TRAINING
COURSE 4

Advanced Mechanics

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

CONTENTS

CHAPTER 1

PUBLIC WORKS

TRANSPORTATION SHOPS SUPERVISOR

A supervisor should possess a large amount of TACT and DIPLOMACY. Directing shop activities requires that you contact all types of people; for example, the mechanics who work for you, the personnel (military and/or civilian) who operate the equipment, and the officer (or civilian) to whom you are responsible. You must be careful not to let prejudices interfere with your good judgment.

A transportation maintenance shop supervisor will need all of his past experience in diagnosing mechanical troubles accurately, scheduling and planning repair work skillfully, using all kinds of repair equipment, and directing the many activities in maintaining transportation and earth-moving equipment.

At some time during your career in the Navy, you may be assigned as a foreman in a public works (PW) transportation maintenance shop. You may also have to serve as supervisor of a Construction Battalion equipment maintenance shop. Because of the variation in the two different types of duty, the responsibilities of a foreman in a PW transportation maintenance shop will be discussed in this chapter, and the battalion equipment company shops supervisor's responsibilities will be discussed in the following chapter. Although many of the positions have the same basic duties, the methods of doing the work may differ considerably. Certain areas of cost control vary a great deal. Duty in a transportation maintenance shop includes work of a continuing nature. Therefore, to provide continuity, civil service personnel are also employed.

PUBLIC WORKS TRANSPORTATION DEPARTMENT FUNCTIONAL ORGANIZATION

A PW transportation department of a naval shore facility is generally stationary. As a supervisor in the PW maintenance branch, you would probably not have to plan and construct a new transportation shop, but, rather, would supervise the repair of equipment. However, if you are involved in the establishment of a new base, you will probably be consulted about the location and layout of the maintenance shops. You can obtain detailed information on the physical layout of the buildings by referring to *Naval Facilities Planning Guide,* P-437, Facilities Number 214 20B, Drawing 6028198. The location of tools and shop equipment depends on the amount and type of equipment to be maintained.

The PW transportation organization discussed in this chapter is typical of the type usually found within a public works activity. The titles and organization may vary from activity to activity. To learn more about these organizations, you should obtain and study current NAVFAC instructions and publications that pertain to the public work centers and public work departments. By referring to figure 1-1, you can see that the

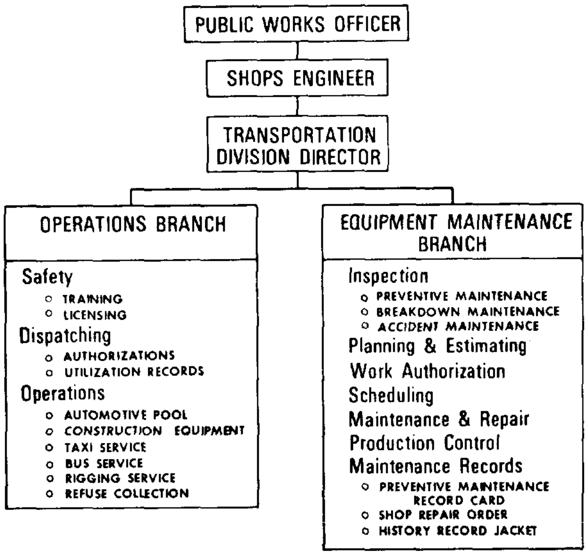


Figure 1-1.—Functional organization for transportation management.

transportation division is broken down into two branches: operations branch and equipment maintenance branch. Note that both come under the control of the transportation division director, who reports through a chain of command to the public works officer (PWO).

DUTIES AND RESPONSIBILITIES OF SUPERVISORY PERSONNEL

This phase of our discussion deals with the duties and responsibilities of various supervisory personnel within the maintenance branch. The individual assignments depend upon the needs of the activity and the skill and experience of personnel available. The public works officer makes the final decision.

TRANSPORTATION DIVISION DIRECTOR

As head of the transportation division, the transportation director exercises full technical, managerial, and administrative responsibility for organizing, directing, and controlling the work of the division. The director also functions as the technical advisor within and outside the activity in planning and procuring vehicle/equipment requirements for the activity and other supported customers.

The transportation director exercises complete managerial responsibilities for the efficient, economical, and timely administration of the divisions; directs operations assignments; manages scheduled preventive maintenance (PM) as well as repair/overhaul; and is charged with the requisition and disposition of automotive vehicles, construction equipment, materials-handling equipment, and miscellaneous specialized equipment.

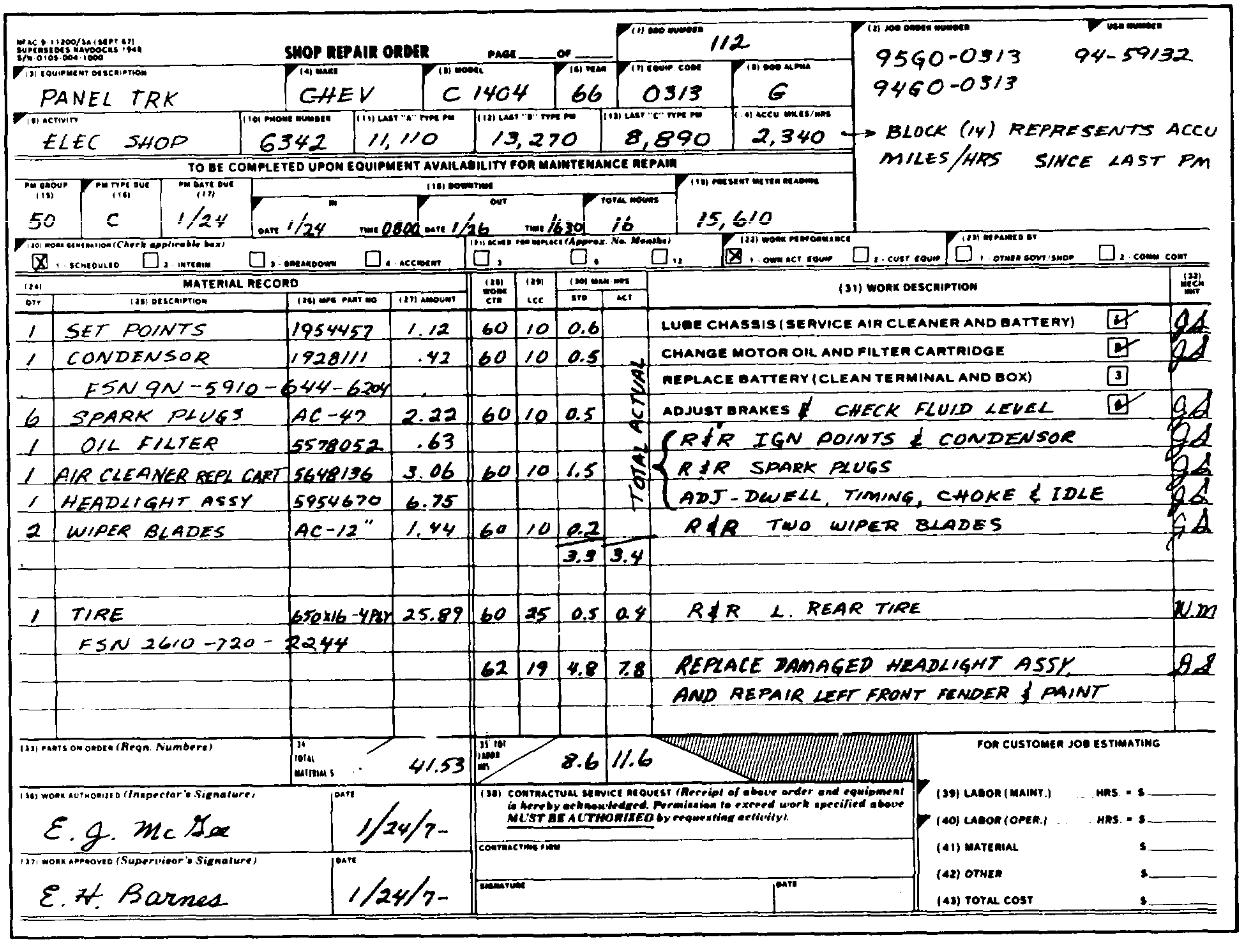
MANAGER OF THE EQUIPMENT MAINTENANCE BRANCH

The manager of the maintenance branch is responsible for planning, work direction, and administration, and acts as, and assumes the duties of, the transportation director in case of the absence of that person. The maintenance branch's responsibilities include the following:

1. Preparing and submitting the maintenance division fiscal financial budget
2. Scheduling work for subordinate supervisors and planning for the efficient use of materials and equipment
3. Organizing, coordinating, and directing the work activities of personnel and units supervised
4. Maintaining a balanced workload for subordinate work units by shifting personnel effectively among the units
5. Coordinating the work in areas of responsibilities with other activities and department/division supervisory personnel to maintain a balanced scheduled work flow
6. Reviewing and analyzing production, cost, and personnel utilization records to evaluate the progress of work and to control or reduce costs
7. Reviewing completed work records (Shop Repair Order, NAVFAC Form 9-11200/3A, shown in figure 1-2, and other computer reports) to assure that production and quality standards are met
8. Inspecting the shop areas periodically and checking safety conditions, cleanliness, security, requirements for materials, and shop equipment
9. Acting on any personnel matter concerning subordinates and assisting in the resolution of grievances referred by subordinate supervisors
10. Promoting safety programs within the immediate organization, reviewing the safety performance of the supervisors, and initiating corrective action as required
11. Seeing that progress, production, cost, and other records are prepared, maintained, and consolidated
12. Developing training programs for employees and subordinate supervisors

PRODUCTION CONTROL SUPERVISOR

The production control supervisor is responsible for receiving, inspecting, and classifying, within applicable Navy codes, all new and used equipment; preparing reports on equipment received; scheduling equipment into the shop for its first servicing; and arranging for its inclusion into the PM program. Additionally, the production control supervisor determines parts and tools required to support equipment during its life cycle; directs the inspection of vehicles coming into the shop to find the nature and extent of repair or PM service required; and determines the most economical means and methods of repairs. The production control supervisor applies standard hours and cost estimates on individual equipment jobs; initiates shop repair orders; and schedules work into the various work centers/shops for orderly accomplishment. Finally, the production control supervisor directs the inspection of the mechanics' work while in progress; ensures a quality inspection upon



NFAC 9-11200/3A (SEPT 67)
SUPERSEDES NAVDOCKS 1948
S/N 0105-004-1000

SHOP REPAIR ORDER PAGE ____ OF ____

(1) SRO NUMBER: 112
(2) JOB ORDER NUMBER: 95G0-0313 / 9460-0313
USN NUMBER: 94-59132

(3) EQUIPMENT DESCRIPTION	(4) MAKE	(5) MODEL	(6) YEAR	(7) EQUIP. CODE	(8) DOD ALPHA
PANEL TRK	CHEV	C 1404	66	0313	G

(9) ACTIVITY	(10) PHONE NUMBER	(11) LAST "A" TYPE PM	(12) LAST "B" TYPE PM	(13) LAST "C" TYPE PM	(14) ACCU MILES/HRS
ELEC SHOP	6342	11,110	13,270	8,890	2,340

→ BLOCK (14) REPRESENTS ACCU MILES/HRS SINCE LAST PM

TO BE COMPLETED UPON EQUIPMENT AVAILABILITY FOR MAINTENANCE REPAIR

PM GROUP (15)	PM TYPE DUE (16)	PM DATE DUE (17)	(18) DOWNTIME IN		(18) DOWNTIME OUT		TOTAL HOURS	(19) PRESENT METER READING
			DATE	TIME	DATE	TIME		
50	C	1/24	1/24	0800	1/26	1630	16	15,610

(20) WORK GENERATION (Check applicable box) ☒ 1 - SCHEDULED ☐ 2 - INTERIM ☐ 3 - BREAKDOWN ☐ 4 - ACCIDENT

(21) SCHED FOR REPLACE (Approx. No. Months) ☐ 3 ☐ 6 ☐ 12

(22) WORK PERFORMANCE ☒ 1 - OWN ACT EQUIP ☐ 2 - CUST EQUIP

(23) REPAIRED BY ☐ 1 - OTHER GOVT/SHOP ☐ 2 - COMM CONT

(24) QTY	(25) DESCRIPTION	(26) MFG PART NO	(27) AMOUNT	(28) WORK CTR	(29) LCC	(30) MAN-HRS STD	(30) MAN-HRS ACT	(31) WORK DESCRIPTION	(32) MECH INIT
1	SET POINTS	1954457	1.12	60	10	0.6		LUBE CHASSIS (SERVICE AIR CLEANER AND BATTERY) ☑	GA
1	CONDENSOR	1928111	.42	60	10	0.5		CHANGE MOTOR OIL AND FILTER CARTRIDGE ☑	GA
	FSN 9N-5910-644-6204						TOTAL ACTUAL	REPLACE BATTERY (CLEAN TERMINAL AND BOX) 3	
6	SPARK PLUGS	AC-47	2.22	60	10	0.5		ADJUST BRAKES & CHECK FLUID LEVEL ☑	GA
1	OIL FILTER	5578052	.63					R&R IGN POINTS & CONDENSOR	GA
1	AIR CLEANER REPL CART	5648136	3.06	60	10	1.5		R&R SPARK PLUGS	GA
1	HEADLIGHT ASSY	5954670	6.75					ADJ-DWELL, TIMING, CHOKE & IDLE	GA
2	WIPER BLADES	AC-12"	1.44	60	10	0.2		R&R TWO WIPER BLADES	GA
						3.3	3.4		
1	TIRE	650x16-4PLY	25.89	60	25	0.5	0.4	R&R L. REAR TIRE	W.M.
	FSN 2610-720-2244								
				62	19	4.8	7.8	REPLACE DAMAGED HEADLIGHT ASSY.	BA
								AND REPAIR LEFT FRONT FENDER & PAINT	

(33) PARTS ON ORDER (Reqn. Numbers)
34 TOTAL MATERIAL $ 41.53
35 TOT LABOR HRS 8.6 11.6

(36) WORK AUTHORIZED (Inspector's Signature) E. G. McGee DATE 1/24/7-
(37) WORK APPROVED (Supervisor's Signature) E. H. Barnes DATE 1/24/7-

(38) CONTRACTUAL SERVICE REQUEST (Receipt of above order and equipment is hereby acknowledged. Permission to exceed work specified above MUST BE AUTHORIZED by requesting activity).
CONTRACTING FIRM
SIGNATURE DATE

FOR CUSTOMER JOB ESTIMATING
(39) LABOR (MAINT.) ____ HRS. = $ ______
(40) LABOR (OPER.) ____ HRS. = $ ______
(41) MATERIAL $ ______
(42) OTHER $ ______
(43) TOTAL COST $ ______

Figure 1-2.—Shop Repair Order, NAVFAC Form 9-11200/3A.

completion of this work; and directs the maintenance of PM records, shop backlog records, and vehicle history files.

