane-shovel, but it is more difficult to locate and eliminate the problem. For example, a 3N crane-shovel operator complains of the main drum shaft clutches either dragging or slipping. A quick check of the operations indicates that the clutches should function properly. But the proper adjustment and lubrication is not easily checked because of the shielding and the location of the main drum shaft and its clutches. Poor lighting and obstructed vision are the biggest problems; confined space is another. Although the control linkage and clutches are protected from the weather, because this crane-shovel is normally used on beaches, it is subjected to a more corrosive-type moisture than usual. This moisture will cause the drums and linkage to rust and affect the engaging and disengaging of the clutches. The abrasive action of the beach sand will cause the linings and other parts to wear faster and may cause the clutches to slip or require more frequent adjusting or replacing. The hard-to-reach lubrication points cause the operator to smear the lubricant on the clutches or to neglect proper lubrication of some parts. Vibration will loosen improperly tightened adjustments, wear linkage parts, or cause bolts and pins to fall out, resulting in dragging or slipping and possibly both. Overheating will cause a band to warp so that it drags when disengaged or slips when engaged

(b) Repair. You can remove and replace the clutch bands without completely disassembling a particular assembly such as the main drum shaft assembly, But to repair or replace some of the linkage such as the clutch spider, you will have to remove the assembly. You should replace the bands before the linings are worn enough for the rivets to score the drums, whenever the linings become oil-soaked or glazed, and whenever the bands are warped or damaged. The linings can be renewed if the clutch band is still good. Remove the old linings and rivets and install a new lining of the correct size by clamping it to the band, drilling the rivet holes, countersinking the holes on the face of the lining, riveting to the band, and beveling the sides and ends of the lining. If new linings or band assemblies are not available, an oil-soaked or glazed lining can be cleaned, dried, and reused as long as the rivets do not score the drum. Clean the linings by brushing and dipping in an approved cleaning solvent and drying with compressed air. Worn or lost linkage pins or parts should be replaced as soon as possible after discovery. Some of the linkage and levers have antifriction bearings which require replacement from time to time. When a part is replaced, the adjustment must be checked and corrected. When making the adjustment, follow the procedures outlined in the TM for that specific clutch or linkage. New linings or band assemblies will require frequent adjustment until worn in. Unless other procedures are specified, operate the machine to warm up the parts before making the adjustments.

3-3. TRANSMISSIONS

All transmissions are designed to perform the same function. They provide a method of changing the power, speed, and direction of rotation. Their construction and application vary. Most of them are produced by a company other than the manufacturer of the machine on which they are used. However, a transmission can be identified by a tag or number, or by the vehicle TM. A transmission is usually located in the power train so that it receives the power flow directly from the engine clutch; for some applications it is located elsewhere on the machine. In the neutral position, some transmissions provide a positive break in the power flow.

a. Sliding-spur gear (fig 3-13). This type of transmission has straight spur gears that mesh with other straight spur gears, It is designed so that some of the gears slide along a splined shaft while other gears are held in position. Forks, controlled by linkage or a lever, move the gears in and out of mesh. Detents hold the forks in position until the operator moves them for another gear selection. Some transmissions may have the detents hold the gear rather than the forks. The transmission shown in figure 3-13 has four forward speeds and a reverse, Other sliding-spur-gear transmissions are very similar.

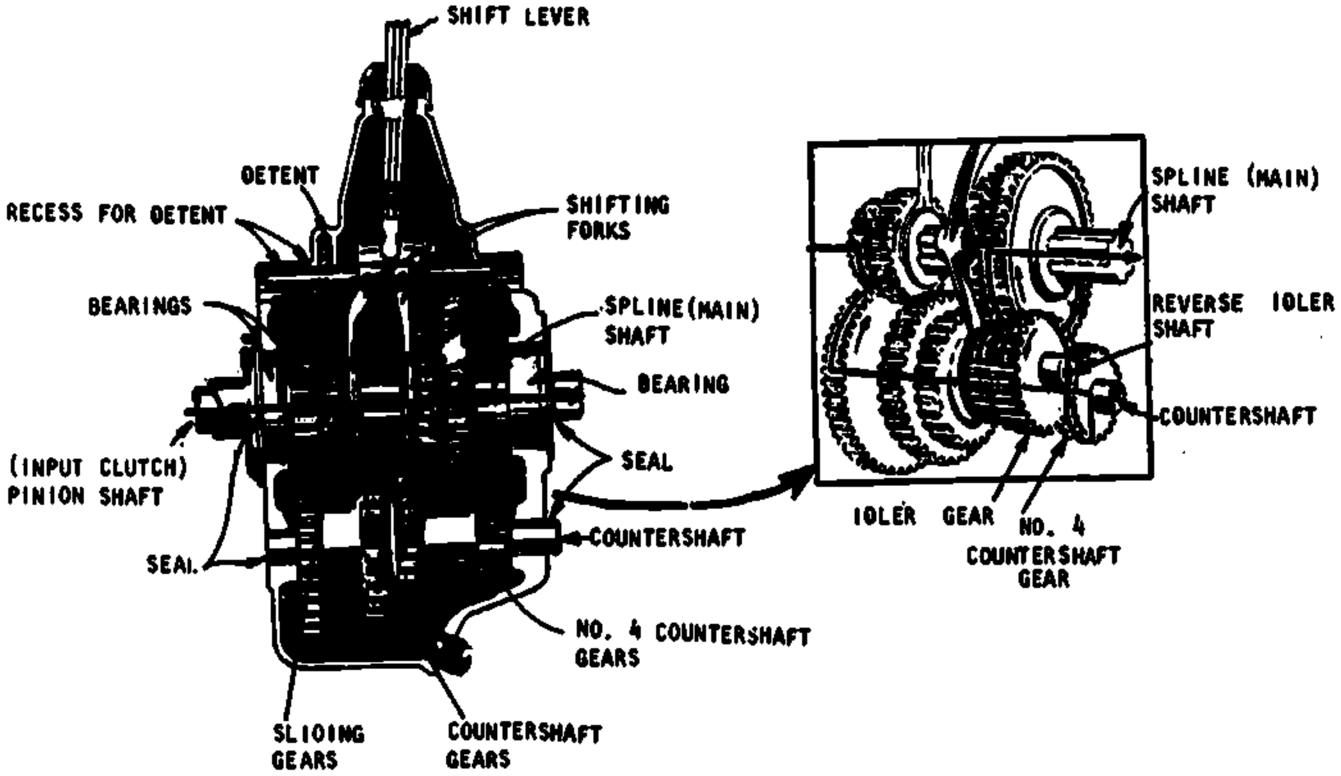


Fig 3-13. Four-speed sliding-spur-gear transmission.

(1) Diagnosis. Some of the problems reported as transmission troubles are actually caused by some other part or component. A well-trained and experienced mechanic is an asset to the maintenance facility, especially for diagnosing transmission troubles. He knows that noises can be transmitted to a transmission from unbalanced drive shafts, worn universal joints, loose drive shaft center bearings, worn or pitted ring and pinion gears, and clutch or engine. But not all units have experienced mechanics, and therefore they must diagnose the problem and repair the component with personnel available. When checking for transmission noise, raise the vehicle off the deck and operate it in all speed ranges, including coasting (neutral). Determine the origin of the noise before condemning the transmission. If the noise does originate in the transmission, try to determine what is causing it. A growl or hum, when the gears are in the neutral position with the engine running, that stops when the clutch is disengaged, indicates insufficient lubricant, worn or broken pinion gear, worn reverse idler or countershaft bearings, worn pilot or pinion shaft bearings, or a bent countershaft. Noises heard in neutral may also appear when the transmission is operated in other gears. If a noise appears only after the transmission is operated in gear, the cause is worn or damaged main shaft bearings, worn or broken sliding gears, or excessive main shaft end play. Noises are not the only problems with a transmission. It will slip out of gear, be hard to shift, or develop leaks. Slipping out of gear is caused by worn detents, gears, bearings, and/or improperly adjusted linkage, including the forks. Excessive end play of the reverse idler and countershaft will allow the gears to work endways and cause them to slip out of mesh. Hard shifting is caused by the clutch not releasing, distorted or burred main shaft splines, or improperly adjusted linkage. Oil will leak by worn seals, damaged or loose gaskets, loose bolts or plugs. A clogged vent will also cause pressure to force the oil out.

(2) Repair. Because of variations in construction of transmissions, different procedures must be followed in removal, disassembly, repair, assembly, and adjustment. Special tools will be required for disassembly and assembly of some transmissions. If any transmission unit is unfamiliar to you, follow the procedures outlined in the TM. Clean the transmission and attached parts thoroughly before removing it from the vehicle. Drain the lubricant, remove the assembly from the vehicle, and then disassemble; some transmissions are disassembled without removal as a component. Clean the parts and case thoroughly with an approved solvent and use a putty knife or similar scraper to remove hardened grease, lacquer deposits, dirt, and old gaskets. Pay particular attention to the small drilled passages and lube troughs: make sure nothing restricts the flow of lubricants. The gears are lubricated by oil which clings to them after being splashed. The bearings are lubricated by oil which is splashed into the troughs; the oil then flows through the drilled passages. Inspect and check all parts for wear or damage. Some defects are visible, others will require the use of special tools and gages to determine their condition. Replace or repair the unserviceable parts. Where there is doubt about the serviceability of a part, it should be replaced. Some parts may require replacement in pairs, such as the replacement of the low-speed sliding gear and the low-speed countershaft gear, if one is defective. Small cracks in the gearcase or covers can sometimes be welded if they do not extend into the bearing bores. Assembly is usually the reverse order of disassembly, but use the TM as a guide. The TM is also used to check the adjustment procedures and specifications.

b. Constant mesh (fig 3-14). The constant-mesh transmission, its problems, and repair procedures are very similar to those for the sliding-spur-gear transmission. However, its internal parts function somewhat differently. The main shaft gears in the constant-mesh transmission do not slide in or out of mesh with the countershaft gears except for reverse. The main gears are helical cut and are free to rotate on the main shaft. Reverse gear is a straight spur gear. The main gears are locked to the main shaft by shifter gear collars controlled by a shifting fork and linkage. All of the gears are turning, and by moving the small shifter gear collar, one of the gears is locked to the shaft and transmits the power. Notice in figure 3-14 that detents hold the shifter gear collar in mesh with the main gear. The main gears may be pressed on the main shaft or retained in position by snap rings. They are mounted on antifriction bearings so they can rotate. Removal, disassembly, assembly, and adjustment procedures vary and the mechanic should follow the procedures outlined in the TM.

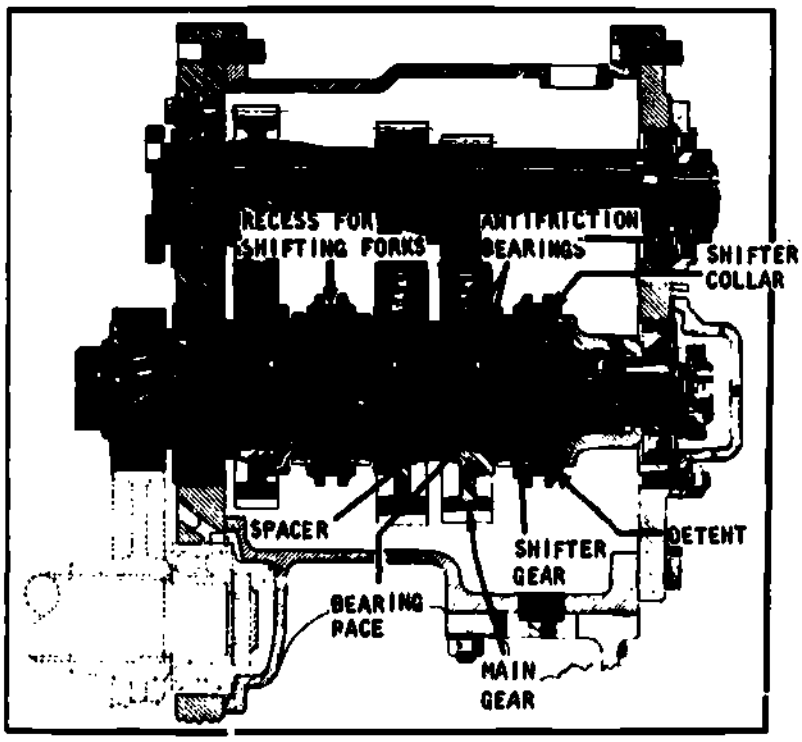


Fig 3-14. Cutaway view of a constant-mesh transmission.

c. Synchromesh. The synchromesh transmission is basically a constant-mesh transmission with synchromesh clutches to engage the gears and transmit the power to the main shaft. The gears are mounted in the same manner as in the constant-mesh transmission with a synchromesh clutch (fig 3-15) replacing the shifter gear and collar. Cone clutch surfaces on the synchromesh clutch contact the cone surfaces of the drive gear and cause the shaft and gear to turn at the same speed before the gear teeth contact. This eliminates the need for double clutching and prevents clashing of the gears. When the main drive gear and the sliding gear, which is keyed or splined to the main shaft, are turning at the same speed, the spring-loaded ball will allow the sliding sleeve to engage the main drive gear. The main drive gear shown in figure 3-15 is a part of a larger gear with helical-cut gear teeth that mesh with a gear on another shaft. Some of the synchromesh transmissions also use a sliding spur gear for first and reverse gear. When diagnosing and repairing the synchromesh transmission, follow the same general procedures as were outlined for the sliding spur gear and the constant-mesh transmissions.