MAINTENANCE AND REPAIR FOREMAN

The foreman of the maintenance and repair shop supervises subcenters, such as the body and paint shop, battery shop, tire shop, toolroom, and lubrication shop. Responsibilities of the foreman include the following:

1. Establishing priorities and sequences in which scheduled workloads will be accomplished, primarily on a day-to-day/job-by-job basis
2. Analyzing and interpreting shop repair orders, work requests, and other work documentation and specifications to determine work requirements
3. Assigning work among subordinates and providing specific material requirements
4. Consulting with higher authority and staff personnel to make sure that appropriate tools, materials, and equipment are available as needed
5. Requesting and coordinating the services and work of other shops when required
6. Assigning work by written or oral orders
7. Assisting in the training of subordinates in work methods, procedures, and the operation of tools and equipment, both new and already in use
8. Certifying that the work is efficient and economical and that the work is performed safely
9. Anticipating operational problems and acting to overcome delays
10. Directing and recommending changes in shop layout to improve efficiency
11. Ensuring that subordinates houseclean
12. Issuing and enforcing safety practices and fire regulations

13. Checking attendance and leave of subordinates and other personnel matters

CONSTRUCTION EQUIPMENT SHOP FOREMAN

The foreman of the construction and specialized equipment shop supervises the machine shop as a subcenter. The responsibilities are basically the same as those given under the maintenance and repair foreman, except for the technical supervision. This shop is responsible for the maintenance, repair, and major overhaul (mechanical and electrical) of specialized equipment, such as tractors, graders, ditchdiggers, bulldozers, road rollers, asphalt machines, farm tractors, jet starters, auxiliary power units, emergency generators, pumps, and aircraft tow-tractors.

The machine shop bores cylinders; rebuilds all types of gasoline and diesel engines, automatic transmissions, and differentials; and performs other related repairs.

PREVENTIVE MAINTENANCE

The most important phase of the maintenance system is scheduled periodic preventive maintenance (PM). PM is the systematic inspection, detection, and correction of potential equipment failures before they develop into major defects. The purpose of PM is to keep equipment in safe and reliable condition with maximum equipment availability and minimum cost of maintenance.

OPERATOR MAINTENANCE

Operators are the first line of defense against equipment wear, failure, and damage. Equipment must be inspected by the operator daily—before, during, and after operations—so that defects or malfunctions can be detected before they result in serious damage, failure, or accident.

It is your responsibility, as a CM1, to see that the operators are performing their duties. You should work with the operations branch in making recommendations regarding operator PM. Changes may be necessary in the operator PM to cope with certain operating conditions. You may need to set up classes of instruction for the operators so that they will become familiar with the right way to maintain their equipment, especially when new equipment is received in the activity. If you do set up classes, be sure to coordinate your training periods with the foreman in charge of the equipment operations branch so that you do not interfere with the foreman's equipment operating schedules. Also, try to have the equipment on hand so you can point out maintenance services that need attention. It is better to hold the instructions with small groups and to keep them as informal as possible. Do not forget to stress operator maintenance on the overall operating efficiency of the equipment.

SERVICE STATION MAINTENANCE

Service station maintenance is the service you would expect from any first-rate filling station when you purchase fuel; namely, washing the windshield and checking the oil, battery and radiator water, fan belt, tire condition, and so forth. Unfortunately, shortages of personnel have sometimes curtailed this type of maintenance. Service station maintenance is a visible area of public works but is not intended to relieve the operators of their responsibility.

SAFETY INSPECTIONS

Vehicles will be inspected periodically by qualified automotive inspection personnel for safety as follows:

Each motor vehicle will be inspected for safety at intervals not to exceed 12 months or 12,000 miles, whichever occurs first. To avoid unnecessary downtime, perform the safety inspection at the time of the scheduled serviceability inspection according to the manufacturer's recommendation.

All deficiencies uncovered during the safety inspection that affect the safe operation of the vehicle will be corrected before the vehicle becomes operational again.

UNSCHEDULED MAINTENANCE SERVICE

Unscheduled maintenance service is the correction of deficiencies reported by the vehicle operator that occur between scheduled safety or other inspection and services prescribed by the manufacturer. Unscheduled maintenance services will be limited to correcting only those items reported as deficient by the operator and confirmed by qualified inspection personnel. Unreported deficiencies observed by the inspector at an unscheduled service and, in particular, those affecting safety are to be corrected before the vehicle is released for service.

COST CONTROL

The Navy's cost control system is designed to obtain complete cost data on maintenance and operation of automotive, construction, fire fighting, railway, weight-handling, and materials-handling equipment. Actual performance of maintenance work is compared to hourly standards for such work, as established and published by various manufacturers and the Naval Facilities Engineering Command (NAVFAC), to determine efficiency of maintenance operations. The Navy also uses cost control to justify the performance of repairs at its activities.

RECORDS AND REPORTS

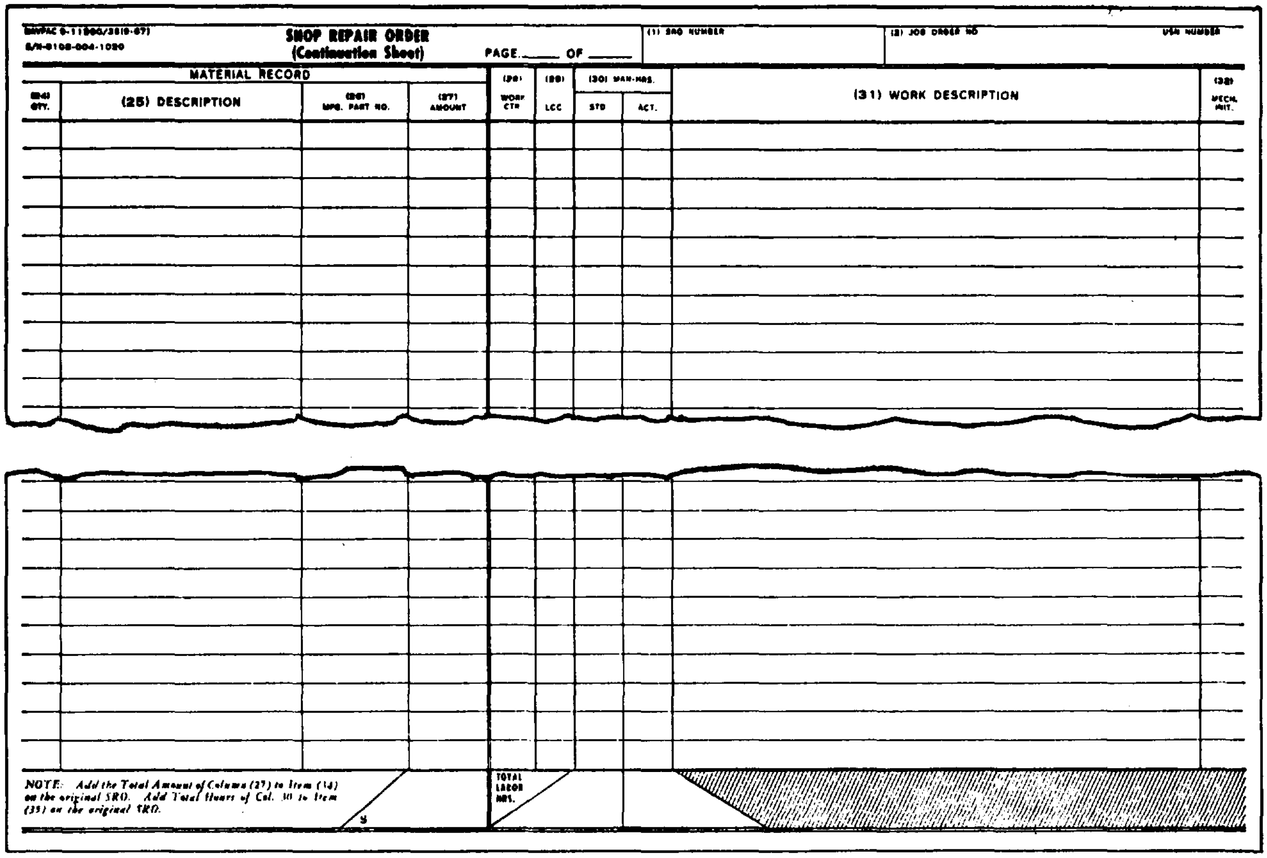
In the cost control system, all costs accumulated in the maintenance and operation of the equipment are recorded and charged to appropriations and allotments. These costs may be director indirect labor or material. They may also include services provided, such as shop stores, utilities, and even building maintenance.

To evaluate performance and to assist in effective management of transportation maintenance, a series of transportation management reports has been designed that will furnish useful information to management at all levels. These reports are prepared by the accountable fiscal office from the cost records maintained in that office and from feeder reports prepared by the transportation office. These reports provide the facts required by supervisors to pinpoint deficient areas and should be used for corrective action.

The objectives of the transportation management reports are to provide the following:

1. Information on the productivity of maintenance shop personnel (actual versus standard hours)
2. Data on overhead costs
3. Comparison between activity costs and commercial costs
4. Comparison between actual direct labor hours expended and established maintenance input standards
5. Comparison between actual and standard maintenance costs

Variances indicated in reports frequently require a searching review of detailed shop records to determine the causes. The individual Shop Repair Order, NAVFAC Form 9-11200/3A, shown in figure 1-2, and the Shop Repair Order (Continuation Sheet), NAVFAC Form 9-11200/3B, shown in figure 1-3, contain all of the basic data required for this review.



NAVFAC 9-11200/3B(9-67)
S/N-0105-004-1020

SHOP REPAIR ORDER
(Continuation Sheet)

PAGE ____ OF ____

(1) SRO NUMBER

(2) JOB ORDER NO

USN NUMBER

MATERIAL RECORD									
(24) QTY.	(25) DESCRIPTION	(26) MFG. PART NO.	(27) AMOUNT	(28) WORK CTR	(29) LCC	(30) MAN-HRS. STD	(30) MAN-HRS. ACT.	(31) WORK DESCRIPTION	(32) MECH. INIT.

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

$

TOTAL LABOR HRS.

Figure 1-3.—Shop Repair Order (Continuation Sheet), NAVFAC Form 9-11200/3B.

A shop repair order (SRO) is the transportation equivalent of the specific job order. It is initiated by the control section inspector/estimator or other specifically authorized personnel designated by the equipment maintenance branch supervisor. It is the authorizing document, estimating form, and cost control record of maintenance expenditures. Repair costs are estimated in advance to ensure that costs stay within economic limitations and to provide a standard against which to measure job performance and productivity of the mechanics. Estimates for transportation repairs are taken from commercial *Flat Rate Manuals* or estimating guides. Labor costs and material costs are logged on the SRO by shop personnel, and the completed document then serves as a principal source of data for transportation reports and analysis.

DEPTH OF MAINTENANCE, REPAIR, AND OVERHAUL

The depth of maintenance, repair, and overhaul is governed by many factors, mainly economics. The goal is to provide the best service available at the least possible costs.

The geographic location of an activity has a great influence on the depth of maintenance, repair, and overhaul that a maintenance shop must perform. Maintenance costs must compare with national standards. It is easy to see that an activity near a large city, where many repair services are available at commercial shops, is limited as to the type of repairs allowed. Because of the large volume of work, many of these specialized commercial shops can perform services at a reduced cost. When the commercial shop is nearby, there are no appreciable transportation or shipping costs to be added to the cost of repairs. On the other hand, an activity located a great distance from commercial sources of repair services and supplies would be able to justify doing its own major repairs because of the time, need, and shipping charges involved in having the work performed outside.

The size of an activity also governs the amount and depth of maintenance, repair, and overhaul services. Here, volume is the determining factor that reduces the maintenance cost to a level comparable to that of available commercial facilities.

COST JUSTIFICATION

The Navy system of preventive maintenance, implemented by the cost control system with its accounting procedures and reports, is a continuing justification for the transportation maintenance shop's existence. Costs must be justified unless the work is highly classified or the geographical location is extreme.

Remember that needed repairs alone do not justify repair by the service maintenance shop.

PRESERVATION, STORAGE, AND DEPRESERVATION OF VEHICLES AND EQUIPMENT

There is more to storing vehicles and equipment than merely driving them into open areas, warehouses, or active storage. The process of preparing vehicles and equipment for storage is complex. It is important that you consider all components of the equipment, as well as the basic unit, to ensure efficient operation with a minimum amount of work after storage. The objective of preservation and storage is to provide efficient and economical protection to components and equipment from environmental and mechanical damage during handling, shipment, and storage from the time of original purchase until they are used. NAVFAC P-434, *Management and Operations Manual for Construction Equipment Departments,* chapters 8 and 9 and appendix E, contains the standards and guides for equipment preservation.

The three levels of preserving and packaging equipment for storage are A, B, and C.

Level A is that level of preservation that will protect adequately against corrosion, deterioration, and physical damage during shipment, handling, indeterminate storage, and worldwide redistribution.

Level B is the degree of preservation and packaging that will protect adequately against known conditions less hazardous than A. Level B should be based on firmly established knowledge of the shipment and storage conditions and a determination that money will be saved. This level requires a higher degree of protection than that afforded by Level C preservation and packaging.

Level C is the level of preservation that protects adequately against corrosion, deterioration, and physical damage during shipment from the supply source to the first receiving activity for immediate use.

The proper level of preservation depends on the availability of information on the probable handling, shipping, storing units, and conditions that the vehicles and equipment will undergo before final issue to the command. Physical characteristics of the vehicles and equipment must also be considered.

An approved cleaning technique is a first in preservation. The effectiveness of an applied preservative may be measured by the quality of the surface preparation. All corrosion and contaminants have to be removed before a preservative is applied.

No single cleaning method or material is suitable for all cleaning situations. The selection of a cleaning method, or combination of methods, depends on one or more of these factors:

1. Material composition of part
2. Complexity of construction and assembly
3. Nature and extent of contaminants
4. Amount and age of equipment
5. Availability of cleaning materials and equipment

Steam cleaning is suitable for removal of greases, tar, road deposits, and other contaminants. This process is particularly adaptable to parts other than the ENGINE and GEARCASE EXTERIORS of vehicles and equipment that ordinarily would not be disassembled before preservation. Engines and gearcases should be cleaned by spraying with a decreasing solvent, by allowing for solvent penetration, and, finally, by flushing with a clean petroleum solvent or by wiping with a clean cloth.

“Active storage” means that complex equipment is maintained in serviceable condition by the operation of all components for brief periods at regularly scheduled intervals. When lubricants are redistributed, friction is reduced and deterioration is prevented or reduced to a minimum. Only unboxed automotive and construction equipment is included in the active storage program.

Upon reactivation, material preserved and packaged for storage or shipment requires depreservation and servicing before use. Equipment is to be lubricated under the manufacturer’s instructions. Seals and closures should be removed. Housings, casings, and other enclosures should be drained of preservatives and refilled with specified operating fluids before operation. Those components that were removed for storage should be reinstalled.

Upon activation, in equipment containing piston-cylinder components, such as internal combustion engines and air compressors, rotate the crankshaft slowly with the throttle closed, ignition off, and compression release lever (if so equipped) in START position.

Avoid abrasives in removing preservatives. Remove blocking, wiring, or strapping from clutch levers or pedals secured in a partially disengaged position. Adjust drive belts on which tension has been released. Flush from the system any corrosion inhibitor mixed with preservative oil.

TECHNIQUES OF SCHEDULING

An effective and efficient maintenance program requires the establishment and upkeep of a preventive maintenance scheduling system and a sound shop control procedure. According to *Management of Transportation Equipment,* NAVFAC P-300, vehicles and equipment are to be scheduled for inspection and servicing according to the time, mileage, or operating hours prescribed by the manufacturer’s recommendations. As a minimum, the schedule is to ensure that each vehicle is inspected for safety at least every 12 months or 12,000 miles, whichever occurs first. The schedule can be formulated by determining the estimated annual miles of each vehicle and dividing by the manufacturer’s recommended service interval. This will determine the number of service intervals per year for each vehicle. Dividing the number of working days per year (252) by the number of service intervals per year will develop the number of working days between

SPECIFICATION FOR SCHEDULED MAINTENANCE INSPECTIONS AND SERVICES

VEHICLE MAKE MODEL(S) YEAR(S)

OPERATION	SERVICE INTERVAL								See Manual Page
1000 MILES →	6	12	18	24	30	36	42	48	
ENGINE									
Change engine oil and filter	X	X	X	X	X	X	X	X	03-12
Clean and refill oil bath air cleaner (if so equipped)	X	X	X	X	X	X	X	X	03-03
Replace dry-type air cleaner filter (6 cyl.)		X		X		X		X	03-03
Replace dry-type air cleaner filter (8 cyl.)				X				X	03-03
Test crankcase emission system. Clean system and replace emission control valve if required	X	X	X	X	X	X	X	X	04-11
Clean crankcase emission system hoses, tubes, fittings, carburetor spacer and replace if necessary. Replace emission control valve		X		X		X		X	04-11
Clean crankcase filler breather cap	X	X	X	X	X	X	X	X	04-11
Replace fuel system filter (gas engine)				X				X	04-08
Inspect thermactor exhaust emission control system hoses and replace if required (on trucks so equipped)		X		X		X		X	
Drain, flush, and refill cooling system	EACH 24 MONTHS								04-06
Check and lubricate exhaust control valve. Free up if necessary (if so equipped)	X	X	X	X	X	X	X	X	03-05
Clean and adjust distributor points—replace as required (Clean distributor cap)		X		X		X		X	04-11
Check and adjust carburetor—idle speed and fuel mixture		X		X		X		X	04-14
Check and clean external choke mechanism		X		X		X		X	04-11
Check and adjust ignition timing—initial timing, mechanical and vacuum advances, and vacuum retard (if so equipped)		X		X		X		X	04-13

Figure 1-4.—Sample Format for Specification for Scheduled Maintenance Inspections and Services.

inspections or the designated inspection group for each vehicle. From this determination, a schedule can be established providing a quota of vehicles for inspection daily that will provide a balanced shop workload. A vehicle/construction equipment service record form similar to that shown in figure 1-4 should be used to record service intervals and service performed.

PROGRESS CONTROL AND SHOP WORKLOAD

Control, positive direction of shop workloads, is achieved through current information on direct labor available in shop work centers, backlog man-hours by work center, and man-hours assigned. One means is a transportation maintenance shop workload control board (fig. 1-5) to display the workload status of the shop/work centers. The indicator on each line can be moved across the scale to show current standard hours of backlog. This board may also show the available man-hours by shop or subcenter.

Progress in obtaining the most availability of safe working equipment within budget restrictions may be charted as required by local commands.

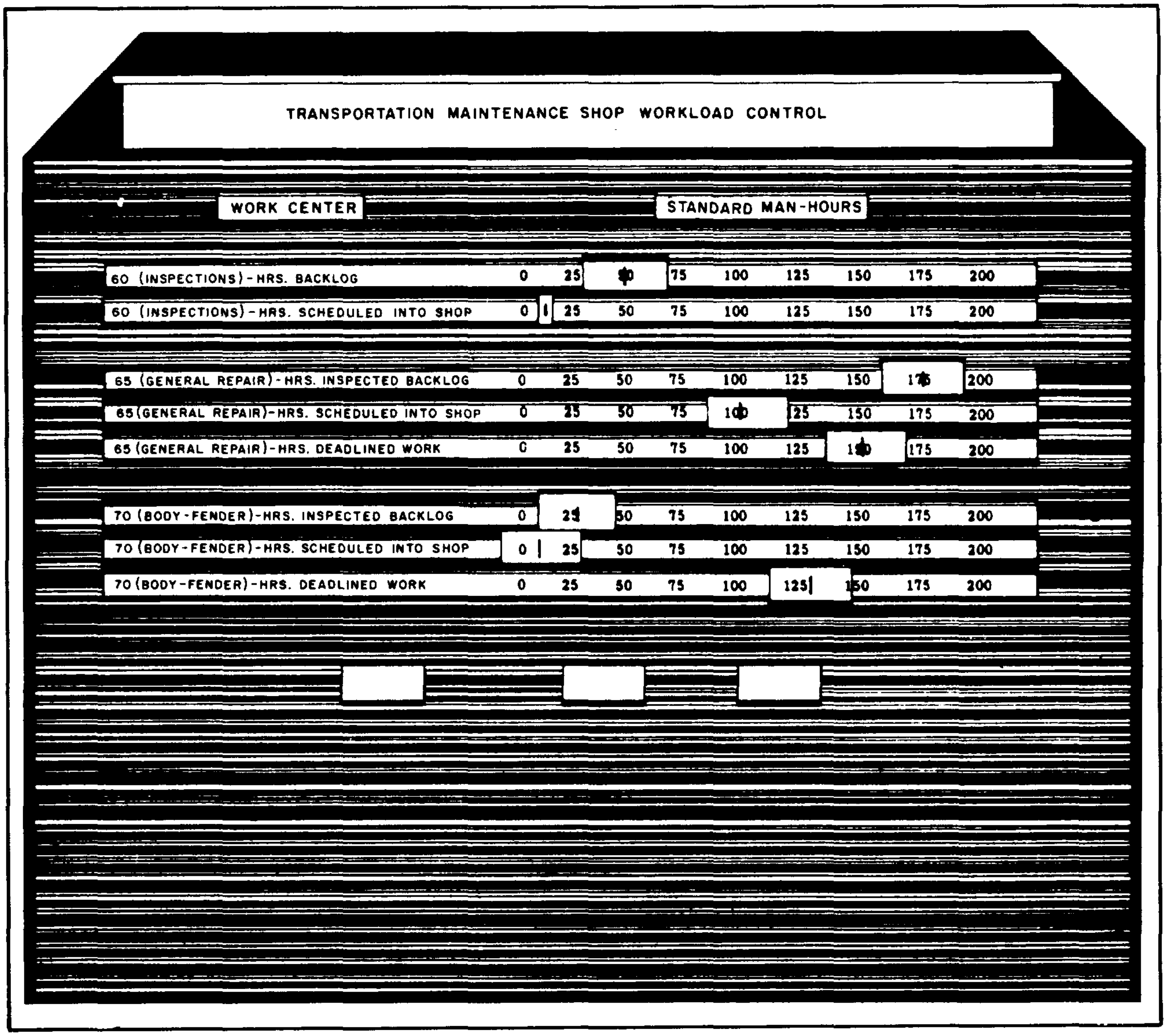
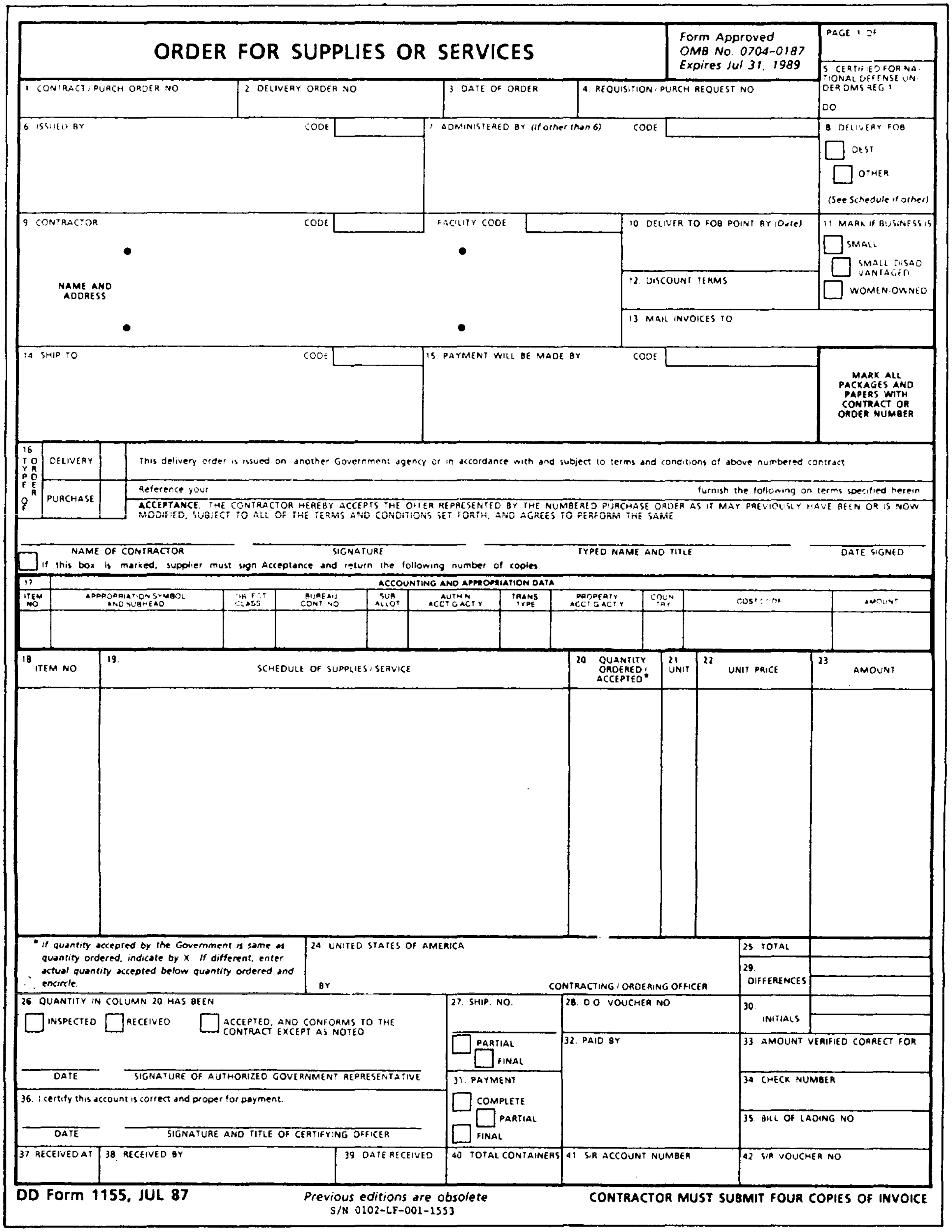