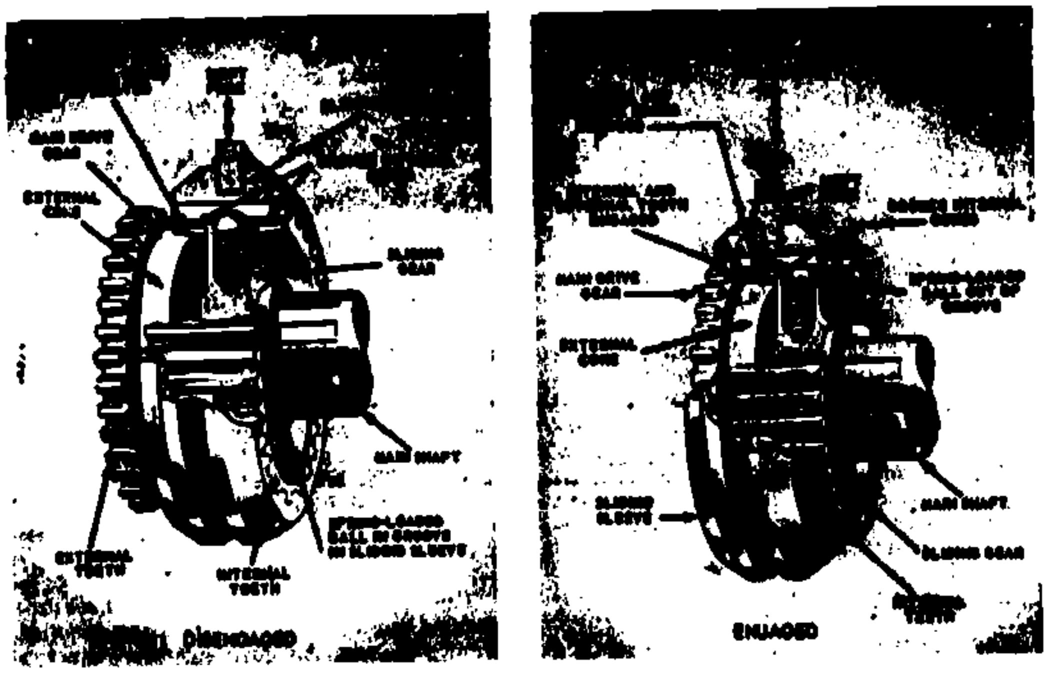
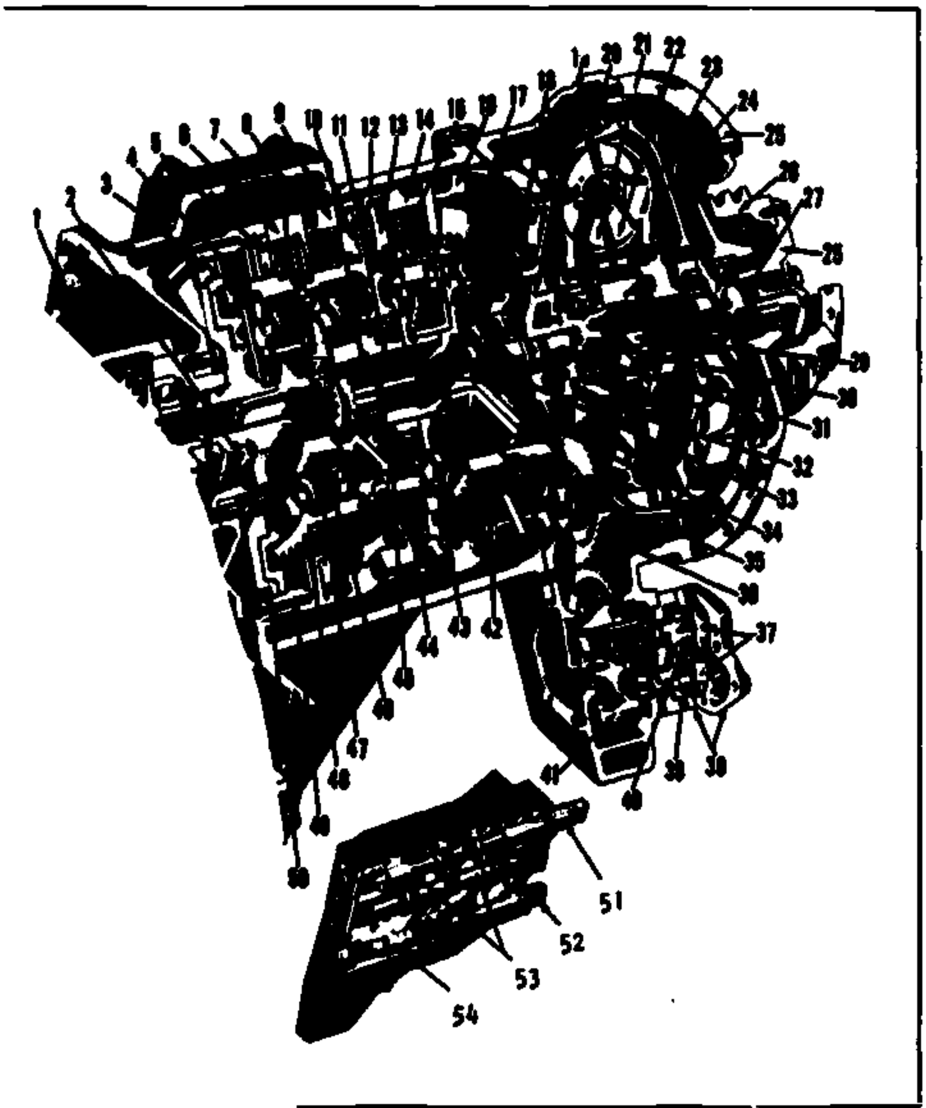


Fig 3-15. Synchromesh clutch.

d. Torqmatic. The torqmatic transmission is used in a variety of engineer equipment and some of the principles are used in other components of the equipment. It is a constant-mesh planetary gear system with hydraulically actuated clutches. A torque converter which multiplies the engine torque transmits the power from the engine to the planetary gears. A pump at the torque converter provides the hydraulic pressure for controlling the planetary clutches and lubricating the transmission. The torqmatic is not an automatic transmission. It must be shifted by positioning a control valve in the hydraulic valve body, but all speed shifts can be made under full power. The shifting can be done through linkage to the hydraulic control valve or electrically through a solenoid. Figure 3-16 is a cutaway view and figure 3-17 a schematic of the hydraulic system of the torqmatic transmission used in the TEREX crawler-tractor. Notice that the planetary gears are in constant mesh. Other torqmatic transmissions are basically the same as the one shown.



1. Planetary gearing housing
2. Planetary gearing output shaft
3. Low-range piston
4. Low-range clutch pack
5. Intermediate-range piston
6. Intermediate-range clutch pack anchor
7. Intermediate-range clutch pack
8. High-range clutch pack
9. High-range clutch pack anchor
10. High-range piston
11. Range input shaft
12. Planet carrier support diaphragm
13. Reverse-range piston
14. Reverse-range clutch pack anchor
15. Reverse-range clutch pack
16. Forward-range clutch pack anchor
17. Forward-range clutch pack
18. Forward-range piston
19. Converter housing
20. Converter pump
21. Second stator
22. First stator
23. Converter turbine
24. Converter pump drive cover
25. Converter cover
26. Fan drive pulley
27. Pump drive cover hub
28. Transmission input flange
29. Stator roller race
30. Ground sleeve
31. Turbine shaft
32. Accessory drive input gear
33. Planetary input sun gear
34. Forward-range planetary assembly
35. Forward-range ring gear
36. Accessory idler gear
37. Scavenging pump gears
38. Output pressure and scavenging pump assembly
39. Output pressure pump driven gear
40. Output pressure pump drive gear
41. Accessory drive gear
42. Reverse-range ring gear
43. Reverse-range planetary carrier assembly
44. High-range ring gear
45. High-range planetary assembly
46. Intermediate-range sun gear
47. Intermediate-range planetary carrier assembly
48. Intermediate- and low-range ring gear
49. Low-range drum assembly
50. Low-range hub assembly
51. Forward & reverse selector valve
52. Low-, intermediate-, & high-range selector valve
53. Trimmer valves
54. Dual control valve assembly

Fig 3-16. Cutaway view of torqmatic transmission.

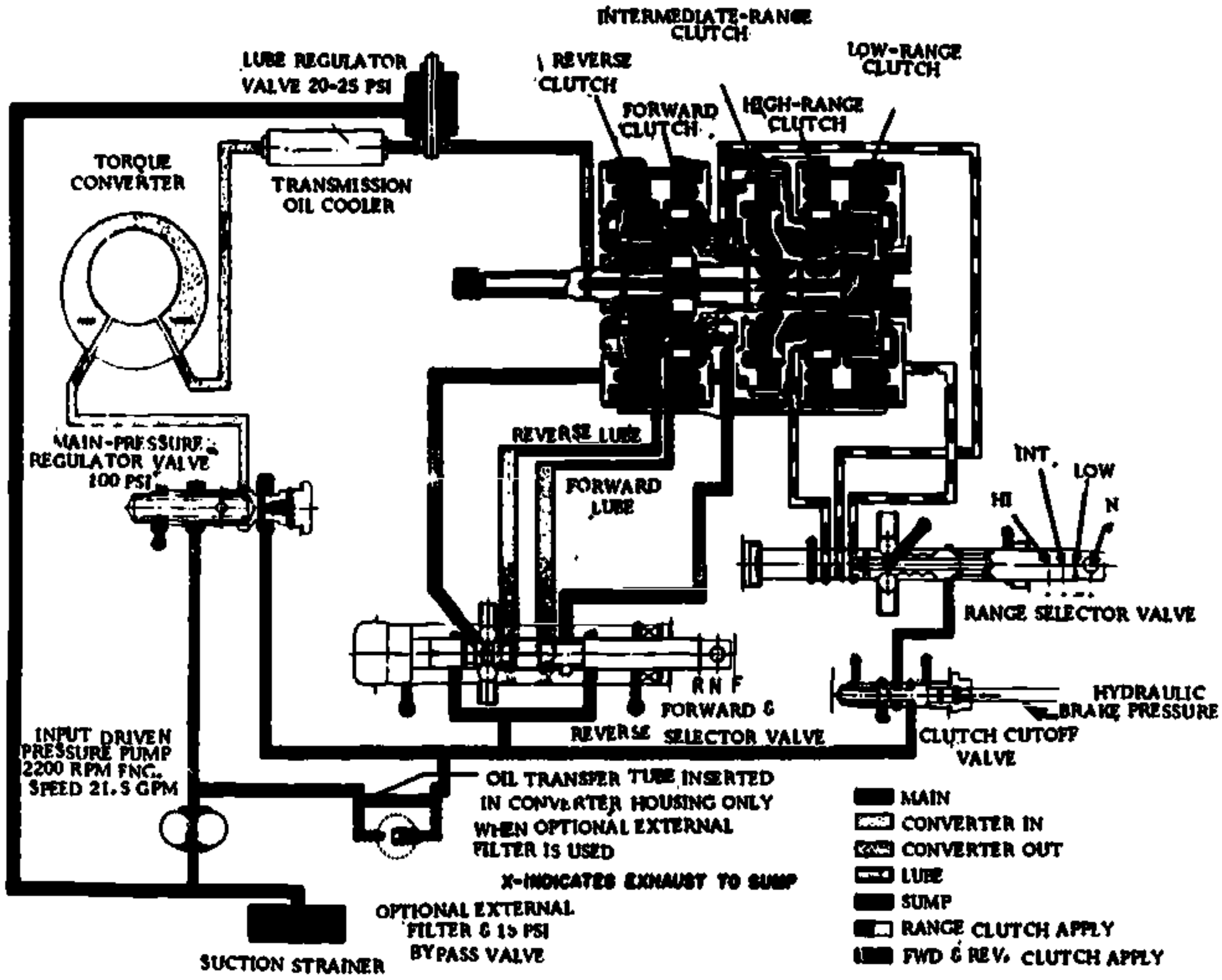


Fig 3-17. Schematic of hydraulic system of a torqmatic transmission.

(1) Diagnosis. In addition to noise caused by worn or defective parts such as gears and bearings, the hydraulic system in the torqmatic transmission causes some problems. Because the transmission operates in oil and the transmission hydraulic systems are run by the same oil, most of the maintenance is concerned with oil replenishment and oil cleanliness. Low oil level, insufficient oil pressure, overheating, and contaminated and foaming oil are some of the problems encountered. Low oil level, a plugged strainer, a defective oil pump and aerated (foaming) oil can cause low converter-out pressure. Since the clutches are engaged by oil pressure, there may be insufficient pressure on the clutches to cause them to engage. High oil temperature can be caused by low oil level, low converter-out pressure, clogged or dirty heat exchanger, locked stators, or overheated engine cooling system. Normal converter-out temperature is 180° F and should not exceed 250° F at any time. Foaming can be caused by incorrect oil, overfilling, leaky system, or contamination. Some of the contaminants are water from condensation or supply source, dirt, and metal particles from the transmission gears, bearings, or other working parts. To properly check and diagnose the transmission, it must be cleaned, serviced, and pressure and temperature gages used. It must be clean to determine the location and cause of leaks. It must be serviced to insure that it contains the proper lubricant and is at the correct level; check the TM to determine if the oil level should be checked when hot or cold. Hot readings are taken with the temperature at 180° F. Oil temperature and pressure must be checked to determine if the problem is caused by the hydraulic system or by defective internal parts.

(2) Repair. Torqmatic transmission repairs below the depot maintenance level are limited to tightening loose connections, checking pressure and temperature, cleaning and replacing filters and strainers, and making minor adjustments and repair. Internal repair, overhaul, and rebuild are performed at the depot level. Intermediate maintenance generally consists of the assembly being removed and replaced with a new or rebuilt one. Removal and installation procedures vary with the different vehicles. For example, the 3-ton hydraulic crane is sectionalized to facilitate transmission removal in addition to helicopter transporting. Therefore the sectionalization skids and tools will be required to remove and install a replacement transmission. Some vehicles, such as the TEREX crawler-tractor, require the transmission to be removed with other components as a unit, then removed and replaced. It should also be noted that a torqmatic transmission from one vehicle will not fit another vehicle. The method of mounting it and the location of the engine and propeller shaft connections are different although it is the same model transmission. Since the procedures for removal and installation vary and the method of mounting and connecting are different, a mechanic should refer to the TM for the specific vehicle before attempting to replace the assembly. Although internal repairs are not performed at the lower echelons, the transmission is thoroughly checked before being replaced. A stall test is performed and pressure checks made to insure that the problems are not caused by lack of maintenance at the lower echelon. To perform a full stall and pressure test, check the oil level and operate the engine and transmission long enough to bring them to operating temperature. Conduct the test according to the procedures outlined in the TM for the vehicle. Figure 3-18 shows where the pressure readings are obtained on one torqmatic transmission; other TM's will show the location for checking a specific vehicle. Engine rpm readings are taken from the vehicle tachometer unless there is doubt about its accuracy.

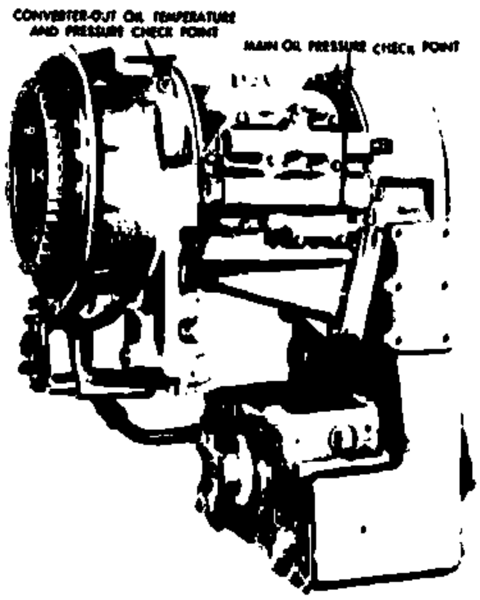


Fig 3-18. Pressure and temperature check points of a CRT-3331 torqmatic transmission.