Figure 1-5.—Transportation maintenance shop workload control board.



ORDER FOR SUPPLIES OR SERVICES

Form Approved
OMB No. 0704-0187
Expires Jul 31, 1989

PAGE 1 OF

1. CONTRACT / PURCH ORDER NO
2. DELIVERY ORDER NO
3. DATE OF ORDER
4. REQUISITION / PURCH REQUEST NO
5. CERTIFIED FOR NATIONAL DEFENSE UNDER DMS REG 1
DO

6. ISSUED BY CODE
7. ADMINISTERED BY *(If other than 6)* CODE
8. DELIVERY FOB
☐ DEST
☐ OTHER
(See Schedule if other)

9. CONTRACTOR CODE FACILITY CODE
NAME AND ADDRESS

10. DELIVER TO FOB POINT BY *(Date)*
11. MARK IF BUSINESS IS
☐ SMALL
☐ SMALL DISADVANTAGED
☐ WOMEN-OWNED

12. DISCOUNT TERMS
13. MAIL INVOICES TO

14. SHIP TO CODE
15. PAYMENT WILL BE MADE BY CODE

MARK ALL PACKAGES AND PAPERS WITH CONTRACT OR ORDER NUMBER

16. TYPE OF ORDER
DELIVERY ☐ This delivery order is issued on another Government agency or in accordance with and subject to terms and conditions of above numbered contract
PURCHASE ☐ Reference your furnish the following on terms specified herein

ACCEPTANCE. THE CONTRACTOR HEREBY ACCEPTS THE OFFER REPRESENTED BY THE NUMBERED PURCHASE ORDER AS IT MAY PREVIOUSLY HAVE BEEN OR IS NOW MODIFIED, SUBJECT TO ALL OF THE TERMS AND CONDITIONS SET FORTH, AND AGREES TO PERFORM THE SAME

NAME OF CONTRACTOR | SIGNATURE | TYPED NAME AND TITLE | DATE SIGNED

☐ If this box is marked, supplier must sign Acceptance and return the following number of copies

17. ACCOUNTING AND APPROPRIATION DATA

ITEM NO	APPROPRIATION SYMBOL AND SUBHEAD	OBJECT CLASS	BUREAU CONT NO	SUB ALLOT	AUTH'N ACCT'G ACT'Y	TRANS TYPE	PROPERTY ACCT'G ACT'Y	COUNTRY	COST CODE	AMOUNT

18. ITEM NO.	19. SCHEDULE OF SUPPLIES / SERVICE	20. QUANTITY ORDERED / ACCEPTED*	21. UNIT	22. UNIT PRICE	23. AMOUNT

* *If quantity accepted by the Government is same as quantity ordered, indicate by X. If different, enter actual quantity accepted below quantity ordered and encircle.*

24. UNITED STATES OF AMERICA
BY CONTRACTING / ORDERING OFFICER

25. TOTAL
29. DIFFERENCES

26. QUANTITY IN COLUMN 20 HAS BEEN
☐ INSPECTED ☐ RECEIVED ☐ ACCEPTED, AND CONFORMS TO THE CONTRACT EXCEPT AS NOTED
DATE | SIGNATURE OF AUTHORIZED GOVERNMENT REPRESENTATIVE

27. SHIP. NO.
☐ PARTIAL
☐ FINAL

28. D.O. VOUCHER NO
30. INITIALS

31. PAYMENT
☐ COMPLETE
☐ PARTIAL
☐ FINAL

32. PAID BY
33. AMOUNT VERIFIED CORRECT FOR
34. CHECK NUMBER
35. BILL OF LADING NO

36. I certify this account is correct and proper for payment.
DATE | SIGNATURE AND TITLE OF CERTIFYING OFFICER

37. RECEIVED AT
38. RECEIVED BY
39. DATE RECEIVED
40. TOTAL CONTAINERS
41. S/R ACCOUNT NUMBER
42. S/R VOUCHER NO

DD Form 1155, JUL 87
Previous editions are obsolete
S/N 0102-LF-001-1553
CONTRACTOR MUST SUBMIT FOUR COPIES OF INVOICE

Figure 1-6.—Order for Supplies or Services, DD Form 1155.

Accuracy in man-hours expended and maintenance cost is essential to meaningful data. Comparison of standard hours with actual man-hours could indicate a shortage of ability, lack of training, or even shop or tool features that cause delays. When standard hours are added to induction time, you should be able to forecast an accurate completion date. Time spent obtaining repair parts may also be charted and used to determine positive or negative availability or management. Some public works have contracted repair parts suppliers to increase availability and reduce lead time.

CONTRACT MAINTENANCE AND REPAIRS

In the event that a public works is undermanned or has the personnel but not the necessary skills, it may be necessary to look for alternatives to keep up with the maintenance and repair schedule. Commercial contractors and other government agencies are two alternatives to help balance your workload.

COMMERCIAL CONTRACTORS

When work is performed by commercial contractors or facilities, an Order for Supplies or Services, DD Form 1155 (fig. 1-6), supported by an SRO is required. The control section supervisor ensures that the SRO covering equipment scheduled for contract work is properly documented and turned over to the shop inspector. The inspector lists the necessary repairs on the SRO, applies the manufacturer's flat rate standards, and returns the SRO to the control section supervisor. After the contract labor rate, contract number, order number, and necessary accounting data are added, the SRO is forwarded to the contracting officer. The contracting officer prepares an original and six copies of the DD Form 1155. One copy is forwarded to the comptroller, where the estimated amount is entered on allotment records as an obligation. The original and four copies, together with both copies of the SRO, are then returned to the shop dispatcher for delivery with the equipment to the contractor. When the equipment is delivered to the contractor, a custody receipt is to be obtained and returned to the shop dispatcher. After the completion of repairs, the contractor returns the equipment to the shop dispatcher with the original and one copy of the SRO, four copies of the DD Form 1155, and the original and three copies of the contractor's bill. The shop dispatcher turns the equipment over to the shop inspector and destroys the custody receipt. The equipment is then reinspected for satisfactory repairs. The inspector and the control section supervisor review the work and the bill. If all is correct, the bill is certified for payment. The original SRO, three copies of the DD Form 1155, and three copies of the contractor's bill are to be forwarded to the appropriate office for final processing and payment. The green copy of the SRO, one copy of the DD Form 1155, and one copy of the contractor's bill are to be filed in the vehicle history jacket for the life of the vehicle.

OTHER GOVERNMENT AGENCIES

The procedures for the performance of work or services by other government agencies, military and nonmilitary, are basically the same as for work performed by commercial contractors. Exact information for these procedures may be found in chapter 18 of *Management of Transportation Equipment,* NAVFAC P-300.

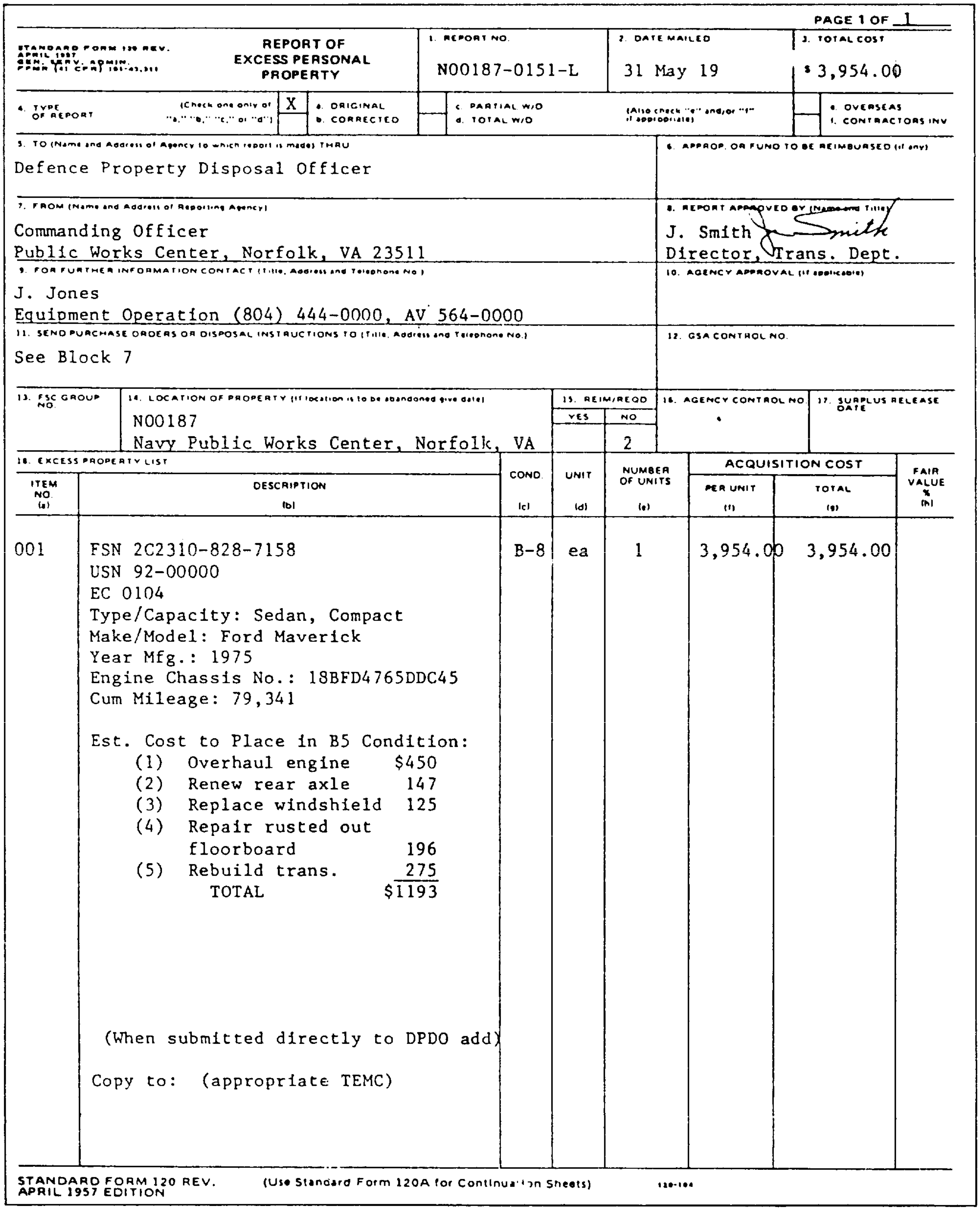
EQUIPMENT WARRANTIES AND DEFICIENCIES

Normally, warranties guarantee the equipment and its parts against defective material and workmanship for a period of time or miles specified in the procurement contract. Activities noting deficiencies within the warranty period should prepare and complete a Quality Deficiency Report, SF 368 (fig. 1-7), and distribute them to the appropriate addressees as soon as possible.