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3-4. PROPELLER SHAFTS

a. Introduction. The vehicle's power, having been transmitted through a component such as the transmission, is carried along the power train by a propeller, or drive, shaft. Propeller shaft is the common term; however, either can be used and is correct. In amphibious vehicles both terms are used; propeller shaft, to indicate the device that carries power to the propeller, and drive shaft, to indicate the device that delivers power to the wheels. The propeller shaft may be either solid or tubular. The twisting stress in a shaft varies from zero at the axis to a maximum at the outside. Since the center of the shaft resists only a small portion of the load, hollow shafts are used wherever practicable. It is attached to the components such as the transmission and differential of automotive vehicles by a universal joint or joints, and slip joints.

b. Slip joints.

(1) Because flexing of the springs, component mounting, or operation cause the component housing to move forward and backward, a slip joint is installed. This allows the propeller shaft to lengthen and shorten as required by operating conditions.

(2) A slip joint consists of a male and a female spline, a grease seal, and a lubrication fitting. The male spline is an integral part of the propeller shaft (fig 3-19) and the female portion is fixed to the universal joint directly behind the driving component. As the component housing moves forward and backward, the slip joint gives freedom of movement in a horizontal direction and yet is capable of transmitting rotary motion.

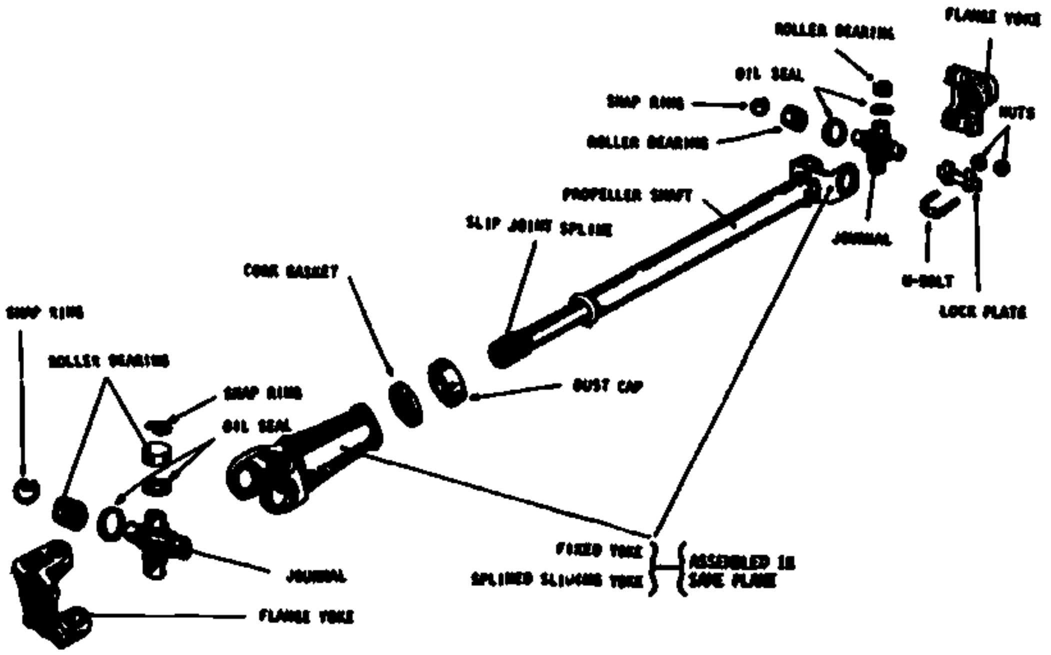


Fig 3-19. Propeller shaft disassembled.

c. Universal joint. A simple universal joint (fig 3-20) is composed of three basic units: one journal, and two yokes. The construction permits each yoke to pivot on the axis of the journal, and carries the rotary motion from one yoke to the other. As a result, the universal joint can transmit the power from the engine through the propeller shaft to the differential, which is constantly moving up and down in relation to the frame.

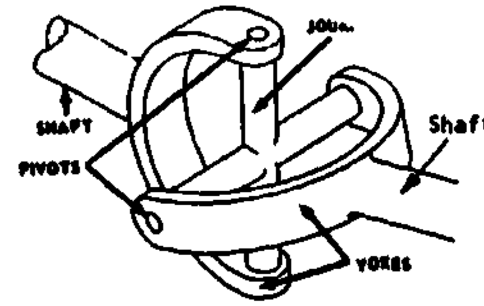


Fig 3-20. Simple universal joint.

(1) Characteristics of universal joints. A peculiar characteristic of the universal joint is that it causes a driven shaft to rotate at a variable speed with respect to the driving shaft. This variation is in the form of acceleration and a deceleration of the speed. twice during each revolution of the driving shaft.

Tnis variation of speed cannot be eliminated when a simple universal joint is used. its effect can be minimized, however, by using two universal joints (one at each end of the shaft). If only one joint is used between the transmission and the differential, the acceleration and deceleration caused by the joint is resisted on one end by the engine and on the other end by the inertia of the vehicle. The combined action of these two forces produces great stress on all parts of the power train, resulting in a nonuniform force being applied to the wheels. When two universal joints are used, the second joint compensates for the speed fluctuations caused by the first. To accomplish this, the angle between the transmission shaft and the propeller shaft must be the same as the angle between the propeller shaft and the differential. Another requirement is that the two yokes of the universal joints which are attached to the propeller shaft, be in the same plane. If the yokes of the joints attached to the propeller shaft are in the same plane, the driving yoke of the first joint will be at an angle of 90° with the driving yoke of the second. The two yokes attached to the propeller shaft act as the driven yoke of the second joint. With this arrangement, the first joint is producing its maximum fluctuation at the same time the second joint is producing its minimum fluctuation. This results in a nonvarying wheel speed for a giv engine speed. even though the speed of the shaft between the joints is constantly changing.

In a universal joint, bearings are included at the four points where the journal is attached to the yokes. In addition. one of the yokes usually incorporates a splined slip joint. In one type of universal joint the joint itself incorporates a feature that permits variations in length of the propeller shaft.

(2) Journal-type universal joint. There are several variations of the journal-type universal joint. two of which are shown in figures 3-21 and 3-22. The universal joints of this type vary from each other mainly in the manner in which the journal is attached to the driving and driven yokes. For example. in the universal joint shown in figure 3-22. the journal is assembled in the shaft and slip yokes; the bearing assemblies are inserted from the outside, and are secured by spring bearing retainers inside the yokes. The bearings on the transverse ends of the journal are clamped to the flange yokes and secured from outward movement by bearing retainers. The universal joint shown in figure 3-22 differs from that shown in figure 3-21 in the manner in which the journal is attached to the flange yoke. In this universal joint, the bearing assembly is contained in bearing blocks. The blocks are mounted against the flange yokes and secured with bolts extending longitudinally through the yokes.

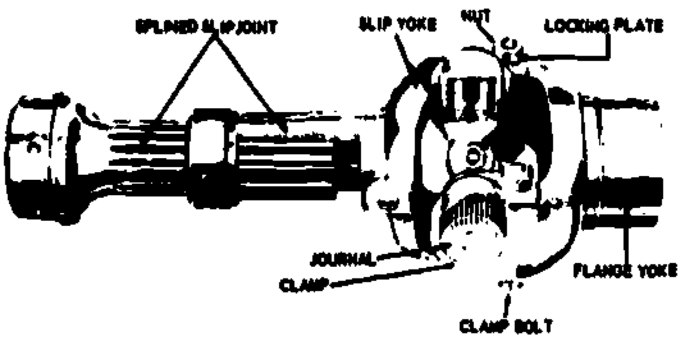
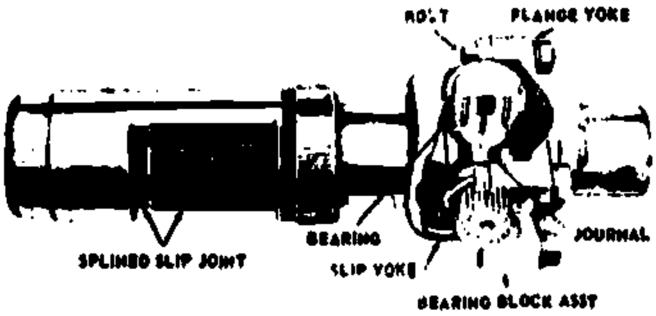


Fig 3-21. Journal-type universal joint with journal assembly in shaft and slip yoke.



3.301

Fig 3-22. Journal-type universal joint with journal attached to flange yoke.

(3) General points.

(a) The universal joint just discussed is the most common on Marine Corps vehicles. Other types of joints may be found, especially on vehicles with 4-wheel drive where a constant-velocity universal joint must be used in the front axle; it reduces speed variations. For more detail on special universal joints, check the TM.

(b) Most universal joints do not require any maintenance for the life of the unit. Others may require disassembly and lubrication periodically.

(c) Worn universal joints will make noise. Check for worn universal joints by turning the propeller shaft by hand. Excessive backlash or looseness can be felt by hand pressure. Roughness at low to moderate speeds often indicates worn universal joints.

3-5. DIFFERENTIALS AND FINAL DRIVES

Tha propelling power must be divided and directed to each driving wheel or track. This is accomplished by a differential or a final drive. The flow of powar is turned 90°. Tha methods of directing the power flow for representative items of equipment are discussed below.

a. M37 crane-shovel. This vehicle uses a differential similar to that shown in figure 3-23. It is located near the center on the underside of the lower base assembly. The power enters at the vertical propelling shaft (pinion shaft) and rotatas each differential propelling shaft (axle shaft). The bevel drive pinion splined to the vertical propelling shaft rotates the ring gear (bevel drive gear). A differential case is splined to the ring gear and rotates with it. Enclosed in the differential case are four differential pinion (spider) gears and two differential side gears. These gears are in mesh with each other, but are free to rotate in the differential case. The differential propelling shafts (one long and one short) are splined to the side gears. If the resistance is equal on both side gears, they do not rotate in the differential case, but turn with the assembly. When there is more resistance on one side gear than on the other, it tries to stop. This will causa the pinions to walk around the gear with the most resistance. The pinions being in mesh with the other side gear cause it to rotate. The differonce in the gear ratio will cause it to rotate faster. As soon as the resistance equalizes, the pinions and side gears stop rotating independently and rotate as a unit with the ring gear and differential case.

(1) Diagnosis. Very few problems are encountered with the differential of the M37 crane-shovel, but, like other parts and components, it will wear and become unserviceable. Incorrect tooth contact and clearance will cause the ring gear and drive pinion teeth to wear enough to break under heavy load. Improper lubrication or adjustment and the presence of abrasives will damage the bearings and change the gear adjustment. This assembly is protected on the bottom by an oil pan and partially protected on the top by the lower base assembly; it is not enclosed in a sealed case like the differential of your automobile

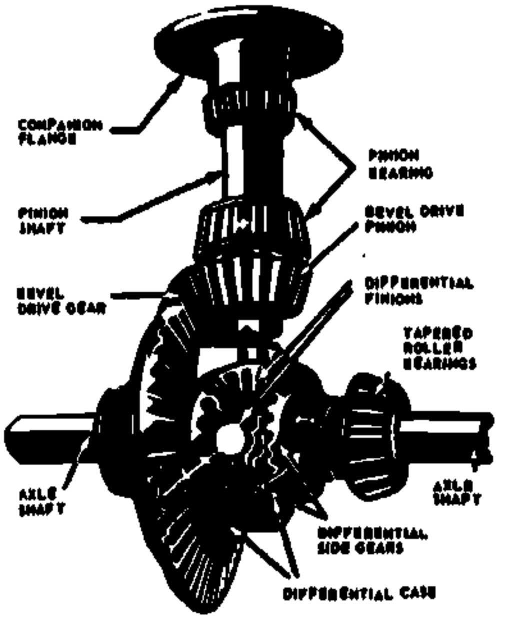
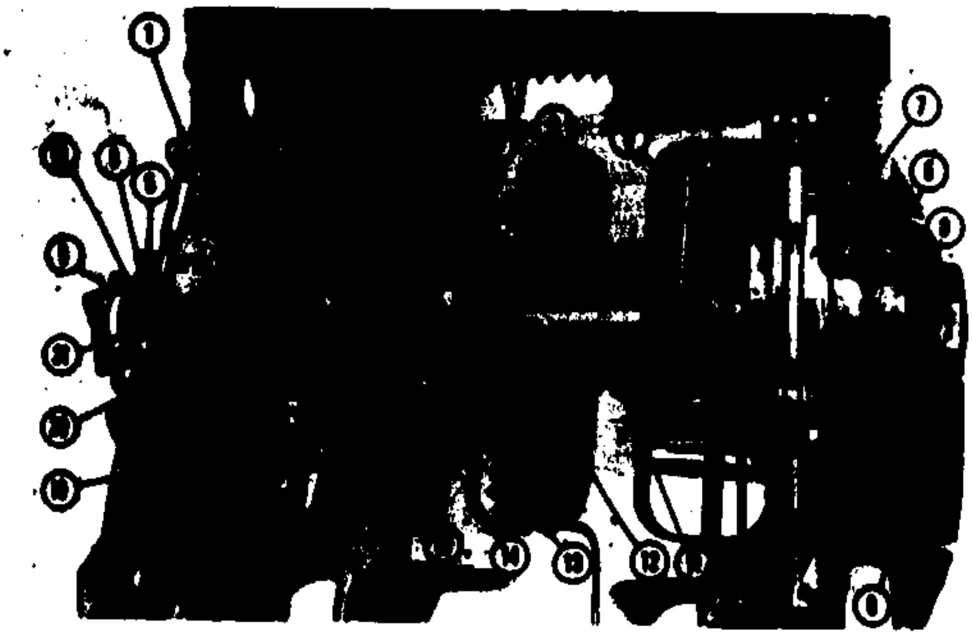


Fig 3-23. Differantial with part of differential case cut away.