1. Original to the appropriate Engineering Field Division (EFD), Transportation Equipment Management Center (TEMC)
2. Copy to CBC Port Hueneme Calif. (CODE 153)
3. Copy to NAVFACENGCOM (CODE 1202)

NOTE

Procedures for submittal for Special Operating Units (SOUs) and Naval Mobile Construction Battalions (NMCBs) can be found in chapter 2, section 5, of *Naval Construction Force Equipment Management Manual,* NAVFAC P-404, or in section 7, paragraph 1705, of COMCB-PAC/COMCBLANTINST 11200 series.



PAGE 1 OF 1

STANDARD FORM 120 REV.
APRIL 1957
GEN. SERV. ADMIN.
FPMR (41 CFR) 101-43.311

REPORT OF EXCESS PERSONAL PROPERTY

1. REPORT NO. N00187-0151-L

2. DATE MAILED 31 May 19

3. TOTAL COST $ 3,954.00

4. TYPE OF REPORT (Check one only of "a," "b," "c," or "d") ☒ a. ORIGINAL ☐ b. CORRECTED ☐ c. PARTIAL W/O ☐ d. TOTAL W/O (Also check "e" and/or "f" if appropriate) ☐ e. OVERSEAS ☐ f. CONTRACTORS INV

5. TO (Name and Address of Agency to which report is made) THRU
Defence Property Disposal Officer

6. APPROP. OR FUND TO BE REIMBURSED (if any)

7. FROM (Name and Address of Reporting Agency)
Commanding Officer
Public Works Center, Norfolk, VA 23511

8. REPORT APPROVED BY (Name and Title)
J. Smith J Smith
Director, Trans. Dept.

9. FOR FURTHER INFORMATION CONTACT (Title, Address and Telephone No.)
J. Jones
Equipment Operation (804) 444-0000, AV 564-0000

10. AGENCY APPROVAL (if applicable)

11. SEND PURCHASE ORDERS OR DISPOSAL INSTRUCTIONS TO (Title, Address and Telephone No.)
See Block 7

12. GSA CONTROL NO.

13. FSC GROUP NO.

14. LOCATION OF PROPERTY (If location is to be abandoned give date)
N00187
Navy Public Works Center, Norfolk, VA

15. REIM/REQD YES NO 2

16. AGENCY CONTROL NO.

17. SURPLUS RELEASE DATE

18. EXCESS PROPERTY LIST

ITEM NO. (a)	DESCRIPTION (b)	COND. (c)	UNIT (d)	NUMBER OF UNITS (e)	ACQUISITION COST PER UNIT (f)	ACQUISITION COST TOTAL (g)	FAIR VALUE % (h)
001	FSN 2C2310-828-7158 USN 92-00000 EC 0104 Type/Capacity: Sedan, Compact Make/Model: Ford Maverick Year Mfg.: 1975 Engine Chassis No.: 18BFD4765DDC45 Cum Mileage: 79,341 Est. Cost to Place in B5 Condition: (1) Overhaul engine $450 (2) Renew rear axle 147 (3) Replace windshield 125 (4) Repair rusted out floorboard 196 (5) Rebuild trans. 275 TOTAL $1193 (When submitted directly to DPDO add) Copy to: (appropriate TEMC)	B-8	ea	1	3,954.00	3,954.00	

STANDARD FORM 120 REV.
APRIL 1957 EDITION
(Use Standard Form 120A for Continuation Sheets) 120-104

Figure 1-8.—Report of Excess Personal Property, SF 120.

Be sure to describe the deficiency in detail. Use photographs and sketches. (Include a ruler in the photograph.) If the deficiency has been corrected before submittal, mark the SF 368, CORRECTIVE ACTION COMPLETED. If the deficiency has not been corrected, mark the SF 368 FOR ACTION.

SAFETY DEFICIENCIES

All civil engineer support equipment (CESE), regardless of warranty coverage, developing design deficiencies affecting safe operation are to be immediately removed from service and reported by message to CBC PORT HUENEME (CODE 153), and followed up with a SF 368. These units are not to be repaired or returned to service until directed by CBC PORT HUENEME (CODE 153).

IN CONTINENTAL UNITED STATES

Activities within the continental United States are to use an available franchised dealer for repairs. If these sources prove unsatisfactory, contact the cognizant engineering field division (EFD) (TEMC) to obtain resolution.

OUTSIDE CONTINENTAL UNITED STATES

Activities outside the continental United States are to request the replacement parts directly from the prime contractor. An SF 368 is to be submitted. The activity is not to forward the defective part.

Further information may be found in the NAVFAC P-300, chapter 23.

TECHNICAL ASSISTANCE

TEMC representatives visit periodically to analyze and assist the activity. These visits are specifically designed to review technical and management procedures to increase the efficiency and effectiveness of the activity. The TEMC representative validates the equipment allowance and reviews operations and maintenance procedures. A report of the visit and its findings, including items of major interest, is made to the commanding officer before the departure of the TEMC representative.

Transportation assistance visits are made at 18-month intervals for activities with 50 or more pieces of CESE. Visits are scheduled each 3 years for activities with less than 50 pieces of CESE. Additional visits are optional and should be requested if desired.

CESE DISPOSAL

As CESE becomes uneconomical to repair, or simply overage, it has to be disposed of properly. Whatever the instance, a Report of Excess Personnel Property, SF 120 (fig. 1-8), is to be submitted to the cognizant TEMC.

SERVICEABLE EQUIPMENT

When CESE is in excess but still serviceable, the TEMC will check and ascertain that no other Navy requirements exist for this CESE. If no other requirements exist, the cogizant TEMC or Port Hueneme (Code 15) will instruct your activity to place the CESE in the nearest Defense Recycling Management Office (DRMO).

UNSERVICEABLE EQUIPMENT

For all unserviceable CESE, contact the cognizant TEMC for disposal instructions and approval. After TEMC approval, turn in the CESE and its history jacket to the nearest DRMO, using a DD Form 1348-1 as a transfer document. Ambulances and dental vehicles have special disposal instructions listed in *Management of Transportation Equipment,* NAVFAC P-300.

INVENTORY RECORDS ADJUSTMENT

Once disposal action is completed, it is important to adjust the records to reflect changes in your activity's CESE inventory allowance. Therefore, it is essential that your TEMC and Port Hueneme (Code 15) receive copies of the Report of Excess Personal Property, SF 120; the transfer document Single Line Item Release/Receipt Document, DD-1348-1, from the disposal office; and the Property Record Card, DD-1342.

ASSIGNMENT 1

Textbook Assignment: "Public Works Transportation Shop's Supervisor," pages 1-1 through 1-14.

1-1. In your work as a PW transportation shop supervisor, you will come in contact with which of the following personnel?

1. Mechanics
2. Military and civilian equipment operators
3. Officers to whom you are responsible
4. All of the above

1-2. What statement best describes the work of a public works transportation maintenance shop?

1. The bulk of the work is of a one-time nature
2. Much of the work is of a continuing nature
3. The work is usually done by military personnel
4. Work methods are the same as those used in a battalion equipment maintenance shop

1-3. Civil service personnel are employed in a PW transportation shop for what purpose?

1. To meet job demands of the civilian commnunity
2. To provide experienced personnel who can be drafted in war
3. To ensure continuity of service

1-4. The physical layout of a maintenance branch mechanic shop may be found in which of the following NAVFAC publications?

1. P-300
2. P-433
3. P-437
4. P-458

1-5. Respectively, the transportation division director reports directly to what person in the chain of command?

1. The base commandinq officer
2. The public works officer
3. The transportation officer

1-6. Within the maintenance branch, who makes the final decision of individual personnel assignments?

1. The public works officer
2. The division director
3. The base commanding officer

1-7. In planning equipment required for the PW center, what person functions as a technical advisor?

1. The equipment operations general foreman
2. The production control supervisor
3. The transportation director
4. The equipment maintenance general foreman

1-8. When the transportation director is absent, who is in charge?

1. The production control supervisor
2. The manager of the equipment branch
3. The maintenance and repair foreman
4. The construction and specialized equipment shop foreman

1-9. To maintain a balanced work flow, which of the following individuals coordinates work with other activities and departments?

1. The manager of the maintenance branch
2. The division director
3. The shop supervisor

1-10. The production control supervisor is responsible for receiving, inspecting, and classifying all new and used equipment. This supervisor must also make which of the following determinations?

1. The number of vehicles required for the activity
2. The parts and tools needed to support this equipment during its life cycle
3. The budgetary requirements for the maintenance division
4. The work load for the transportation department

1-11. Who is responsible for scheduling the work load for the various centers of the transportation department?

1. The maintenance and repair foreman
2. The manager of the equipment branch
3. The production control supervisor
4. The construction and specialized equipment shop foreman

IN ANSWERING QUESTIONS 1-12 THROUGH 1-16, SELECT FROM THE COLUMN B THE SUPERVISOR WHO IS RESPONSIBLE FOR THE DUTY IN COLUMN A. RESPONSES MAY BE USED MORE THAN ONCE.

A. DUTIES

1-12. Supervises the tire shop, body and paint shop, and battery shop

1-13. Exercises full managerial and administrative responsibility of the PW transportation activity

1-14. Issues and enforces safety practices and fire regulations

1-15. Maintains shop backlog records and vehicle history files

1-16. Supervises the machine shop

B. SUPERVISORS

1. Transportation director
2. production control supervisor
3. Maintenance and repair foreman
4. Construction and specialized equipment shop foreman

1-17. The construction equipment shop foreman has all except which of the following responsibilities?

1. Technical supervision of the work center
2. Analyzing and interpreting SROs
3. Issuing and enforcing safety practices and fire regulations
4. Maintenance, repair, and major overhaul of specialized equipment

1-18. What is the most important phase of preventive maintenance?

1. Scheduled command inspections
2. Unscheduled inspections
3. Scheduled, periodic preventive maintenance
4. Unscheduled periodic preventive maintenance

1-19. What is the first line of defense against equipment wear, failure, and damage?

1. Unscheduled periodic inspections
2. Scheduled command inspections
3. Daily inspections by the equipment operators
4. Minor repairs made by the mechanics

1-20. Your maintenance shop has noted that the operators are not properly performing daily PM on their equipment. To set up training periods, you should consult with whom?

1. The equipment operator
2. The equipment operation branch foreman
3. The maintenance shop inspector
4. The production control supervisor

1-21. When a public works station is short of personnel, what person is responsible for performing service station maintenance?

1. The operator
2. The mechanic
3. The yard boss
4. The dispatcher

1-22. Your personnel should inspect vehicles for safety and serviceability at intervals not to exceed 12 months or what maximum number of miles?

1. 10,000 miles
2. 12,000 miles
3. 14,000 miles
4. 16,000 miles

1-23. When, if ever, should the safety and serviceability inspections be performed at the same time?

1. When it reduces downtime
2. When it conserves funding
3. Never, they are always performed separately

1-24. Vehicle safety deficiencies were discovered during a safety inspection. When should the deficiencies be corrected?

1. When funds are available
2. Durinq the next PM
3. Before the vehicle becomes operational
4. Immediately

1-25. Unscheduled maintenance is limited to those items reported or confirmed deficient by which of the following personnel?

1. The shop supervisor
2. The inspector
3. Both 1 and 2 above
4. The operator

1-26. The cost control system provides a means for comparing the actual performance of maintenance work on transportation equipment to the hourly standards established by what means?

1. The man-hours accumulated in the use of the equipment
2. The equipment manufacturers and the Naval Facilities Engineering Command
3. The past work records
4. The volume of work done

1-27. In the cost control system, which of the following costs are charged to allotments and appropriations?

1. Indirect labor and material costs of equipment maintenance and operations
2. Direct labor and material costs of equipment maintenance and operations
3. Costs of building maintenance, shop stores, and utilities
4. All of the above

1-28. Reports required by supervisors to pinpoint deficient areas of operation are prepared by which of the following individuals?

1. The shop supervisor
2. The accountable fiscal officer
3. The division director
4. The assistant public works officer

1-29. Transportation management reports include data for comparing actual maintenance costs and standard maintenance costs.

1. True
2. False

1-30. Figure 1-2 in your textbook is an example of a Shop Repair Order. Such an order is used for recording which of the following information?

1. The cost of repairs
2. The materials used
3. The hours required to do the work
4. Each of the above

1-31. The extent of the services a PW maintenance shop provides in maintaining, repairing, or overhauling an activity's automotive equipment depends on which of the following factors?

1. Economics
2. Distance of the activity from commercial repair shops
3. Size of the activity
4. Each of the above

1-32. The cost of repair services by the preventive maintenance shop must be justified when the nature of the work is classified.

1. True
2. False

1-33. Guidance for equipment preservation is contained in what NAVFAC publication?

1. P-437
2. P-434
3. P-405
4. P-458

1-34. The level of preservation to be applied to construction equipment depends on which of the following factors?

1. Information received as to how the equipment is to be handled, shipped, and stored
2. Conditions to which the equipment will be subjected during its storage period before issue
3. Physical characteristics of the equipment
4. Each of the above

1-35. Before applying preservatives to CESE, which of the following actions must you take?