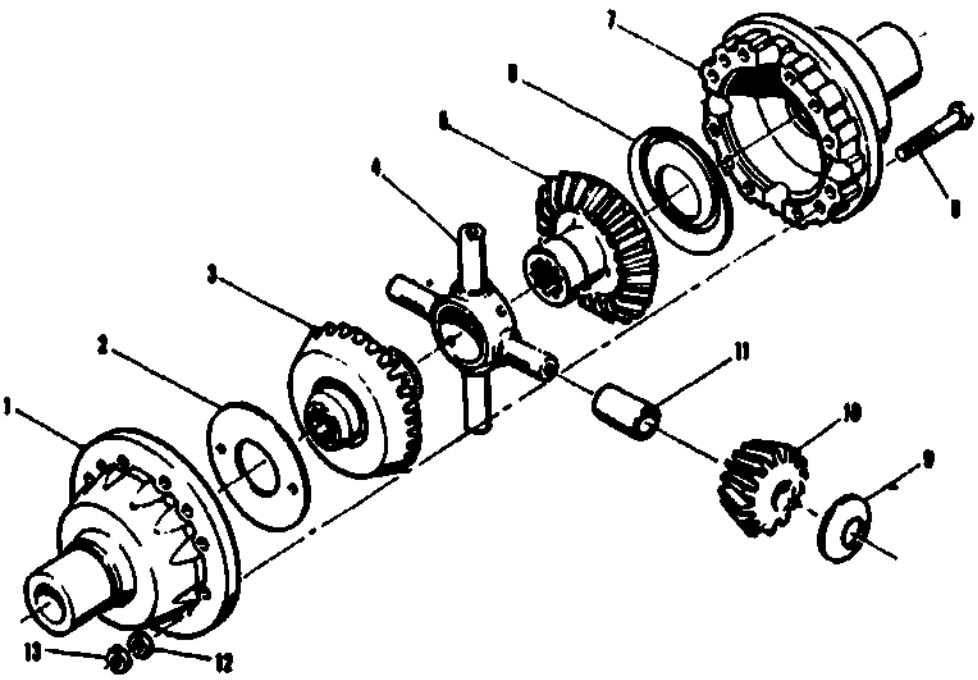
(2) Repair. Although the complete differential propelling shaft assembly is usually removed when repairs to the differential are required, the differential assembly can be removed without removing all of the other parts (fig 3-24). To remove only the differential, drain the lubricant from the pan and remove the pan and the lubrication lines. Place jack stands or cribbing under the propelling shaft between the collar clamp and the steering mechanism to support the weight of the parts when the bearing caps that support the differential case are removed. Remove the chains from the sprockets and the collar clamps from the propelling shafts. The propelling shafts can now be pulled out just far enough to clear the differential case. Remove the bearing caps on each side and remove the differential.



1. Hanger
2. Pin
3. Links
4. Center bearing cap
5. Nut
6. Lower base assembly
7. Propelling brake drum
8. Bearing cap
9. Propelling brake drum sprockets
10. Tubing differential shaft outer bearing
11. Shaft
12. Bevel pinion
13. Tubing differential shaft center bearing
14. Bevel ring gear
15. Bearing cap
16. Tubing differential shaft side bearing
17. Split collar
18. Pin
19. Lower crank
20. Pin
21. Reach rod

Fig 3-24. Differential propelling shaft assembly.

and ring gear. The bevel drive pinion is splined to the vertical propelling shaft and retained by capscrews. A gear puller may be required to remove and install it. When worn beyond specifications, the tooth clearance and contact are adjusted by shims and replacing of the thrust washers. Before disassembling the differential (fig 3-25), if the gears are still serviceable, mark them so that they can be reinstalled in the same position. Clean the parts in an approved cleaning solvent and inspect them. Check the antifriction bearings for pits and scores. Check the thrust washers and bushings for wear. Check the gears very closely for pits and cracks, and the wear pattern on the gear teeth. Check the shaft splines for bent, cracked, chipped, or twisted splines. Replace all defective parts; some of the gears must be ordered and replaced as sets. Reassembly and installation are the reverse of disassembly and removal.



1. Half case male
2. Washer
3. Side gear
4. Differential spider
5. Side gear
6. Washer
7. Half case female
8. Capscrew
9. Pinion washer
10. Bushed Pinion
11. Pinion bushing
12. Plain nut
13. Jam nut

Fig 3-25. Exploded view of differential.

b. Grader. Attached to the rear of the grader lower transmission is the final drive assembly (fig 3-26). It turns the power flow 90° just as the differential in other machines, but it does not allow one wheel to rotate while the other is being held. Wheels on both sides of the grader are receiving power when power is being transmitted through the final drive. Power is transmitted by the bevel pinion gear, which is made as part of the lower transmission shaft, being in mesh with and rotating the ring gear. The ring gear is keyed to a shaft and bull pinion; the component is called the jack shaft assembly when the ring gear and parts are assembled. The bull pinion is in mesh with and rotates a bull gear. Splined to each side of the bull gear are axle shafts which transmit the power to both tandem assemblies. The gear on the lower transmission pinion shaft and the ring gear are the spiral bevel type. This provides more tooth contact and quieter operation. The bull gear and the bull pinion are the straight spur gear type. The bull gear and the jack shaft assembly are mounted on tapered roller bearings which require adjustment. The bearing preload is adjusted by adding or removing shims on the jack shaft assembly and an adjusting nut on the bull gear assembly.

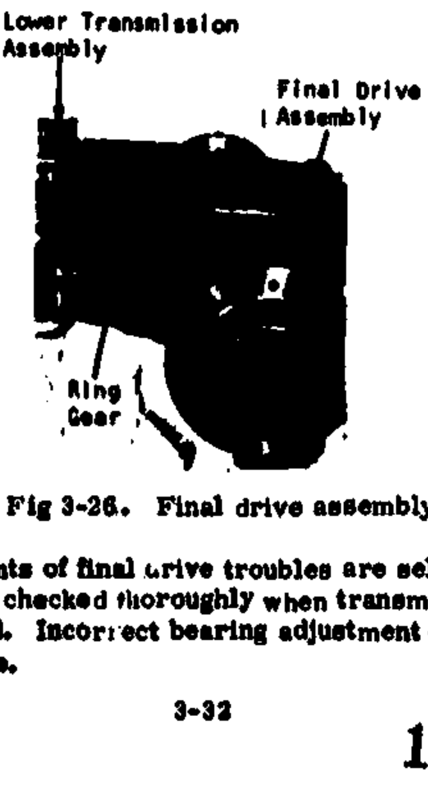


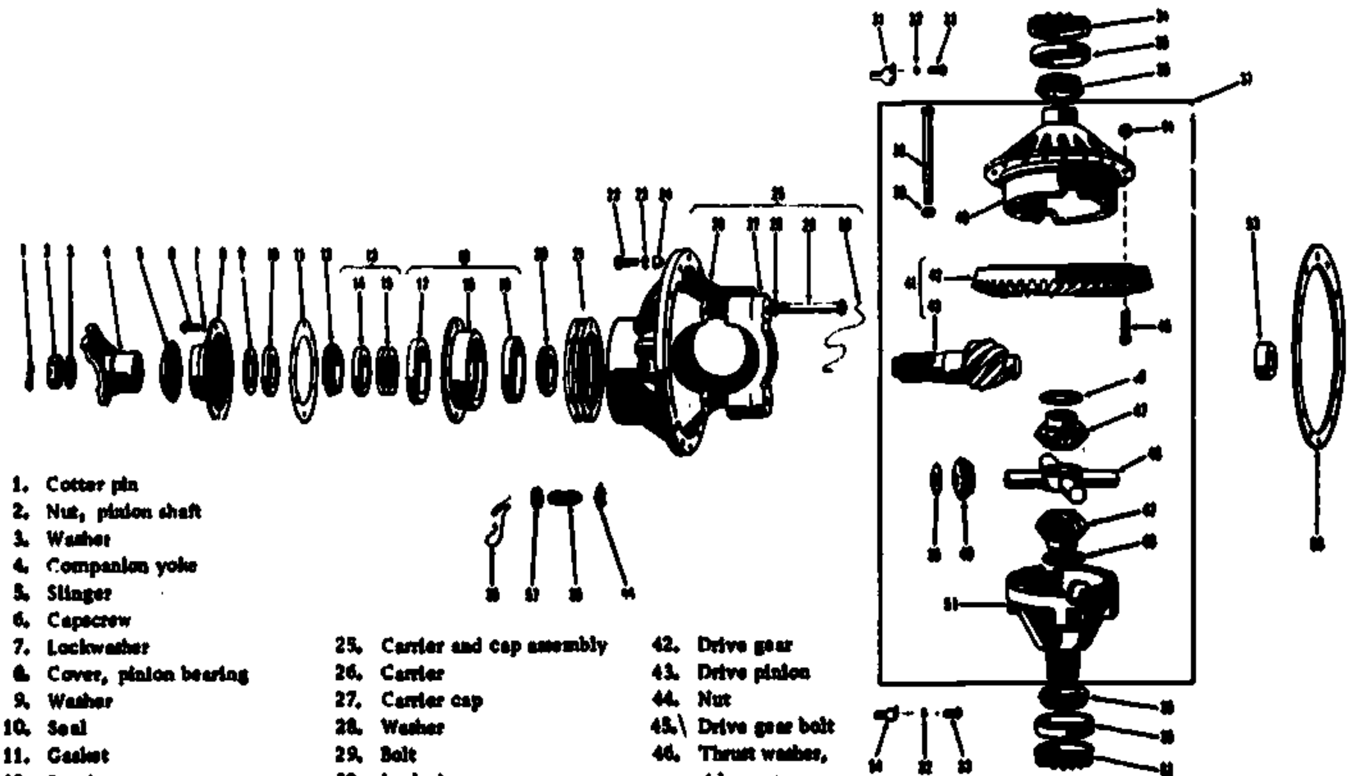
Fig 3-26. Final drive assembly.

(1) Diagnosis. Complaints of final drive troubles are seldom received. However, the component should be checked thoroughly when transmission noise problems are being checked and repaired. Incorrect bearing adjustment or gear teeth contact, or defective parts can cause noise.

(2) Repair. Because the tandem, final drive, transmission, and engine must be removed, repairs are performed at fourth and fifth echelon facilities. Lower echelon shops are not normally equipped with the special tools necessary to perform the repairs. Some of the special tools required are scales, gage block, dial indicator, pullers and press, and a means of heating oil for heating parts.

c. MRS-100 wheeled tractor. This vehicle is equipped with two identical axle assemblies. The only difference between the two is the manner in which they are connected to the tractor. The rear axle has a rigid connection with the tractor frame. The front axle is connected so that it can swivel, preventing torsional strain when traveling over rough terrain. Each axle consists of an axle housing, a differential, two axle shafts with constant-velocity type universal joints, two steering spindle groups, and wheels. Some of the parts other than the differential will be discussed briefly because they must be removed to perform differential repairs and must be considered when diagnosing problems.

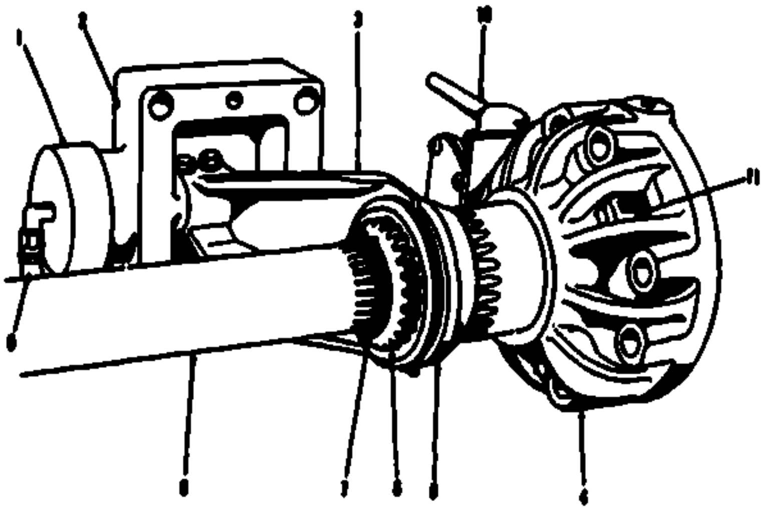
(1) Axle assembly. The differential (fig 3-27) used in these assemblies is very similar to the differential used in the M37 crane-shovel. It performs four functions: transmits torque from the drive pinion to the axle shafts, changes the direction of rotation of the drive parts 90°, provides for a reduction in the double-reduction axle, and allows one wheel to turn at a different rpm from the opposite wheel. This tractor is also equipped with a differential lock which prevents wheel-spinning where the traction is poor. When the locks are engaged, the two wheels will rotate at the same rpm regardless of resistance. The axle is a double-reduction axle assembly; the first reduction is in the differential and the second reduction is in the planetary gearing in the wheels. Power from the propelling shaft enters the axle housing at the drive pinion. The drive (ring) gear is bolted to the differential case and is in mesh with the drive pinion. Therefore, it will rotate when the drive pinion rotates. The differential pinions and side gears function the same as those in the M37 crane-shovel differential unless the differential locks are engaged.



1. Cotter pin
2. Nut, pinion shaft
3. Washer
4. Companion yoke
5. Slinger
6. Capscrew
7. Lockwasher
8. Cover, pinion bearing
9. Washer
10. Seal
11. Gasket
12. Bearing cone
13. Bearing spacer and shims
14. Spacer
15. Shims
16. Bearing cage assembly
17. Bearing cup
18. Bearing cage
19. Bearing cup
20. Bearing cone
21. Shims
22. Capscrew
23. Lockwasher
24. Dowel (tapered)
25. Carrier and cap assembly
26. Carrier
27. Carrier cap
28. Washer
29. Bolt
30. Lockwire
31. Lock
32. Lockwasher
33. Capscrew
34. Adjusting ring
35. Bearing cup
36. Bearing cone
37. Differential, drive gear and pinion assembly
38. Case bolt
39. Nut
40. Case, half, flanged
41. Gear set
42. Drive gear
43. Drive pinion
44. Nut
45. Drive gear bolt
46. Thrust washer, side gear
47. Side gear
48. Spider
49. Differential pinion (four)
50. Thrust washer (four)
51. Case half, plain
52. Adjusting ring
53. Bearing (drive pinion; hose)
54. Lock
55. Nut lock
56. Thrust screw
57. Jam nut

Fig 3-27. Exploded view of MRS-100 wheeled tractor differential.

The axle shafts rotate with the side gears or the differential case. Splines on one side of the differential case and a splined sleeve on one axle (fig 3-28) allow the operator to lock that axle shaft to the case by moving a collar to engage both sets of splines. With the axle shaft splined to the side gear and locked to the case, the side gear must rotate at the same speed as the case. This prevents wheel-spin because one side gear must rotate faster and one slower than the differential case during wheel-spin.



1. Air cylinder
2. Shift housing
3. Shifting fork
4. Differential case
5. Shifting collar
6. Spacer (internal and external splines)
7. Snap ring
8. Axle shaft
9. Air hose
10. Control lever
11. Side gear

Fig 3-28. Differential lock.

It was stated earlier in this course that unless a special universal joint is used there will be fluctuation in the speed of the shaft. To prevent this, a constant-velocity universal joint similar to that shown in figure 3-29 is used. The universal joint provides a means of transmitting power to the wheels as they are turned at different angles. The spindle group (fig 3-30) serves as a means of supporting and steering the wheels. It also houses the constant-velocity universal joint. Removal of the spindle group is necessary to remove the differential.