1. Repair the vehicle
2. Remove all corrosion and contaminants
3. Repaint the vehicle
4. Notify the safety officer

1-36. What single cleaning method, if any, is the best for all equipment?

1. Steam cleaning
2. Fresh water washing
3. Solvent wipe down
4. None

1-37. Steam cleaning is suitable for the removal of which of the following substances?

1. Tar
2. Heavy grease
3. Road deposits
4. All of the above

1-38. Active storage equipment must be operated for short periods of time at regular intervals to keep it in serviceable condition.

1. True
2. False

1-39. When depreserving stored equipment before it is operated, you should take all except which of the following actions?

1. Remove seals and closures
2. Remove preservatives with abrasives
3. Lubricate the movable parts of the equipment
4. Reinstall the components removed for storage

1-40. In addition to safety inspection regulations, what rule applies to vehicle inspection and servicing?

1. Perform as prescribed by the manufacturer
2. Perform as often as mechanics are available
3. Perform as little as possible to keep the cost down
4. Perform as prescribed by the dealers

1-41. At a public works department, the PM schedule for a vehicle is determined by dividing the estimated miles and hours by what factor?

1. That of 40 workdays
2. The manufacturer's recommended service interval
3. The number of workdays per year

IN ANSWERING QUESTION 1-42, REFER TO FIGURE 1-4 IN THE TEXT.

1-42. The emissions control devices should be serviced at what maximum number of miles?

1. 1,000 miles
2. 2,000 miles
3. 6,000 miles
4. 12,000 miles

1-43. Direct labor is the only factor to be considered when maintaining a work load control board.

1. True
2. False

1-44. Which of the following means may be used by a maintenance shop to display the work load status effectively?

1. A work load control board
2. Equipment repair orders
3. Shop repair orders
4. A vehicle/construction equipment service record

1-45. When standard hours are compared with actual man-hours, which of the following factors is indicated?

1. Shortage of funding
2. Possible lack of training for personnel
3. Both 1 and 2 above
4. Shortage of tools

1-46. A public works department may have a contract repair parts supplier to increase availability.

1. True
2. False

1-47. In an undermanned public works station, the supervisor may need to take which of the following actions to keep up with the maintenance and repair schedule?

1. Hire additional personnel
2. Use commercial contractors
3. Extend working hours
4. Each of the above

1-48. In ordering work to be performed by commercial contractors, you should use what form?

1. DD Form 1155
2. Standard Form 120
3. NAVFAC Form 9-11200/3A

1-49. After the inspector adds the labor rate, contract number, order number, and accounting data, the shop repair order is forwarded to what person?

1. The division director
2. The shop supervisor
3. The contracting officer
4. The public works officer

1-50. Upon completion of contract repairs, what should the shop dispatcher do with the custody receipt?

1. File it for 90 days
2. Route it to the maintenance shop
3. Destroy it
4. Return it to the contractor

1-51. The DD Form 1155 should be filed in the equipment history jacket for what period of time?

1. 90 days
2. 6 months
3. 1 year
4. The life of the vehicle

1-52. The period of time a vehicle is warranted is found in what document or publication?

1. The procurement contract
2. The NAVFAC P-300
3. In COMCBPAC/COMCBLANTINST 11200.1 series

1-53. Equipment deficiencies should be noted on which of the following forms?

1. SF 120
2. SF 364
3. SF 368

1-54. Procedures for submitting a quality deficiency report for a special operating unit of the Naval Construction Force may be found in which of the following NAVFAC publications?

1. P-405
2. P–300
3. P-404
4. P-434

1-55. If action has been completed correcting an equipment deficiency, a quality deficiency report is not required.

1. True
2. False

1-56. Regardless of warranty coverage, which of the following actions should you take with CESE that have design deficiencies affecting safe operation?

1. Remove the CESE from service immediately
2. Report the deficiencies to CBC, Port Hueneme (Code 155) by message
3. Both 1 and 2 above
4. Repair and return the CESE to service

1-57. Warranty repairs are normally completed by what means?

1. A public works maintenance shop
2. A franchised dealer
3. Other government sources

1-58. The efficiency of a public works activity is normally increased after a visit by a representatives from what activity?

1. TEMC
2. CESO
3. COMCBPAC
4. COMCBLANT

1-59. Upon the departure of the visiting TEMC representative, he or she will submit a report to what individual person?

1. The division director
2. The public works officer
3. The commanding officer

1-60. For sites with more than 50 pieces of CESE, transportation assistance visits are made at what intervals?

1. Every year
2. Every 18 months
3. Every 2 years
4. Every 4 years

1-61. When disposal of CESE is requested, you must submit what form to the cogizant TEMC?

1. SF-346
2. SF-368
3. SF-120
4. SF-46

1-62. When CESE is turned in to DRMO, what is done with the vehicle history jacket?

1. It is destroyed
2. It is turned in to DRMO with the equipment
3. It is kept on file for 1 year
4. It is sent to CBC, Port Hueneme, code 153

1-63. Special disposal instructions for ambulances and dental vehicles are contained in which of the following NAVFAC publications?

1. P-404
2. P-405
3. P-300
4. P-437

1-64. After a disposal action is completed, what action, if any, should you take next?

1. Adjust the inventory records
2. Notify the commanding officer
3. Notify the division director
4. None

CHAPTER 2

ALFA COMPANY SHOPS SUPERVISOR

In a Naval Mobile Construction Battalion (NMCB), the equipment maintenance branch is composed of four sections: administrative, automotive repair, heavy equipment repair, and support shops. These sections, or shops, come under the overall supervision of the maintenance supervisor, who is normally a CMCS. As a CM1, you may be assigned as an inspector or a shop supervisor in any one of these shops within the maintenance branch. In small units (CBMUs, BMUs, and so forth) and large detachments, it is common to have a CM1 working as the maintenance supervisor.

In your role as shop supervisor, inspector, or maintenance supervisor, you will not only need to call upon all of your past experience, but also you will have to be constantly alert for new ideas and ways of accomplishing your mission within the time frames allotted. Of course, skillful predeployment planning is essential; but deployments rarely go according to plan, especially with equipment. Remember, in addition to facing unusual maintenance problems not encountered at a public works duty station, you must be ready to pack your gear and mount out at any given moment.

This chapter describes the composition of different equipment maintenance branch shops and small units. It describes the duties and responsibilities you will be expected to perform. Remember, these duties and responsibilities may vary in each battalion, small unit, or detachment, Assignments are made by the maintenance supervisor.

One of the most important tasks is to stay abreast of developments in equipment maintenance. Here are some publications to consult that will help you keep up to date: *Naval Construction Force Manual,* NAVFAC P-315; *Naval Construction Force Equipment Management Manual,* NAVFAC P-404; *Naval Construction Force Safety Manual* (COMCB-PAC/COMCBLANTINST 5100.1 series); COMCBPAC/COMCBLANT and NAVFACINST 11200 series; Civil Engineer Support Office Maintenance Bulletins; Equipment Officer Technical Bulletins; and Equipment Officer Modification Work Orders.

SETTING UP A MAINTENANCE BRANCH

Currently most areas that Naval Construction Force (NCF) units, especially Mobile Construction Battalions (MCBs), deploy to, have maintenance facilities already in place. Normally only upgrading and maintenance of these areas is required. However, during a contingency, your unit could go into an area without any facilities. In this instance you will be required to assist the maintenance supervisor in setting up the maintenance branch. In the event that you are attached to a small unit as the senior CM (maintenance supervisor), it will be up to you to set up the maintenance branch and make it operational.

AREA SELECTION

The number and types of vehicles to be maintained are an important consideration in selecting the area, determining the size of the shop, and in laying out the shop. Placement is most important. If possible, avoid locating the shop in a low-lying area. Select a site large enough to allow for expansion, near the center of activity where there are existing roadways and parking areas. Proper layout will reduce maintenance bottlenecks and induce equipment to flow through the shop. You can obtain more information on the physical arrangement of buildings from the *Facilities Planning Guide,* NAVFAC P-437, especially in chapter 1.

HEAT, LIGHT, AND VENTILATION

Heat, light, and ventilation for a large, permanent maintenance shop are included in the plan specification. However, the installation of these facilities in the small or temporary shop depends on the maintenance supervisor.

The decision of whether to heat your shop depends upon its geographical location. Heaters should be arranged to provide warmth where it is most needed. Persons working at benches or in the shop store require more heat than people working in the main shop for comparatively short periods. For this reason, you should place heaters in corners convenient to workbenches and away from shop doors.

For adequate lighting, most maintenance shops depend upon lights arranged in the overhead of the main shop, lights and windows near the workbenches, and extension lights that can be plugged into electrical outlets. When you are in charge of setting up a maintenance shop, make sure that enough electrical outlets are provided for extension lights and electric power tools. Only the most elaborate shops have enough windows for efficient lighting.

Removing exhaust gases becomes a big problem in every maintenance shop. Large doors in the front and rear of the shop and windows at the workbenches normally supply all the fresh air needed, but even these are inadequate to remove excessive amounts of exhaust gases. These gases rise and are trapped in the shop overhead unless roof openings with ventilating fans are provided. Normally, it is up to the supervisor of a temporary shop to provide his own method of ventilation. A piece of flexible steel or neoprene hose attached to the exhaust on a running engine and carried outdoors through an opening in the building will serve the purpose. Do not allow any unnecessary operation of an engine inside the shop.

When stationary gasoline or diesel engines are used to produce power in the maintenance shop, provide exhaust outlets for them. Do not depend on natural ventilation through door and windows.

At least once during each deployment have the maintenance shop evaluated by the local base industrial hygienist, if the service is available. Do this through your battalion safety office.

TOOLS AND EQUIPMENT

The quantities and kinds of tools and equipment required for a maintenance shop vary with each shop. In deciding what tools and what type of equipment to have on hand, consider two factors: (1) the operational needs of the battalion and (2) the cost of the work at a component overhaul facility. Of course, the needs of the service come first, but not entirely without cost justification. Base your decision concerning the second factor solely on the facts and figures given in transportation maintenance management reports.

In a maintenance shop setup for repairing all types of equipment, you will coordinate and supervise work on many different types; therefore, study carefully the layout of the shop and the placement of shop equipment. You will probably be the one to decide whereto put the shop equipment. This is where experience counts, You should know where the repair equipment is needed and where it will be accessible to the operators who will use it. Without careful planning you can waste a lot of space and time in shifting equipment from one place to another. If space in the main shop is critical, special repair equipment can be put in smaller shops or rooms adjoining the main shop.

Power tools, such as drill presses and bench grinders commonly used in repairing all kinds of equipment, should be located in or near the main shop area. The locations of other power tools, such as hydraulic or electric lifts, valve grinders, and machines for aligning wheels and relining brakes, depend on where the tools will be best utilized. **The master switch that controls all power in the shop should be installed where it can be reached quickly in an emergency.**

In placing power tools, secure the legs or bases to a level surface strong enough to support them and make sure they will not move or bounce when in use. Before connecting stationary, electrically operated power tools to power outlets, be sure that each one is positioned so that the starting and stopping switch is within easy reach of the operator. **Ground-fault interrupters should be installed to prevent accidental electrical shock.** When the connection is complete, test the tools to ensure that the installation is safe. Also, let your mechanics operate them and consider any suggestions they may have for improvements. As always, make sure your tool and equipment operators wear protective gear. Double-check often, looking for ways to improve the efficiency, as well as the safety, of the whole maintenance shop.

Welding equipment must be operated in an area apart from the rest of the shop. Post hazard warning signs in the area and equip it with fire-fighting equipment. Erect screens that will confine flying sparks to reduce the chances that they will start fires or get into somebody's eyes.

Tire repair equipment should also be in a separate section of the shop, located near one of the shop entrances. With this arrangement, tire tools, tube-patching equipment, and air hoses can be used by the EOs as readily as by the CMs.

Before deciding where to place an air compressor (the large shops have more than one), consider the uses you have for air and where the air outlets would be most convenient. Compressed air is needed for operating pneumatic power tools, cleaning parts, and inflating tires. By keeping compressor lines as short and free of bends as possible, you minimize drops in air pressure at the outlets. Short lines do not collect as much water as long lines and are therefore less likely to freeze in cold weather. When you have long lines, install condensation traps in them and drain the traps daily.

Battery-charging equipment must be in a well-ventilated section of the shop away from the welding area, or in a separate well-ventilated, explosiveproof building. Because hydrogen fumes produced by a charging battery are highly explosive, always install an exhaust fan near the battery charger. Make sure a water outlet is available because an approved eyewash and shower have to be installed so that anyone involved in a battery shop accident can be bathed immediately to prevent severe burns. **Delay in diluting or washing out sulphuric acid from a victim's eyes could result in loss of sight.**

SAFETY

Safety is everyone's responsibility. It is a never-ending job that cannot be left to one individual or one office. Everyone must always be alert to accident prevention. It is imperative that you emphasize safe working practices to the point that they are routine.

One of the basic rules of shop safety requires that everyone behave himself. Practical jokes and horseplay cannot be tolerated. The possible consequences of such actions are too high a price to pay for the little humor derived.

You can help prevent accidents by appointing a shop safety petty officer to detect unsafe practices, bad habits, and defective tools that would otherwise go unnoticed. You should replace your shop safety petty officer periodically, thereby rotating these duties.

You can reduce the number of personal injuries in a shop by requiring good housekeeping practices; for example, keeping the shop floor free of grease and oil to help prevent mechanics and others from slipping or falling. Likewise, clearing the floor of creepers, stray tools, and parts will eliminate the chances of tripping over them.

Accidents and injury may be reduced or cut to zero by starting each day with a stand-up safety lecture. True, this absorbs valuable time, but it is worth it.

Crack down on bad habits, such as leaving jack handles sticking out into walkways and leaving vehicle doors open while mechanics work underneath.

THE MAINTENANCE SUPERVISOR

The battalion equipment maintenance supervisor, usually a CMCS, is responsible for that battalion's entire equipment maintenance program and all assigned CESE for the battalion and all its assigned detachments. The senior CM of a detachment, working in the equipment maintenance shop, is the maintenance supervisor for that detachment site. Maintenance supervisors have direct control over the administrative section. Specifically their duties include the following:

1. Control and supervision of all maintenance personnel, through the shop supervisors.
2. Ensuring adherence to the scheduled preventive maintenance program.
3. Ensuring accurate cost control, record maintenance, and updating.
4. Submitting equipment reports to the ALFA Company commander and the commanding officer for distribution to higher authority.
5. Maintaining the Construction Mechanics' tool allowance and ensuring that biweekly tool inventories are conducted.
6. Providing technical and safety training.
7. Providing technical assistance to the supply and logistics officer with regard to repair parts.
8. Ensuring quality control of the repair and maintenance work.
9. Ensuring that the Battalion Equipment Evaluation Program (BEEP) is carried out under the latest instructions.
10. Ensuring that the preventive maintenance schedule is entered into the ALFA Company minicomputer equipment program. The use of the minicomputer can then aid in the execution of the preventive maintenance program.

SHOP INSPECTORS

One of the keys to a successful maintenance program is good shop inspectors. Shop inspectors need maturity and tact when dealing with shop supervisors who are often militarily senior. Chapter 9 of this TRAMAN covers the duties and responsibilities of shop inspectors more completely.

AUTOMOTIVE SHOP SUPERVISOR

The automotive shop supervisor, who is usually a CMC, has direct control over the automotive repair shop and works directly for the maintenance supervisor. Among this supervisor's duties are the following:

1. Controlling and supervising all maintenance personnel assigned to the shop
2. Ensuring that preventive maintenance is performed under current instructions
3. Submitting accurate maintenance records to the cost control section
4. Maintaining the mechanics' tool kits and conducting required inventories
5. Providing necessary technical and safety instruction and-leadership
6. Ensuring that all work listed on EROS is performed and that any additional work is authorized, recorded, and performed
7. Ensuring that only top quality work is performed in the shop

HEAVY SHOP SUPERVISOR

The heavy equipment repair supervisor, who is usually a CMC, has direct control over the heavy equipment repair shop and works directly for the maintenance supervisor. In addition to the duties of the automotive repair supervisor just listed, the heavy equipment repair supervisor is responsible for the assignment and supervision of the field maintenance crew and injector shop if one is established.

Field Maintenance

The importance of field maintenance and field repairs cannot be overemphasized. The success or failure of the deployment from an equipment maintenance standpoint, and in some cases from the project standpoint, can be traced to the unavailability of equipment because of poor field maintenance or inability to perform adequate and timely repairs in the field. Experienced field mechanics are worth their weight in gold, and the heavy equipment repair supervisor must be careful in the selection of the field mechanics, even to the point of shortchanging himself in the shop. In the long run, good field maintenance will reduce the shop workload and improve the operator's concern for the equipment. Remember, it is the responsibility of the heavy equipment repair supervisor to provide the tools and equipment required by the field mechanics.

Injector Shop

When an area or shop has been established to repair injectors and injection pumps, it will normally be under the supervision of the heavy equipment repair supervisor. In addition to the necessary testing equipment, an injector repair shop requires a method of controlling the temperature and cleanliness.

SUPPORT (OR 5000) SHOP SUPERVISOR

The support (or 5000) shop supervisor, usually a CMC, reports directly to the maintenance supervisor. This supervisor is responsible for training, supervising, and cent rolling personnel performing the support functions assigned to him or her by the maintenance supervisor. The support shop normally includes the toolroom and shops described in the following paragraphs. All of these shops perform their services to support the heavy and automotive repair shops, which have the basic maintenance responsibility for all civil engineer support equipment (CESE) assigned to the battalion. Requests for support services (machine shop, steel shop, and so forth) from other companies within the battalion will be routed through the maintenance supervisor.

MR Shop

Machinery Repairmen (MRs) are assigned to operate the machine shop trailer, which contains lathes, drill presses, grinders, and other machine tools. It should be located near the repair shops to make it convenient for the crews of both shops to work together on joint projects. The MRs are capable of manufacturing or repairing equipment parts, tools, and machine parts. Valid inventory lists for the MR trailer may be obtained from COMCBPAC equipment office or COMCBLANT DET, Gulfport.

Electrical Shop

Manned by Construction Mechanics, the electrical shop repairs, rebuilds, cleans, adjusts, and tests all automotive electrical parts and accessories, such as generators, starters, and voltage regulators. In many battalions, Construction Electricians (CEs) are assigned to conduct load tests and make electrical repairs to light plants, generators, and welders.

Battery Shop

CMs assigned to the battery shop maintain and recharge wet cell batteries, mix electrolyte, and keep a supply of fully charged, spare batteries for equipment used by the battalion.

The battery shop should be well separated from any open flames. It must be well ventilated to prevent accumulation of explosive hydrogen gas fumes given off during battery charging. Adequate safety equipment, located within the battery shop, includes rubber aprons and gloves, face shields, eyewash, and treadle shower. Electrical light fixtures and plug-in connections should be of explosiveproof design.

Mechanics' Toolroom

The mechanics' toolroom is the central point for issue of all mechanics' tools under an approved custody control system. Each shop supervisor is the custodian of kits and tools needed continuously for the shop. These are checked out by mechanics of the shop on signed custody receipts. Tools needed to perform particular job assignments are signed out on an individual basis. The toolroom petty officer will have an updated copy of the CESO Sets Kits and Outfits Book (SKO) to provide accurate inventory lists of all tool kits by NAVFAC assembly number. A partial listing of tool kits available to the mechanic stationed in an NMCB follows.

NAVFAC Assembly Number	Kit Name
80012	Tire service tools
80013	Mechanics' hand tools, for two people
80015	Battery service tools
80016	Automotive tune-up
80017	Automotive body tools
80023	Radiator tools
80031	Metric hand tools
80072	Puller set mechanical, 13 ton
80081	Diesel engine test kit
80414	ALFA Company toolroom kit

Be sure to check your toolroom SKO for additional tool kits and their applications. Toolroom personnel perform tool repair within their capabilities and ensure that preventive maintenance service and electrical safety checks (according to COMCBPAC/COMCBLANTINST 5100.1 series, art. 215) are conducted by battalion toolroom personnel.

ALFA Company Steel Shop

In construction battalions, Steelworkers (SWs) and Hull Technicians (HTs) form the nucleus of the ALFA Company steel shop. Their work includes repair and rebuilding of chassis components and body parts; repair and testing of radiators; and repair of any other metal components by welding, soldering, brazing, and so on.

Tire Shop

Personnel assigned to the tire shop repair and replace pneumatic tires on CESE assigned to the battalion.

This shop should be located in an easily accessible area, as over 90 percent of the CESE assigned to a construction battalion uses pneumatic tires. The SKO, volume 2, kit 80012, lists items required to operate a battalion-size tire shop. An air compressor, separate from the maintenance shop, is required because of the large volume of air used.

Lubrication Rack

The mechanics assigned to the lubrication racks maintain adequate stocks of all lubricants required by the battalion and lubricate automotive and construction equipment as required under the preventive maintenance (PM) program.

Although you will have skid-mounted lubricators and lubricating teams for servicing equipment in the field, most of your scheduled PMs will be accomplished in the maintenance shop area. Outdoor locations for lubrication stalls are satisfactory in temperate climates and during favorable weather, but efficiency is increased by providing suitable shelter. PM racks should include provisions for storage of greases and oils, preferably at a distance from your other shop areas, as a precaution against fire.

In addition to facilitating lubrication services, these racks should provide for easier inspection and cleaning of underneath parts and surfaces of CESE.

COST CONTROL SUPERVISOR

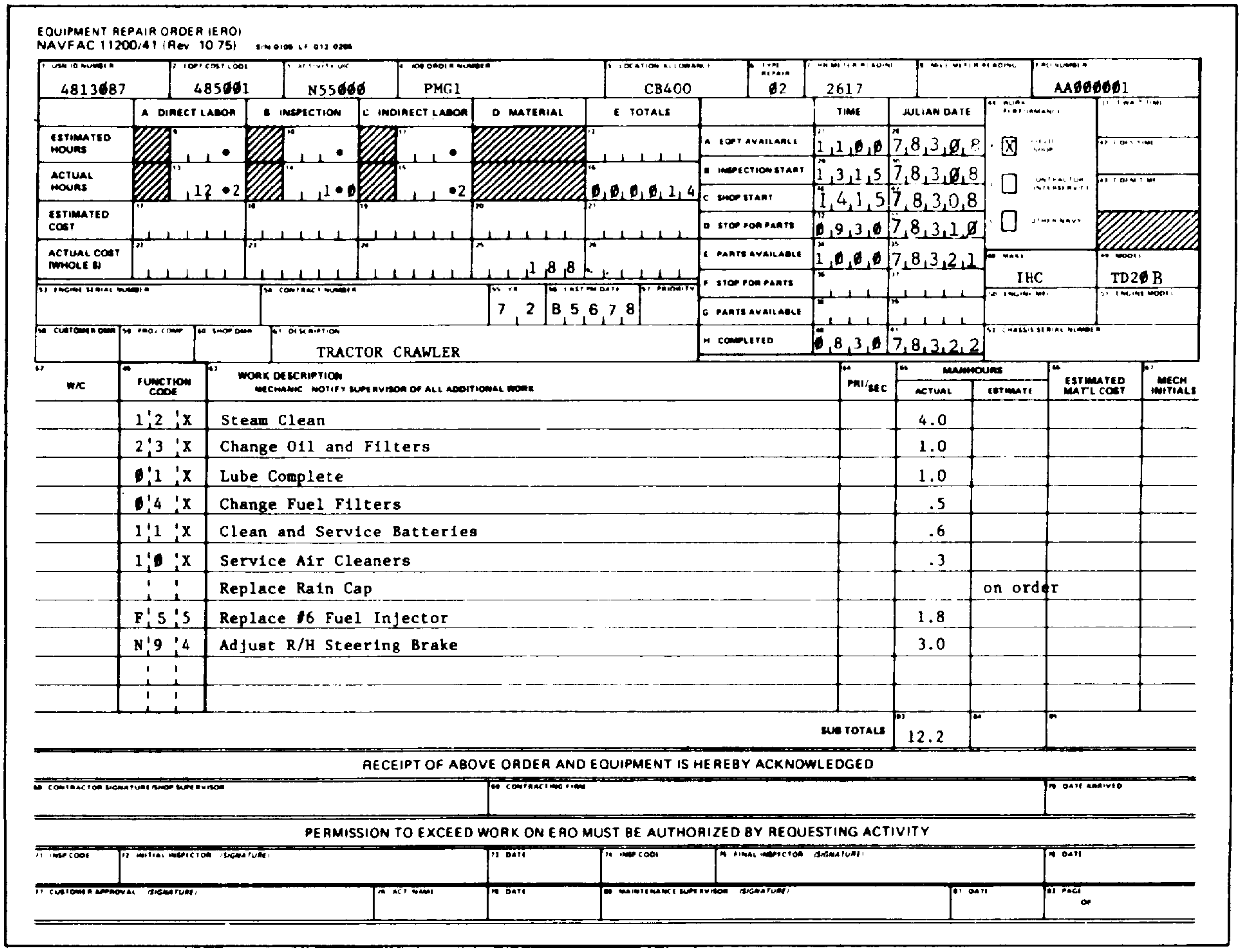
At main body sites and large detachment sites, the person assigned as cost control supervisor is normally a CM1. The duties of this supervisor include monitoring the PM clerk, cost control clerk, and direct turnover parts (DTO) clerk. When necessary, he or she will keep the vehicle status boards current, act as liaison to detachments, and keep the maintenance supervisor up to date on any incoming and outgoing action correspondence. The cost control supervisor may also be responsible for updating the equipment computer program for the maintenance supervisor. It is essential that there be a highly reliable person in this job.