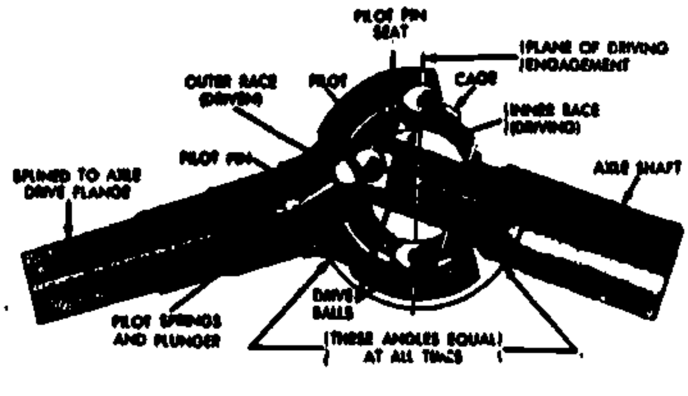
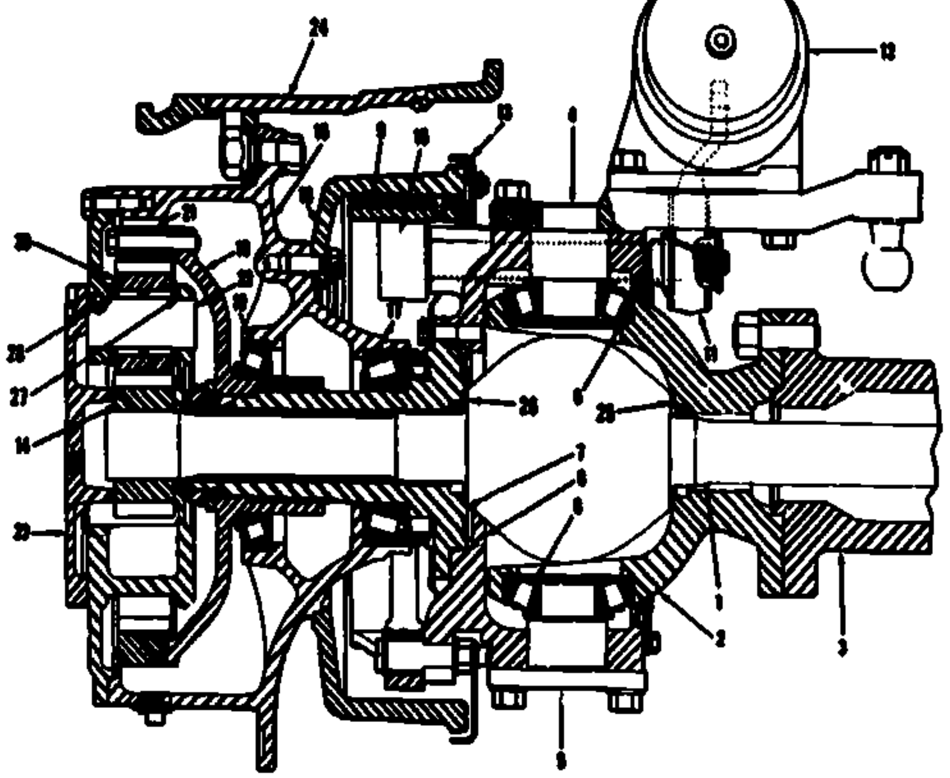


Fig 3-29. Constant-velocity universal joint.



1. Axle shaft
2. Housing outer end
3. Axle housing
4. Steering arm and upper trunnion
5. Lower trunnion
6. Roller bearing
7. Spindle
8. Spindle support
9. Brake shoe
10. Brake camshaft
11. Slack adjuster
12. Brake chamber
13. Brake rock guards
14. Sun gear
15. Wheel
16. Brake drum
17. Roller bearing
18. Roller bearing
19. Ring gear spider
20. Planet gear
21. Ring gear
22. Planetary gear shaft
23. Hub cap
24. Rim
25. Thrust washer, inner
26. Thrust washer, outer
27. Thrust washer, inner
28. Thrust washer, outer

Fig 3-30. Sectional view of axle steering end.

(a) Diagnosis. Most of the problems encountered with the axle assemblies will be noise, vibration, loss of lubricant, and hard steering. Vibrations at the differential are usually caused by broken gear teeth or excessive runout of the drive pinion or bearing. Noise usually occurs in four different situations: continuous, while under load, while coasting, or when turning. Worn or damaged bearings will cause a noise while coasting or during continuous operation. Damaged or worn gears will also cause a continuous noise. If the ring and pinion gear adjustment is too tight, the noise will occur when under load. Loose ring and pinion gear adjustment and excessive pinion gear end play will cause a noise during coasting. Worn differential pinion (spider) gears or side gears will cause a noise when turning. Worn, defective, or improperly installed oil seals, loose nuts and bolts, defective gaskets, and cracked housings are all possible causes for loss of lubricant. The differential can cause hard steering if the differential lock is engaged; remember that one wheel must rotate faster than the other during turns.

(b) Repair. To repair or adjust the differential, it must be removed from the axle assembly. Clean the assembly thoroughly and drain the oil from the axle housing. Mark the housings so they can be replaced in the same position. Remove the nuts holding the housing outer end to the axle housing (fig 3-30). This will allow the axle shafts to be pulled far enough from the side gear splines to clear the differential case. Do not pull the axle shaft on the differential lock side out too far before removing the differential locking parts. Remove the propeller shaft and nuts holding the differential carrier to the axle housing and remove the differential assembly. Repairs and adjustment can be made with the differential carrier assembly out of the axle housing. Clean and inspect the assembly and repair or replace and adjust all defective parts. The spindle group must be disassembled to replace or repair the axle shafts. For detailed instruction pertaining to the axle assembly repair, refer to the TM for the vehicle being repaired.

(2) Relation to other vehicles. The axle assemblies used on the MRS-100 wheeled tractor are very similar to those used on other wheeled vehicles. Some parts of the axle assemblies are interchangeable, but be sure to check the stock number before substituting one of the parts. The axle assemblies of the MRS-100 tractor, the M60 crane, the scoop loader, and the forklift function alike. However, some of the vehicles are not equipped with differential locks and some of the axle assemblies are not steerable.

UNITED STATES MARINE CORPS
MARINE CORPS INSTITUTE, MARINE BARRACKS
BOX 1775
WASHINGTON, D.C. 20013

ENGINEER EQUIPMENT MECHANIC

Lesson 3

Diagnosis and Repair of Power Train Components

STUDY ASSIGNMENT: MCI 13.41c, Engineer Equipment Mechanic, chap 3.

LESSON OBJECTIVE: Successful completion of this lesson, combined with on-the-job training using the principles presented, will enable you to diagnose and repair power train components such as clutches, transmissions, propeller shafts, differentials, and final drives.

WRITTEN ASSIGNMENT:

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

Value: 1 point each

1. Which component of a vehicle transmits the energy produced by the engine to the part doing the work?

   a. Clutch
   b. Power train
   c. Crankshaft
   d. Transmission

2. What type of engine clutch is used in the mobile crane carrier?

   a. Disk
   b. Cone
   c. Contracting
   d. Expanding

3. What part of the engine clutch connects the engine power to the transmission?

   a. Pressure plate
   b. Input shaft
   c. Driven disk
   d. Left output shaft

4. What is the cause of most engine clutch problems?

   a. Slipping
   b. Grabbing
   c. Rattling
   d. Dragging

5. When an engine clutch starts to grab, the easiest place to check first is the

   a. clutch lining.
   b. control linkage.
   c. engine mountings.
   d. burred splines.

6. What clutch deficiency can cause a rattling type of noise?

   a. Weak retractor springs
   b. Over lubrication
   c. Cracks and heat checks
   d. Oil soaked linings

7. When troubleshooting the grader clutch, looso bolts in the front power unit support clamp would be indicated by insufficient free pedal in

a. forward gear.
b. neutral.
c. reverse.

8. Which of the below listed tractors has track controls which allow the tracks to operate independently of each other?

a. 72-31MP
b. 82-30M
c. Case MC1150
d. MRS100

9. The clutch of an MC1150 torque converter that is not fully engaging could be caused by

a. high drive oil pressure.
b. low drive oil pressure.
c. high engine rpm.
d. low engine rpm.

10. The last items to check on the TEREX 82-30M tractor for steering trouble are

a. leaking lines and defective valves.
b. clogged strainers and filters.
c. worn clutch and brake pack parts.
d. valve springs and pump.

11. When bleeding the steering control system, what type of fluid should you put in the master cylinder?

a. 5W engine oil
b. 10W 30 engine oil
c. Brake fluid
d. Heavy-duty brake fluid

12. Engaging and disengaging the 2N crawler crane-shovel steering system is through what type of linkage?

a. Air and mechanical
b. Hydraulic
c. Electrical
d. Air and hydraulic

13. The causes of most M-37 crane steering problems are improper lubrication, dirt, and defective

a. linkage.
b. tracks.
c. propelling shaft.
d. upper machinery.

14. Failure ot the 2N crawler crane-shovel to turn when the correct lever is moved indicates incorrect clutch or brake adjustment, defective air cylinder and

a. defective tracks.
b. defective levers.
c. excessive speed.
d. defective valves.

15. The brakes on the 2N crawler crane-shovel are engaged by ______ and released by ______

a. air pressure -- hydraulics
b. hydraulics -- vacuum
c. spring tension -- air pressure
d. spring tension -- hydraulics

16. Should the lower traction shaft assembly be removed and disassembled, why is it necessary to insure that the drilled air passages are properly alined during reassembly?

a. To insure proper lubrication.
b. Unalined air passages will prevent installation of all parts.
c. So that the brake linings may be adjusted.
d. So that the clutch may be adjusted.

17. Most of the attachment control clutches are of what types?

a. External contracting or internal expanding
b. Jaw and cone
c. Cylinder and cone
d. External expanding and jaw

18. Light rust on clutch or brake band drums on the attachment control clutches can best be removed by

a. sanding.
b. turning on the lathe.
c. use.
d. 5W oil.

19. Most problems encountered with the operating clutch on the M37 crane-shovel are either failure to disengage completely or

a. slipping.
b. dragging.
c. grabbing.
d. rattling.

20. Most maintenance problems encountered in the torqmatic transmission concern oil __________ and __________.

a. pressure-overheating
b. replenishment-cleanliness
c. temperature-level
d. IN pressure-OUT pressure

21. The torqmatic transmission is lubricated by the same oil which is used

a. to lubricate the engine.
b. to cool the engine.
c. to engage the transmission clutches.
d. to lubricate the differential,

22. In a torqmatic transmission, locked stators, low oil level, clogged or dirty heat exchangers or overheated engine cooling system would be indicated by

a. high converter-out temperature.
b. low converter-out temperature.
c. high converter-out pressure.
d. low converter-out pressure.

23. Major repairs to the torqmatic transmission are made at what level(s) of maintenance?

a. Organizational and intermediate (field)
b. Intermediate (field) and depot
c. Organizational and depot
d. Depot only

24. What test(s) are performed at the lower echelons on a faulty torqmatic transmission to insure that the problem is not caused by lack of maintenance?

a. Stall
b. Pressure checks
c. Stall tests and pressure checks
d. Stall tests and tachometer tests

25. By what means is a propeller shaft attached between a transmission and differential?

a. Universal joints
b. Splines
c. Shifting collar
d. Keyed and pressed

26. How can the effects of speed variation in a universal joint be minimized?

a. By using a slip joint
b. By using two universal joints with the yokes on the propeller shaft in the same plane
c. By using journal-type universal joints
d. By changing the angle between the driving component and the propeller shaft, and between the propeller shaft and the driven component

27. Which statement about the MRS-100 differential is NOT true?

a. Differential noise usually occurs while vehicle is under load.
b. Differential noise is usually intermittent.
c. Differential noise usually occurs when vehicle is turning.
d. Differential noise is usually continuous.

28. A differential noise that occurs under load is probably caused by

a. loose ring gear and pinion adjustment.
b. tight ring gear and pinion adjustment.
c. worn bearings.
d. worn spider and side gears.

Total Points: 28

* * *

Chapter 4

DIAGNOSING, TROUBLESHOOTING, AND REPAIRING AUXILIARY EQUIPMENT

Chapter objectives: A student successfully completing this chapter will be able to identify the procedures necessary to diagnose and correct malfunctions of the:

1. hydraulic system,
2. compressor,
3. electrical system,
4. steering system,
5. tracks and track frame assemblies.

4-1. GENERAL

Under normal operating conditions the auxiliary equipment seldom needs repairs. Of the auxiliary systems, the electrical will be the most troublesome; therefore, more emphasis is put on troubleshooting this system. For more specific information, the TM for an individual piece of engineer equipment should be used.

4-2. HYDRAULIC SYSTEMS

Hydraulic systems are precision units and their continued smooth operation depends on frequent inspection and servicing. It is of primary importance that they be kept clean, with oil and filters changed at established intervals. If, in spite of these precautions, improper operation does occur, the cause can usually be traced to one of the following:

- Use of wrong viscosity or type of oil.
- Presence of air in the system.
- Insufficient fluid in the system.
- Mechanical damage or structural failure.
- Internal or external leakage.
- Dirt, decomposed packing, water, sludge, rust and other foreign matter in the system.
- Improper adjustments.
- Heat exchanger plugged, dirty, or leaking.

a. Testing. Many believe that fluid flow is a function of pressure and that pressure gage readings alone indicate good or bad circuits and components. The only positive way to test a hydraulic system is to use a hydraulic circuit tester.

b. Troubleshooting. Troubleshooters should follow a set procedure when troubleshooting a hydraulic system. The procedure of STOP described below is one such procedure.

S - Study the hydraulic circuit diagrams

T - Test, using the correct tester

O - Organize the knowledge gained from circuit test results

P - Perform repairs, taking time to do the job well

Any troubleshooting procedure must be "by guess or by gage", but you should always test flow and pressure at the same time. If you use a hydraulic circuit tester to test individual components, the return fluid must be directed back to the reservoir via piping outside the system. If the fluid is returned to the reservoir through the system's piping, the result will be an incorrect reading because of buildup of back pressure. The following tables will list some of the problems which may be encountered and their remedies. They are not necessarily listed in the order of most frequent occurrence. Check the applicable TM for the equipment being worked on for specific information about its hydraulic system. In general, cylinders will fail first. Packing will wear because of friction and loading against the cylinder walls. Therefore, the cylinders should be isolated first. When test results indicate a properly operating circuit, it is positive proof of cylinder malfunction. Other conditions could occur not directly related to, nor caused by, the various parts of the hydraulic system which might show the same general malfunction of an improperly operating system. Some of them, such as leaking hoses, packing glands, and seals, would be visually apparent; others, such as binding in the directional control valve or cylinder piston rod, a dented or deformed hydraulic cylinder, or a crimped or restricted pressure line, would be harder to detect.

Table 4-1. Improper Operation of Pumps

Possible Causes	Remedies
Complaint: Failure of pump to deliver fluid	
Low fluid level in reservoir.	Add recommended oil and check level on both sides of tank baffle to be certain pump suction is submerged.
Oil intake pipe or inlet filter plugged.	Clean filter or otherwise remove obstruction.
Air leak in inlet line preventing priming or causing noise and irregular action of control circuit.	Repair leaks.
Pump shaft turning too slowly to prime itself (vane type pumps only).	Check minimum speed recommendations in appropriate TM.
Oil viscosity too heavy to pick up prime.	Use lighter viscosity oil. Follow appropriate TM's recommendations for given temperature and service.
Wrong direction of shaft rotation.	Must be reversed immediately to prevent seizures and breakage of parts due to lack of oil.
Broken pump shaft or parts broken inside pump. Shear pin or shear linkage broken.	Refer to appropriate TM for replacement instructions.
Dirt in pump.	Dismantle and clean pump, and flush system.
On variable delivery pumps, the stroke is not right.	Check appropriate TM for instructions.
Complaint: No Pressure in system	
Pump not delivering oil for any of the reasons given above in this table.	Follow remedies given above in this table.
Relief valve not functioning properly. (a) Valve setting not high enough. (b) Valve leaking. (c) Spring in relief valve broken.	Proceed as follows: (a) Increase pressure setting of valves (check TM for correct pressure). (b) Check seat for score mark and reseat. (c) Replace spring and readjust valve.
Vane or vanes stuck in rotor slots (vane type pumps only).	Inspect for wedged chips. Inspect oil for excessive viscosity.
Head loose (very infrequent).	Must not be tightened too tightly. See TM's instructions before tightening.
Free recirculation of oil to tank being allowed through system.	A return line may be open due to either a directional valve being set in the open-center neutral position or some other valve unintentionally open.
Internal leakage in control valves.	To determine location progressively, block off various parts of circuit. When trouble is located, repair.

Table 4-1. Improper Operation of Pumps --contd

Complaint: Pump making noise	
Possible Causes	**Remedies**
Partially clogged intake line, intake pipe.	Clean out intake, strainer, or eliminate restrictions. Be sure inlet line is completely open.
Air leaks (a) At pump intake piping joints. (b) At pump shaft packing (if present). (c) Air drawn in through inlet pipe openings.	Proceed as follows: (a) Test by pouring oil on joints while listening for change in sound of operation. Tighten as required. (b) Pour oil around shaft while listening for change in sound of operation. Follow appropriate TM's recommendations when changing packing. (c) Check to be certain inlet and return lines are well below oil level in reservoir. Add oil to reservoir, if necessary.
Air bubbles in intake oil.	Use hydraulic oil containing a foam depressant.
Reservoir air vent plugged.	Air must be allowed to breathe in the reservoir. Clean or replace breather.
Pump running too fast.	Check recommended maximum speeds from appropriate TM.
Too high oil viscosity.	Use lower viscosity oil. Follow appropriate TM's recommendations for given temperature and service.
Coupling misalinement.	Realine.
Pump head too loose, or a faulty head gasket.	Test by pouring oil over head. Replace gasket or tighten head, as necessary.
Stuck pump vane (vane type pump).	Inspect for wedged chips or sticky oil and reassemble.
Worn or broken parts.	Replace.
Complaint: External oil leakage around pump	
Shaft packing worn.	Replace.
Head of oil on inlet pipe connection.	Sometimes necessar [illegible] will usually cause slight leakage. Keep all [illegible] tight.
Damaged head packing.	Replace.

Table 4-1. Improper Operation of Pumps--contd

Complaint: Excessive wear	
Possible Causes	**Remedies**
Abrasive matter in the hydraulic oil being circulated through the pump.	Install adequate filter or replace oil more often.
Viscosity of oil too low for working conditions.	Check pump TM's recommendations or consult the lubrication chart.
Sustained high pressure above maximum pump rating.	Check relief or regular valve maximum setting.
Drive misalinement or tight belt drive.	Check and correct.
Air recirculation causing chatter in system.	Remove air from system.

Complaint: Breakage of parts inside pump housing	
Possible Causes	**Remedies**
Excessive pressure above maximum pump rating.	Check relief or regulator valve maximum setting.
Seizure due to lack of oil.	Check reservoir level, oil filter, and possibility of restriction in inlet line.
Solid matter being wedged in pump.	Install filter in suction line.
Excessive tightening of head screws.	Follow appropriate pump TM's recommendations.

Table 4-2. Improper Operation of Actuating Mechanisms

Complaint: System inoperative	
Possible Cause	**Remedy**
Any of the reasons listed in tables.	Follow remedies given in tables.
Complaint: Mechanisms creep when stopped in intermediate position	
Air in system.	Bleed the system.
Internal leak in actuating cylinder or directional control valve.	Replace piston packing or replace cylinder if walls are scored. Replace or repair valve. Clean unit to remove foreign matter, then check cam clearance.
Worn pump.	Repair or replace.
If action is sluggish on starting up, but somewhat less sluggish after operating temperatures have increased, or if action slows down after warm up (depending on equipment and circuit design), it is probable that viscosity of oil is too high.	Check TM lubrication order.

Table 4-2. Improper Operation of Actuating Mechanisms--contd

Complaint: External oil leakage	
Possible Causes	**Remedies**
End caps.	Tighten, if possible, or replace gasket.
Chevron seals.	Adjust or replace seal.
Complaint: Abnormal packing gland wear	
Cylinder not securely fastened to frame, causing vibration.	Tighten. This should be checked periodically.
Misalinement of cylinder and piston rod extension.	Check and correct.
Side load on piston rod.	Check for alinement of cylinder, worn pins or ball joints.

Table 4-3. Improper Operation of Accumulator

Complaint: Pressure from accumulator drops suddenly when position of selector valve is changed	
Possible Cause	**Remedy**
Internal or external leak in accumulator.	Repair leak or replace accumulator.
Complaint: When pump is running pressure is normal, but when pump is stopped no pressure is available	
Leaking gas valve or leaking check valve in hydraulic line.	Replace check valve or gas valve.
Complaint: Sluggish response from accumulator	
Stoppage of oil screen in accumulator.	Dismantle accumulator and clean screen.
Gas precharge not sufficient.	Precharge according to appropriate TM's instructions; also check for gas leaks.
Note. Be sure all internal pressure is released before repairs are made on accumulators.	

Table 4-4. Excessive Heating of Oil in System

Possible Causes	Remedies
Complaint. Heating caused by power unit (reservoir, pump, relief valve, and coolers)	
Relief valve is set at a higher pressure than necessary. Excess oil dissipated through increased slippage in various parts, or through relief valve or through directional valve.	Reset relief valve, after checking TM for correct pressure.
Internal oil leakage due to wear in pump.	Repair or replace pump.
Viscosity of oil too high.	Check LO for correct oil viscosity grade to be used at various temperatures.
Pumps assembled after overhaul may be assembled too tightly. This reduces clearances and increases friction.	Follow TM when rebuilding a pump.
Leaking check valves or relief valves in pump.	Repair or replace.
Improper functioning of oil cooler, or coolant in cut off.	Inspect cooler and see that it is clean inside and outside and that air flow or coolant flow around fins is not cut off.
Complaint: Heating because of conditions in system	
Restricted lines.	If lines are crimped, replace; if partially plugged for any reason, remove obstruction.
Large pump deliveries not unloaded properly.	Make certain that open-center valves are neutralized and that any pressure-relieving valves are in the correct position. Only small pump volumes should be allowed to remain at high pressures when running idle for long periods of time.
Insufficient radiation.	Use artificial cooling.
Internal leaks.	Locate leaks, then replace packing.
Reservoir too small to provide adequate cooling.	Replace with larger reservoir, or install cooler.
Undersize valves or piping.	Check flow velocity through lines and valves and compare with TM's recommendations. If excessive, replace by installing larger equipment.

Note. If the system operates continually at high operating temperatures, considerations should be given to the installation of an oil cooler.

Table 4-5. Improper Operation of Fluid Motors

Possible Cause	Remedy
Complaint: Motor turning in wrong direction	
Conductors crossed between control valve and motor.	Check circuit to determine correct conductor connection between control valve and motor.
Complaint: Motor not turning or not developing proper speed or torque	
System overload relief valve adjustment not set high enough.	Check system pressure and reset relief valve.
Relief valve sticking open.	Clean or replace relief valve and adjust.
Free recirculation of oil to reservoir being allowed through system.	Directional control valve may be in open center neutral (spool not shifting when control is operated), check control valve linkage.
Driven mechanism binding because of misalinement.	Check motor shaft for alinement.
Pump not delivering enough GPM or pressure.	Check pump GPM and pressure, repair or replace.
Motor yoke not set at proper angle (on adjustable motors).	Adjust pump yoke angle.
Complaint: External oil leakage from motor	
Seals leaking (may be due to drain not being connected from motor to tank).	Check motor for 3d line (this drain line must go to tank used on piston and vane motors).

4-3. COMPRESSOR

The compressor utilized as auxiliary equipment provides the compressed air necessary for equipment brake and steering systems. The proper maintenance is a necessity as the failure of this compressor would result in unsafe operating conditions. Table 4-6 lists a few of the failures and causes. They are not listed in the order of most frequent occurrence.

Table 4-6. Compressor Malfunctions and Remedies

Complaint	Cause	Remedy
a. Improper air pressure.	1. Air pressure in system is above normal.	1. Check governor settings. Adjust air compressor unloading valves. Replace governor if necessary.
	2. Air reservoir damaged	2. Inspect air reservoir and replace if necessary.
b. Slow buildup of air pressure	1. Leaking foot brake valve.	1. Replace valve.
	2. Leaking air compressor discharge valve.	2. Replace air compressor head assembly.
	3. Leaking air pipes or connections.	3. Tighten connections or replace pipe.
	4. Air compressor unloader valve not adjusted correctly.	4. Adjust unloader valve.
	5. Clogged air compressor filter.	5. Clean filter.
	6. Worn air compressor pistons and rings.	6. Replace pistons and rings.
	7. Leaking relay valve.	7. Replace valve.
c. Rapid loss of air pressure when engine is stopped.	1. Worn or leaking air compressor discharge valves.	1. Replace head assembly.
	2. Leaking air pipes or connections.	2. Tighten connections or replace pipe.
	3. Leaking foot brake valve.	3. Replace valve.
	4. Leaking safety valve.	4. Replace safety valve.
	5. Leaking governor.	5. Replace governor.
	6. Leaking relay valve.	6. Replace relay valve.
d. Air pressure too high.	1. Broken air compressor unloader mechanism.	1. Replace cylinder head assembly.
	2. Governor not operating.	2. Replace governor.
	3. Defective air gage.	3. Replace governor.
	4. Restriction in line between governor and compressor loading mechanism.	4. Remove line and clear restriction. Replace damaged line.

Table 4-6. Compressor Malfunctions and Remedies--contd

Complaint	Cause	Remedy
	5. Faulty unloading valve or compressor.	5. Remove head, clean carbon and reseat valves.
	6. Unloading valve stuck closed.	6. Remove cylinder head and free valve.
e. Air pressure will not rise to normal.	1. Defective air gage.	1. Replace gage.
	2. Excessive leaks.	2. Locate and correct leaks.
	3. Reservoir drain cock left open.	3. Close drain cock then check pressure buildup.
	4. Faulty unloader valve or compressor.	4. Adjust unloader valve.
	5. Compressor drive belts slipping.	5. Adjust belt tension.
	6. Faulty compressor.	6. Repair or replace compressor.
f. Compressor knocks continuously or intermittently.	1. Loose drive pulley.	1. Tighten pulley. Replace pulley or key if worn or damaged.
	2. Worn or burned bearings.	2. Replace.

4-4. ELECTRICAL SYSTEM

a. General. This paragraph provides a guide for troubleshooting the electrical charging system (both a.c. & d.c.) and cranking system including the storage battery. These tables should be used as a guide only; for more specific information consult the TM for the specific item of equipment being worked on. The complaints and causes are not listed in the order of most frequent occurrence.

b. Generators. The charts below give general troubleshooting guidelines for d.c. generators and alternators.

Table 4-7. D.C. Generator Troubleshooting

Symptom	Cause	Remedy
a. No output.	1. Sticking brushes	1. Free. replace brushes & springs.
	2. Gummy or dirty commutator.	2. Clean; turn commutator.
	3. Burned commutator.	3. Clean; turn commutator and under cut mica. Check current-regulator setting.
	4. Loose connections or broken leads.	4. Tighten or solder connections. Replace leads.
	5. Grounded armature.	5. Check with tester. Repair or replace.
	6. Open armature.	6. Repair or replace.
	7. Shorted armature.	7. Check on growler. Repair or replace.
	8. Grounded field.	8. Check with tester.
	9. Open field.	9. Check with tester. Repair or replace.

Table 4-7. D. C. Generator Troubleshooting--contd

Symptom	Cause	Remedy
	10. Shorted field.	10. Check with ammeter. Repair or replace.
	11. Grounded terminal.	11. Repair or replace. Replace insulation or terminals as needed.
	12. Broken drive belt.	12. Replace belt.
b. Excessive output.	1. Grounded field circuit.	1. Check with tester. Repair or replace.
	2. Shorted field circuit with field grounded in generator.	2. Test with ammeter. Repair or replace.
c. Unsteady or low output.	1. Loose or worn fan belt.	1. Tighten or replace.
	2. Sticking brushes.	2. Free: replace brushed and springs as needed.
	3. Low brush spring tension.	3. Retension or replace.
	4. Dirty, burned or gummy commutator.	4. Clean, turn commutator and undercut mica as needed. Check armature for opens.
	5. Out-of-round, dirty, worn or rough commutator.	5. Clean, turn commutator, and undercut mica as needed.
	6. Partial short, ground, or open in armature.	6. Repair or replace armature.
d. Noisy generator.	1. Loose mounting.	1. Tighten mounting.
	2. Loose pulley.	2. Tighten pulley.
	3. Worn or dirty bearings.	3. Clean or replace.
	4. Improperly seated brushes.	4. Seat brushes properly.

Table 4-8. Alternator Troubleshooting

Symptom	Cause	Remedy
a. No output.	1. Open grounded, or shorted stator winding.	1. Replace stator.
	2. Field winding, grounded, open, or shorted.	2. Replace rotor.
	3. Brushes do not control slip rings.	3. Check brushes and brush springs. Replace if necessary.
	4. Faulty diodes.	4. Check with LOW voltage d.c. test lamp. Replace if necessary.
	5. Dirty slip rings.	5. Clean with 400 grain polishing cloth.
b. Excessive output.	1. Grounded field circuit.	1. Check with tester. Repair or replace.
	2. Shorted field circuit.	2. Test with ammeter. Repair or replace.
c. Unsteady or low output.	1. Loose or worn drive shaft.	1. Tighten or replace.
	2. Sticking brushes.	2. Free; replace brushes and springs as needed.
	3. Low brush spring.	3. Retension or replace springs.
	4. Partial tension short, ground, or open in field.	4. Repair or replace fields.
	5. Dirty or worn slip rings.	5. Clean, turn, or replace.
	6. Open or shorted rectifier or stator winding.	6. Replace.

Table 4-8. Alternator Troubleshooting--contd

Symptom	Cause	Remedy
d. Noisy alternator.	1. Loose mounting.	1. Tighten mounting.
	2. Loose pulley.	2. Tighten pulley.
	3. Worn or dirty bearings.	3. Clean or replace.
	4. Improperly seated brushes.	4. Seat brushes properly.
	5. Shorted or open rectifier or stator winding.	5. Replace.

c. Voltage regulator. Different manufacturers of voltage regulators have different procedures for making checks and adjustments of their regulators. Always check the manual before making adjustments. If there is any doubt and no manual is available, it is usually better not to attempt adjustments, since the wrong adjustment may be worse than no adjustment at all. In the following tables, some troubleshooting procedures are given.

Table 4-9. Voltage Regulator Troubleshooting

Symptom	Cause	Remedy
a. Charged battery ano low charging rate.	1. This is normal operation.	1. Check regulator setting if desired.
b. Charged battery and high charging rate.	1. High voltage-regulator setting.	1. Reduce setting.
	2. High temperature.	2. Reduce voltage-regulator setting, reduce battery specific gravity.
	3. Generator-field windings grounded or shorted.	3. Repair generator.
	4. Short, ground or open in regulator.	4. Repair or replace regulator.
	5. Shorted transistor or faulty diode (a.c.).	5. Replace.
c. Discharged battery and a low or no charging rate.	1. Defective wires or connections.	1. Replace wires; clean and tighten connections.
	2. Low voltage-regulator setting.	2. Adjust regulator.

d. Charging system. The generator and regulator must be considered as a system when troubleshooting. Certain tests must be made when trouble is experienced to determine whether it is the generator, regulator, or wiring causing the trouble. If tests show that the generator is at fault, then the troubleshooting procedures on the following pages should be used to determine what has caused the trouble in the generator.

(1) No output. Check for brush condition, burned commutator bars, or a loose connection. Burned bars, with others fairly clean, indicate open circuit coils. If the brushes appear to be making good contact with the commutator, and the commutator appears normal, remove the wiring harness and use test probes and a test light to locate the trouble as outlined in (a), (b), and (c) below.

(a) Open field circuit. Check for open field circuit by placing one test probe on the receptacle pin field (b) terminal and the other on the field frame or any convenient ground. If the test bulb does not light, the field circuit is open. If the open is from a bad connection or broken lead, it can be repaired, but if it is inside one of the field coils, the coil must be replaced.

(b) Shor ed field. If the field circuit is not open, check for a shorted field by connecting a six-volt battery and an ammeter in series with the field circuit. Current flow in excess of 0.21 amps indicates a shorted field. If a shorted field is indicated, check the regulator contact points, since a shorted field may have permitted excessive field current to burn the points.

(c) Grounds or shorts. If these tests do not locate the trouble, disassemble the generator and test the armature, field, and brush holders for grounds or shorts.

(2) Low or intermittent output. Check generator drive belt tension as specified in equipment TM. Check for worn brushes; if less than 1/2 their original length, replace. Inspect the commutator for roughness, grease, dirt, high mica, out-of-round or burned bars. Burned bars indicate an open circuit in the armature which must be corrected or the armature must be replaced.

(3) Excessive output. Excessive generator output usually results from improper voltage regulator setting; defective regulator; short circuit between the armature and field circuits in the generator, regulator, or wiring; poor ground connection at the regulator; or high battery temperature which permits the battery to accept a high charge rate even with a normal regulator setting. If the battery temperature is not high, check the cause of excessive generator output by disconnecting the field lead between the generator and regulator with the generator operating at medium speed. If the generator output drops off, the regulator is at fault and must be checked for high setting or short circuits.

(4) Noisy operation. A noisy generator can be caused by loose mountings, loose drive pulley, worn bearings, or improperly positioned brushes. Some heavy duty operations, such as those on the Terex 82-30M tractor require proper brush position in relation to the neutral point. Neutral point refers to the brush location on the commutator with respect to the armature coils and poles. Check the TM for the piece of equipment being worked on for proper procedure for installing new brushes.

e. Storage batteries. Storage batteries provide electrical energy through chemical reaction. They do wear out but, with proper maintenance and care, the life expectancy may be prolonged. In the following paragraphs some of the usual problems encountered with storage batteries will be discussed. Troubleshooting procedures are covered in Table 4-10.

(1) Overcharging. Overcharging will cause overheating and is first indicated by excessive use of water. Also, overheating will cause overcharging. The reason is an overheated battery will accept more charge current at a given charge voltage. If this condition is allowed to continue, cell covers will push up at the positive ends and in extreme cases the battery case will become distorted and cracked. An overcharging or overheating condition normally indicates the need for a lower voltage regulator setting or better ventilation of batteries or both. If overheating and overcharging continue after the batteries are properly ventilated and the voltage regulator setting is adjusted, it is likely that the battery has already been permanently damaged by continued overcharging. When reducing the voltage regulator setting, do not reduce below minimum regulator setting recommended by TM.

(2) Undercharging. This is another source of trouble which must be corrected promptly. A battery operated with insufficient charge over an extended period of time is likely to become sulphated; that is, the lead sulphate on the plates becomes crystalized. This condition is caused by either a faulty generator/alternator or an incorrect voltage regulator setting. A battery in this condition should be removed from the vehicle and subjected to a prolonged slow charge. A fast or overcharging will result in buckled plates, which pinch and chafe the separators and eventually perforate the separator, causing a short circuit in the cell.

(3) Overloading. Installing extra electrical units may disturb the balance of the electrical system. Additional electrical units should never be installed until it has been established that the existing system is adequate to supply the required current. An overloaded system may result in sulphated batteries.

(4) Leakage. Leakage can be detected by continual wetness of the battery or excessive corrosion of the terminals, battery carrier, and surrounding area.

Table 4-10. Battery Troubleshooting

Symptom	Cause	Corrective Action
a. Overcharging.	1. Charging voltage high.	1. Check generator, regulator system.
	2. High temperature.	2. Provide proper ventilation. Reduce battery specific gravity.
b. Battery uses excessive water.	1. Overcharging.	1. Check as in item a.
	2. Case cracked	2. Replace battery.
	3. Leakage.	3. Reseal or replace battery.
c. Run down.	1. Undercharging.	1. Check generator/regulator system.
	2. Wiring circuit faulty.	2. Check and replace if faulty.
	3. Excessive load demand.	3. Reduce load.
	4. High self discharge.	4. Recharge periodically; do not allow battery to stand idle.
	5. Defective or old battery.	5. Recharge, test, replace if necessary.
d. Cracked case.	1. Loose holddown clamps.	1. Retighten.
	2. Holddown clamp too tight.	2. Tighten properly.
	3. Battery frozen.	3. Keep charged to prevent freezing.
e. Bulged case.	1. Hot battery.	1. If from overcharge, reduce regulator voltage.
	2. Holddown clamps too tight.	2. Loosen and adjust properly.
f. Corrosion.	1. Overfilling.	1. Avoid overfilling; clean holder.
	2. Overcharging.	2. Adjust regulator voltage.

4-5. CRANKING SYSTEM

When a problem develops in the cranking system, the operator will probably not come in and say "It's the solenoid," or "It's the starter." About the only complaints you will hear are slow cranking or no cranking at all. Sometimes the operator might say there's a chattering noise whenever he presses the starter button. To determine the problem, a logical procedure of diagnosing should be followed. Table 4-11 that follows lists conditions that occur along with possible causes and checks and corrections. Note: The conditions listed are not in order of frequency of occurrence. That is condition a does not occur more often than condition b, nor does cause 1 necessarily occur more often than cause 2.

Note: An aid to troubleshooting the cranking system is to turn on the light switch before engaging the starter (conditions a thru e).

Table 4-11. Cranking System Troubleshooting

Condition	Cause	Remedy
a. No cranking. No lights.	1. Battery dead.	1. Recharge or replace battery.
b. No cranking. Lights go out.	1. Poor connection, probably at battery.	1. Clean cable clamp and terminal; tighten clamp.

Table 4-11. Cranking System Troubleshooting--contd

Condition	Cause	Remedy
c. No cranking. Lights dim slightly.	1. Pinion (Bendix) not engaging. 2. Excessive resistance or open circuit in cranking motor.	1. Clean pinion and sleeve; Replace damaged parts. 2. Clean commutator; replace brushes; repair poor connections.
d. No cranking. Lights dim heavily.	1. Trouble in engine. 2. Battery low. 3. Very low temperature. 4. Pinion (Bendix) jammed. 5. Frozen shaft bearings, direct short in cranking system.	1. Check engine to find trouble. 2. Check, recharge, or replace. 3. Battery must be fully charged, engine wiring circuit and cranking motor in A-1 condition. 4. Free pinion. 5. Repair cranking motor.
e. No cranking. Lights stay bright.	1. Open circuit in switch. 2. Open circuit in cranking motor. 3. Open in control circuit.	1. Check switch contacts and connections.. 2. Check commutator brushes, and connections. 3. Check solenoid and switch connections.
f. Engine cranks slowly but does not start.	1. Battery run down. 2. Very low temperature. 3. Cranking motor defective. 4. Undersized battery cables. 5. Mechanical trouble in engine. 6. Also driver may have run battery down attempting to start.	1. Check, recharge or replace. 2. Battery must be fully charged. 3. Test cranking motor. 4. Install cables of adequate size. 5. Check engine. 6. See g. below.
g. Engine cranks at normal speed but does not start.	1. Ignition system defective. 2. Fuel system defective. 3. Air leaks in intake manifold or fuel lines. 4. Engine defective.	1. Try spark test; check timing and ignition. 2. Check fuel pump, lines, carburetor, and injectors. 3. Tighten mountings and lines. Replace gaskets as needed. 4. Check compression and valve timing.
h. Solenoid plunger chatters.	1. Hold-in winding of solenoid open. 2. Low battery with high solenoid relay setting.	1. Replace solenoid. 2. Charge battery. Reset relay.
i. Pinion disengages slowly after starting.	1. Sticky solenoid plunger. 2. Engaging mechanism sticks. 3. Engaging mechanism defective. 4. Return spring weak.	1. Clean and free plunder. 2. Clean armature shaft. 3. Replace. 4. Install new spring.

o. No cranking, no lights, or lights go out. When the battery is completely discharged or there is an open in the circuit, the lights will burn very dimly or not at all. Check the wiring, connections, and switch. A bad connection between the cranking motor and battery will be indicated by the lights coming on when the light switch is turned on but going off when the cranking motor circuit is closed. The bad connection is probably at one of the battery terminals. You can often tell if there is a bad connection by keeping the cranking motor circuit closed for a few seconds.

If there is a bad connection, heat will develop. Sometimes there is so much heat that the connection starts to smoke. You can find almost any bad connection in a circuit through which current is flowing by putting a voltmeter across the connection.

b. No cranking, lights dim. When the cranking motor circuit is closed, try to determine whether the lights dim slightly or considerably. If the lights dim only slightly with no cranking action, there could be excessive resistance or a partial open in the cranking motor. If slight dimming is accompanied by the sound of a running electric motor, it is possible that the pinion is not engaging. If the lights dim considerably without cranking action, there could be mechanical trouble in the engine, the battery could be run down, temperatures might be very low, or there could be trouble in the cranking motor itself.

c. No cranking, lights stay bright. When the cranking notor circuit is closed and no cranking action takes place and the lights stay bright, it means that there is no current flowing from the battery to the cranking motor. Remember that on some pieces of equipment there is a safety switch that prevents starting unless the transmission lever is in neutral.

d. Engine cranks slowly but does not start. This condition may be caused by several things. The battery may be run down, the temperature may be so low as to cause cranking difficulty, cranking motor may be defective, undersize cables may have been installed or there may be mechanical trouble in the engine.

e. Solenoid chatters. This condition is caused by an open circuit in the hold-in windings of the solenoid which in turn causes the plunger to pull in and release repeatedly when the control circuit is closed.

f. Pinion disengages slowly after starting. Possible causes are a sticky solenoid plunger, a defective clutch, weak return spring or clutch sticking on the armature shaft. If slow disengagement is noted, prompt measures to eliminate the troubles should be taken before the armature is ruined by thrown windings.

4-6. STEERING SYSTEM

There are many types of steering systems used on Marine Corps engineer equipment for both tracked and wheeled vehicles. Proper maintenance eliminates the need for major repairs on these steering systems. Tables 4-12 and 4-13 are guides for troubleshooting steering problems for wheeled and tracked vehicles respectively. The problems and causes are not listed in the order of most frequent occurrence. For more detailed information, consult the specific TM for the piece of equipment being worked on.

Table 4-12. Troubleshooting Chart for Wheeled Vehicles

Trouble	Probable Cause	Remedy
a. Steering hard in one direction only.	1. Steering booster out of adjustment.	1. Adjust piston travel in booster valve to obtain equal case of steering in either direction.
b. Steering hard in both directions.	1. Defective booster pump.	1. Repair or replace pump (see engine manual).
	2. Low oil supply.	2. Replenish oil supply.
	3. Clogged oil filter.	3. Clean filter.
	4. Volume control valve of power cylinder defective or out of proper adjustment.	4. Repair or replace valve.
	5. Incorrect steering gear adjustment.	5. Adjust steering gear.
	6. Binding ball joints.	6. Replace ball joints.
	7. Tires not inflated to proper pressure.	7. Inflate to proper pressure.

Table 4-12. Troubleshooting Chart for Wheeled Vehicles -- contd

Trouble	Probable Cause	Remedy
c. Excessive free play at steering wheel.	1. Worn steering gear.	1. Replace.
	2. Steering gear out of adjustment.	2. Adjust steering gear.
d. Excessive slack in steering mechanism.	1. Excessive wear at trunnion bearings.	1. Replace.
	2. Worn or damaged ball joints.	2. Replace ball joints and realine wheels.
	3. Loose steering gear mounting.	3. Tighten mounting hardware.
	4. Wheel bearings improperly adjusted or damaged.	4. Readjust or replace.
	5. Excessive wear at tie rod ends.	5. Replace tie rod.
e. Steering feels lumpy, rough, and hangs up occasionally.	1. Steering gear dry.	1. Add proper quantity and type grease.
	2. Defective bearings in steering gear.	2. Replace bearings. Refill with proper grease.
	3. Dirt or foreign material in steering gear.	3. Disassemble, clean, grease, and reassemble.
	4. Broken or rough worm or sector in the steering gear.	4. Disassemble, replace worn or damaged parts.
f. Malfunction of power steering hydraulic system.	1. Fluctuation of pressure due to faulty relief valve, caused by foreign material lodged on valve seat, or by damaged or worn valve.	1. Flush and refill system. If condition still exists, overhaul valve assembly.
	2. Slippage of pump drive or pump malfunction causing loss of pressure.	2. Check pump in accordance with engine manual.
	3. Piston rod binding or sticking caused by cramping wheels.	3. Shut off hydraulic flow and uncouple rod. The rod should slide freely in or out by hand with a maximum force of 30 lb. If binding is apparent, replace unit and readjust wheel stops to prevent recurrence of damage.
	4. Chattering caused by loose mountings or linkage; relief valve set too low or insufficient pump flow.	4. Make certain all ball stud mountings and other linkage is tight. Set relief valve at least 150 psi higher than normal steering requirements of the vehicle. Bleed air from system. Insufficient pump flow at idle speeds can be corrected by increasing engine idle speed.
	5. Unsatisfactory steering in either direction, caused by air in system, excessive wear in steering cylinder, incorrect system pressure, worn pump.	5. Check for air in system. Excessive noise or foamy condition of oil indicates aeration. Check to be sure air is not entering system through poor threads, hoses, pump seals, "O" rings, gaskets or loose connections. Excessively worn cylinders result in leakage past the piston. Replace cylinder. Set relief valve at least 150 psi above normal steering requirements. Repair or replace pump.

Table 4-13 Troubleshooting Chart for Tracked Vehicles

Trouble	Probable Cause	Remedy
a. Engine operates but tractor will not move.	1. Steering brakes locked.	1. Release steering brake pedals from latching pawls.
	2. Steering clutches slip.	2. Adjust steering clutches.
b. Tractor will not turn.	1. Steering clutch does not disengage.	1. Pull steering clutch lever all the way back.
	2. Steering clutch not properly adjusted.	2. Adjust steering clutch and controls.
	3. Steering clutch faulty.	3. Remove, and repair or replace.
c. Tractor will not make short (pivot) turn.	1. Steering clutch does not disengage.	1. Refer to "Tractor Will Not Turn".
	2. Steering brake will not hold.	2.
	a. Steering brake not properly adjusted.	a. Adjust steering brake and controls.
	b. Steering brake worn or faulty.	b. Replace steering brake.
d. Tractor loses pulling power.	1. Steering brakes drag.	1. Remove inspection cover and hand-feel the steering brake bands. If bands are hot, brakes are dragging. Adjust brakes.
	2. Steering clutches slip.	2. Adjust steering clutches. If clutches are faulty, remove and repair.
	3. Engine clutch slips.	3. Refer to "Engine Clutch" paragraph 3-2b(1)(a).
e. Steering clutches overheat.	1. Improper use of steering brakes.	1. Steering brakes should never be applied unless steering clutches are completely disengaged.
	2. Steering brakes drag.	2. Remove inspection cover and hand-feel the steering brake bands. If bands are hot, brakes are dragging. Adjust brakes.
	3. Steering clutches slip.	3. Adjust steering clutches. If clutches are faulty, remove and repair.
f. Steering brakes overheat.	1. Brakes adjusted too tight.	1. Adjust brakes to proper clearances.
	2. Steering clutch does not disengage.	2.
	a. Improper adjustment.	a. Adjust steering clutch.
	b. Warped discs.	b. Replace warped discs.
	3. Oil on brake lining.	3. Wash or replace lining.
	4. Binding in brake controls.	4. Free controls and lubricate with light oil.

Table 4-14. Steering Booster Hydraulic Pump

Problem	Probable Cause	Probable Remedy
a. Pump unusually noisy.	1. Low oil supply.	1. Fill to proper level.
	2. Restriction in suction line.	2. Remove the line and clean out thoroughly.
b. Pump takes too long to respond or fails to respond.	1. Low oil supply.	1. Fill to proper level.
	2. Pump worn or damaged.	2. Inspect, repair or replace.

Table 4-14. Steering Booster Hydraulic Pump--contd

Problem	Probable Cause	Probable Remedy
c. Oil heats up.	1. Low oil supply.	1. Fill to proper level.
	2. Dirty oil.	2. Drain, flush and refill with clean oil.
	3. Pump worn.	3. Repair or replace.
d. Oil foaming.	1. Air leaking into suction line from reservoir to pump.	1. Tighten all connections.
	2. Wrong type oil being used.	2. Drain and refill with proper grade of oil.
	3. Low oil supply.	3. Fill to proper level.
e. No booster action (Manual steering only).	1. Spool valve sleeve fits too tight and "hangs up" (caused by dirt).	1. Disassemble the booster and clean all moving parts thoroughly.
	2. Loose fitting spool valve sleeve.	2. Replace spool valve and sleeve as a matched set.
	3. Loss of oil in system.	3. Check for leaks in system. Fill oil reservoir to proper level with correct grade of oil.
	4. Worn piston rings.	4. Replace the cast iron piston rings.
	5. Hydraulic pump damaged, or worn excessively resulting in loss of pressure.	5. Remove pump and repair or replace.
	6. Broken linkage to control lever or booster out of adjustment.	6. Check linkage and repair. Recheck booster adjustment.
f. Partial steering. (One track only)	1. Defective hydraulic pump.	1. Reverse pressure connections at pump and check to see if the opposite track is now affected. If so, remove pump and repair. Or, check booster for failure.
	2. One or the other booster cylinder inoperative.	2. Determine which and make repair.

4-7. TRACKS AND TRACK FRAME ASSEMBLIES

These assemblies bear the brunt of the wear and tear on the piece of equipment. They are subjected to the forces and torques caused by the rough terrain they are designed to travel over. Proper maintenance minimizes the need for major overhauls. Table 4-15 lists some of the problems and remedies for track and track frame assemblies. They are not listed in the order of most frequent occurrence.

Table 4-15. Troubleshooting Tracks and Track Frame Assemblies

Problem	Probable Cause	Probable Remedy
a. Track chain loose.	1. Track not properly adjusted.	1. Adjust track tension.
	2. Sprocket worn.	2. Remove, and repair or replace.
	3. Track links or bushings worn.	3. Remove, and repair or replace.
	4. Track springs broken.	4. Remove the track spring guard and inspect track springs for breakage. If none apparent, remove the springs and check their free length and test length for evidence of weakness.

Table 4-15. Troubleshooting Tracks and Track Frame Assemblies--contd

Problem	Probable Cause	Probable Remedy
b. Excessive track wear.	1. Damaged sprocket. 2. Front idler misalined. 3. Improper track tension. 4. Track rollers or idlers do not turn.	1. Remove, and repair or replace. 2. Remove, and repair or replace. 3. Adjust track tension. 4. Clean and lubricate, or remove and repair or replace as required.
c. Track shoes loose.	1. Insufficient torque on shoe bolts.	1. Apply correct torque.
d. Track rollers do not turn.	1. Insufficient lubrication. 2. Bushings seized. 3. Packed dirt between roller and track frame.	1. Lubricate as frequently as directed in the lubrication chart. 2. Remove faulty roller and replace bushing. Lubricate thoroughly as directed. 3. Remove the packed dirt.
e. Track idlers do not turn.	1. Insufficient lubrication. 2. Dirt packed tight against idler. 3. Internal seizure on shaft.	1. Lubricate as directed in the lubrication chart. 2. Remove packed dirt. 3. Remove the idler and inspect parts. Thoroughly clean and replace parts if necessary.
f. Front idler does not turn.	1. Insufficient lubrication. 2. Dirt packed around idler. 3. Bearing seized.	1. Lubricate as directed in the lubrication chart. 2. Remove dirt. 3. Remove the front idler and replace part if necessary.
g. Lubricant leakage.	1. Failure of sealing through wear on seals and gaskets.	1. Remove parts affected and replace seals and gaskets with new.
h. Excessive or uneven wear of track rollers track idlers, front idler, and sprocket.	1. Track tension incorrect. 2. Front idler misalined.	1. Adjust track chain tension. 2. Realine.
i. Tractor loses power.	1. Track chains too tight.	1. Adjust track chain tension. Tight track chains may cause tractor to lose up to 75 percent of power.
j. Track chain comes off during operation.	1. Rocks in track assembly. 2. Track chain loose. 3. Track spring broken, front idler worn or misaligned. 4. Worn sprocket teeth.	1. Clean rocks and dirt from tracks. 2. Adjust track chain tension. 3. Remove, and repair or replace. 4. Reverse or replace sprockets.
k. Tractor creeps to one side.	1. Track loose on one side. 2. Track shoes loose. 3. Track spring broken or adjusting rod misalined.	1. Adjust track tension. 2. Tighten capscrews properly. 3. Remove track spring assembly and check alinement. Replace parts as necessary.

4-8. SUMMARY

Specific information for troubleshooting auxiliary equipment should be obtained from the TM for the equipment concerned. Chapter 4 is intended as a training aid and guide only and is only general in nature. This information coupled with on-the-job training should familiarize you with some of the problems and start you on the road to being a competent troubleshooter.

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UNITED STATES MARINE CORPS
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BOX 1775
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ENGINEER EQUIPMENT MECHANIC

Lesson 4

Diagnosing, Troubleshooting, and Repairing Auxiliary Equipment

STUDY ASSIGNMENT: MCI 13.41c, Engineer Equipment Mechanic, chap 4.

LESSON OBJECTIVE: Successful completion of this lesson, combined with on-the-job training using the principles presented, will enable you to identify: the basic components of vehicular engineer equipment, the diagnostic and repair procedures of the hydraulic systems, compressor, electrical systems, steering systems, tracks, and track frame assemblies.

WRITTEN ASSIGNMENT:

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

Value: 1 point each

1. Which of the following is NOT a cause of hydraulic system failure?

   a. Insufficient fluid
   b. Air in system
   c. Leakage in system
   d. Broken crankshaft

2. The only positive way to test a hydraulic circuit is

   a. to use a hydraulic circuit tester.
   b. to use a fluid flow tester.
   c. to use a fluid pressure gage.
   d. to use a temperature gage.

3. When testing a hydraulic circuit, the return fluid must be directed to the reservoir through

   a. a return hose outside the system.
   b. the systems piping inside the system.
   c. the hydraulic pump inside the system.
   d. the cylinders inside the system.

4. Generally, the first part of a hydraulic system to fail is the

   a. pump.
   b. cylinders.
   c. hoses.
   d. valves.

B. Matching: In the groups below, match the appropriate item in column 1 with the corresponding item in column 2. After the corresponding number on the answer sheet, blacken the appropriate box.

Value: 1 point each

Note: In the first group, refer to table 4-1.

Column 1

Cause

5. Wrong direction of shaft rotation

6. Internal leakage in control valves

7. Reservoir air vent plugged

8. Damaged head packing

9. Air recirculation

Column 2

Complaint

a. Excessive wear
b. Pump, making noise
c. No pressure in system
d. Failure of pump to deliver fluid
e. External oil leakage

Note: In the second group, refer to Table 4-2.

Column 1

Cause

10. Internal leakage in actuating mechanisms or operating valves

11. Worn pump

12. Side load on piston rod

13. Chevron seals

Column 2

Complaint

a. Abnormal packing gland wear
b. Mechanisms creep in intermediate position
c. External oil leakage
d. Times of operation longer than specified

Note: Items in this group deal with the compressor.

Column 1

Symptom

14. Slow buildup of air pressure

15. Rapid loss of air pressure when engine is stopped

16. Air pressure too high

17. Compressor knocks

Column 2

Cause

a. Broken air compressor unloader mechanism
b. Worn or burned bearings
c. Worn or leaking air compressor discharge valves
d. Air pressure will not rise to normal
e. Worn air compressor piston and piston rings

Note: Items in this group deal with a d.c. generator.

Column 1	Column 2
Cause	**Symptom**
18. Loose or worn fan belts	a. No output
19. Worn or dirty bearings	b. Excessive output
20. Shorted field circuit with field grounded in generator	c. Unsteady or low output
21. Open armature	d. Noisy generator

Note: Items in this group deal with wheeled vehicle steering systems.

Column 1	Column 2
Cause	**Complaint**
22. Binding balljoints	a. Steering hard in both directions
23. Worn steering gear	b. Steering feels lumpy or rough, hangs up occasionally
24. Defective bearings in steering gear	c. Excessive free play at steering wheel

Note: Items in this group deal with tracks and track frame assemblies.

Column 1	Column 2
Cause	**Problem**
25. Sprocket worn	a. Excessive track wear
26. Front idler misalined	b. Track shoes loose
27. Insufficient lubrication	c. Track rollers do not turn
28. Insufficient torque on shoe bolts	d. Track chain loose

C. Multiple Choice: Select the ONE answer which BEST completes the statement or answers the question. After the corresponding number on the answer sheet, blacken the appropriate box.

Value: 1 point each

29. When troubleshooting the charging system, you should consider the generator and the __________ as a system.

a. wiring harness.
b. regulator.
c. battery.
d. starter.

30. A fully charged battery and low charging rate is considered

   a. normal voltage regulator operation.
   b. high voltage regulator setting.
   c. low voltage regulator setting.
   d. excessive voltage regulator output.

31. A cranking motor pinion disengaging slowly after starting indicates

   a. low battery with high relay setting.
   b. hold-in winding of solenoid open.
   c. weak return spring.
   d. undersized battery cables.

32. A dead battery or open electrical circuit is indicated by which of the following symptoms?

   a. No cranking, lights go out
   b. No cranking and no lights
   c. Excessive resistance in circuit
   d. Solenoid chatter

33. A battery using an excessive amount of water indicates

   a. overloading.
   b. normal operation.
   c. undercharging.
   d. overcharging.

D. True or False: Indicate your choice of true or false by marking a for true and b for false after the corresponding letter on the answer sheet.

An operator has indicated that his tracked vehicle loses pulling power. Considering only the steering system as being at fault, indicate which of the following would or would not cause the above problem.

34. Steering clutch does not disengage

35. Steering brakes drag

36. Steering clutches slip

37. Engine clutch slips

Total Points: 37

* * *

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