Preventive Maintenance Clerk

The PM clerk is responsible for completing the basic information on the Equipment Repair Order (ERO) (figs. 2-1, 2-2, and 2-3), maintaining the Equipment Repair Order Log Sheet (fig. 2-4) and the PM Record Card (figs. 2-5 and 2-6), preparing the annual PM Schedule (fig. 2-7) and the Equipment Repair Order Worksheet (fig. 2-8), and ordinarily also notifying the dispatcher in advance of equipment due into the shop and keeping status boards current as to units in the shop.

Cost Control Clerk

Cost control in any NCF unit consists of accurate reporting of all costs, downtime, and other maintenance data that relates to CESE repairs. The cost control clerk is responsible for summarizing the total cost of repair parts and labor expended and of making these entries in the appropriate ERO blocks.



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

4813087	485001	N55000	PMG1	CB400	02	2617		AA000001

	A DIRECT LABOR	B INSPECTION	C INDIRECT LABOR	D MATERIAL	E TOTALS
ESTIMATED HOURS	•	•	•	▨	
ACTUAL HOURS	12 •2	1•0	•2	▨	000014
ESTIMATED COST					
ACTUAL COST (WHOLE $)				188	

	TIME	JULIAN DATE
A EQPT AVAILABLE	1100	78308
B INSPECTION START	1315	78308
C SHOP START	1415	78308
D STOP FOR PARTS	0930	78310
E PARTS AVAILABLE	1000	78321
F STOP FOR PARTS		
G PARTS AVAILABLE		
H COMPLETED	0830	78322

☒
☐
☐

MAKE: IHC
MODEL: TD20 B

YR: 72
LAST PM DATE: B5678

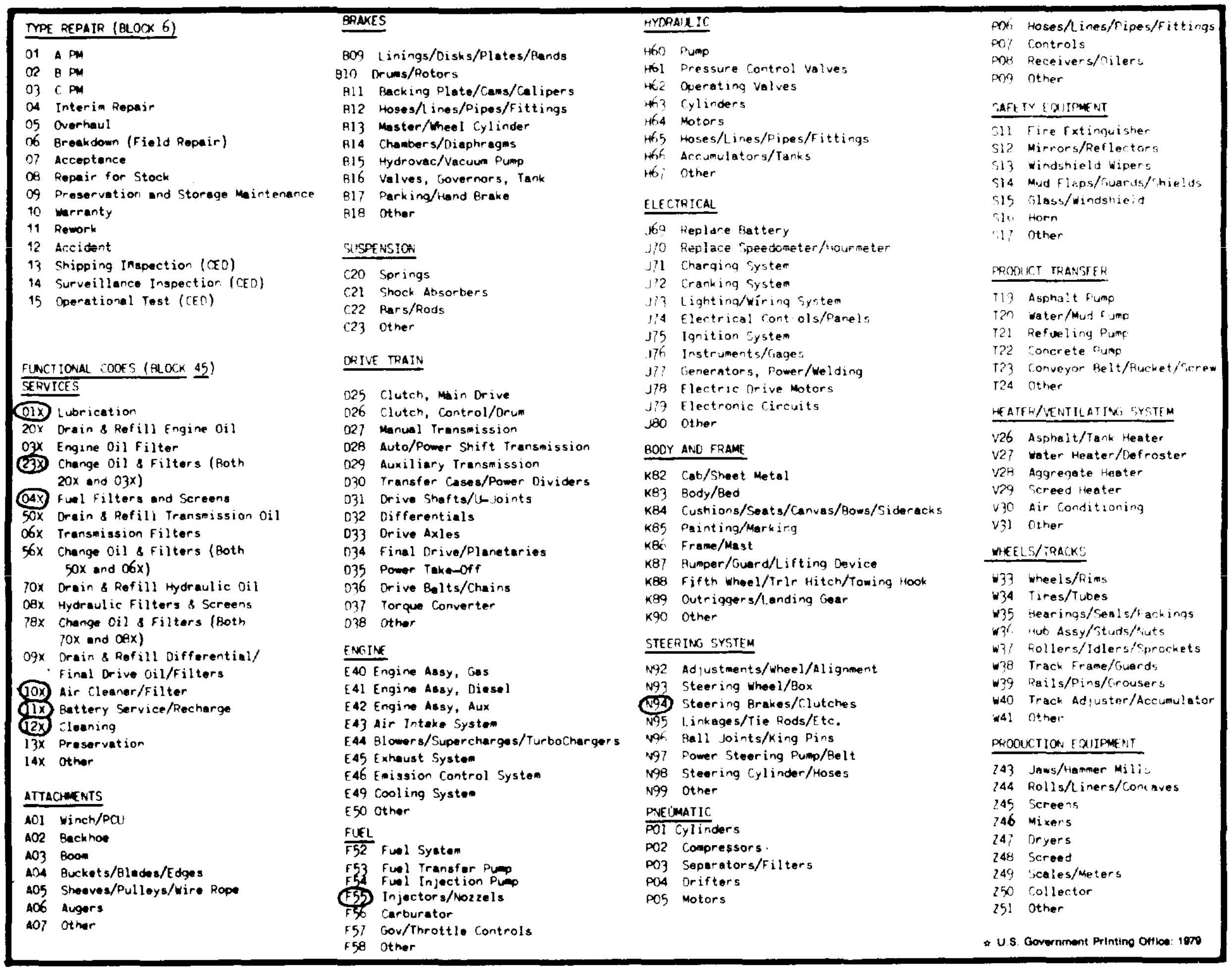
DESCRIPTION: TRACTOR CRAWLER

W/C	FUNCTION CODE	WORK DESCRIPTION MECHANIC NOTIFY SUPERVISOR OF ALL ADDITIONAL WORK	PRI/SEC	MANHOURS ACTUAL	MANHOURS ESTIMATE	ESTIMATED MAT'L COST	MECH INITIALS
	12 X	Steam Clean		4.0			
	23 X	Change Oil and Filters		1.0			
	01 X	Lube Complete		1.0			
	04 X	Change Fuel Filters		.5			
	11 X	Clean and Service Batteries		.6			
	10 X	Service Air Cleaners		.3			
		Replace Rain Cap			on order		
	F 5 5	Replace #6 Fuel Injector		1.8			
	N 9 4	Adjust R/H Steering Brake		3.0			
			SUB TOTALS	12.2			

RECEIPT OF ABOVE ORDER AND EQUIPMENT IS HEREBY ACKNOWLEDGED

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

Figure 2-1.—Equipment Repair Order (ERO), NAVFAC 11200/41.



TYPE REPAIR (BLOCK 6)

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

FUNCTIONAL CODES (BLOCK 45)
SERVICES

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

ATTACHMENTS

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

BRAKES

B09 Linings/Disks/Plates/Bands
B10 Drums/Rotors
B11 Backing Plate/Cams/Calipers
B12 Hoses/lines/Pipes/Fittings
B13 Master/Wheel Cylinder
B14 Chambers/Diaphragms
B15 Hydrovac/Vacuum Pump
B16 Valves, Governors, Tank
B17 Parking/Hand Brake
B18 Other

SUSPENSION

C20 Springs
C21 Shock Absorbers
C22 Bars/Rods
C23 Other

DRIVE TRAIN

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

ENGINE

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

FUEL

F52 Fuel System
F53 Fuel Transfer Pump
F54 Fuel Injection Pump
[✓ F55] Injectors/Nozzels
F56 Carburator
F57 Gov/Throttle Controls
F58 Other

HYDRAULIC

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

ELECTRICAL

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

BODY AND FRAME

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

STEERING SYSTEM

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

PNEUMATIC

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

SAFETY EQUIPMENT

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

PRODUCT TRANSFER

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

HEATER/VENTILATING SYSTEM

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

WHEELS/TRACKS

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

PRODUCTION EQUIPMENT

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

☆ U.S. Government Printing Office: 1979

Figure 2-2.—Equipment Repair Order (ERO), NAVFAC 11200/41 (back).

Direct Turnover Parts (DTO) Clerk

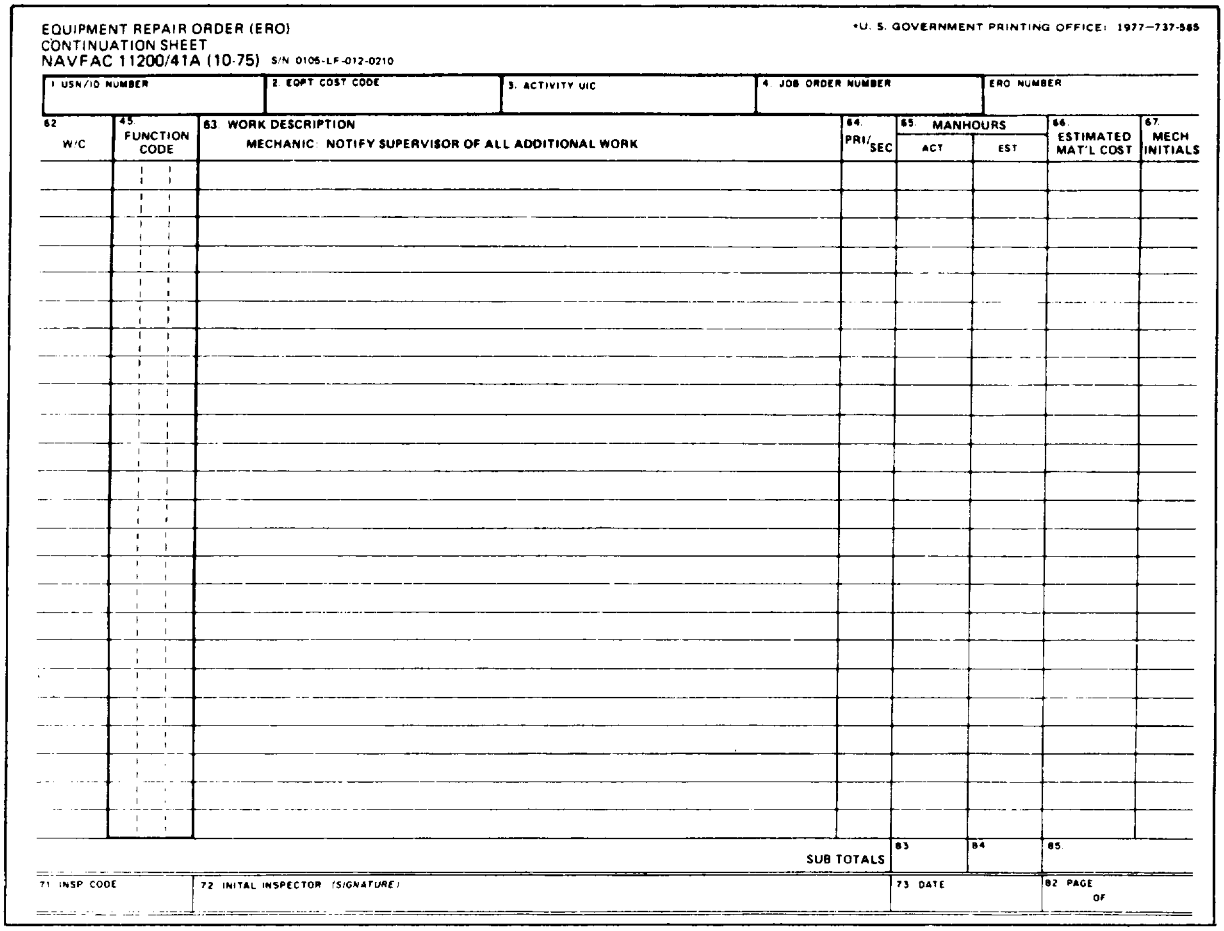
All requisitions for not in stock (NIS) and not carried (NC) material must pass through the DTO clerk. The individual assigned as DTO clerk will maintain the DTO Log (fig. 2-9), Repair Parts Summary Sheets (fig. 2-10), deadline file, and deadline status board. The DTO clerk is also responsible for receipt and turn-in of DTO repair parts and for maintaining the DTO parts storage room.

TECHNICAL LIBRARIAN

The technical librarian is responsible for all of the CESE maintenance, parts, and operators' manuals assigned to the NCF unit. The librarian works according to COMCBPAC/COMCBLANTINST 5600.1 series in establishing the inventory and enforcing check-out procedures, Replacement manuals for older CESE are normally expensive and hard to obtain. Without these publications, CESE cannot be properly maintained, repaired, or operated, and the unit is largely "dead in the water." The technical librarian maintains all required reference materials, such as microfiche, COSAL, and so forth, needed to research and initiate parts requisitions. The technical librarian normally researches and prepares parts requisitions to free the floor mechanic to perform maintenance functions.

BATTALION MAINTENANCE PROGRAM

The purpose of the battalion maintenance program is to keep CESE in a constant safe and



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

*U. S. GOVERNMENT PRINTING OFFICE: 1977—737-585

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

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

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

Figure 2-3.—Equipment Repair Order Continuation Sheet, NAVFAC 11200/41A.

serviceable condition at a minimum cost and to detect and correct minor deficiencies before they lead to costly repairs. The CESE Maintenance System of the NCF and special operating units (SOU) has three categories of maintenance: (1) organizational, (2) intermediate, and (3) depot.

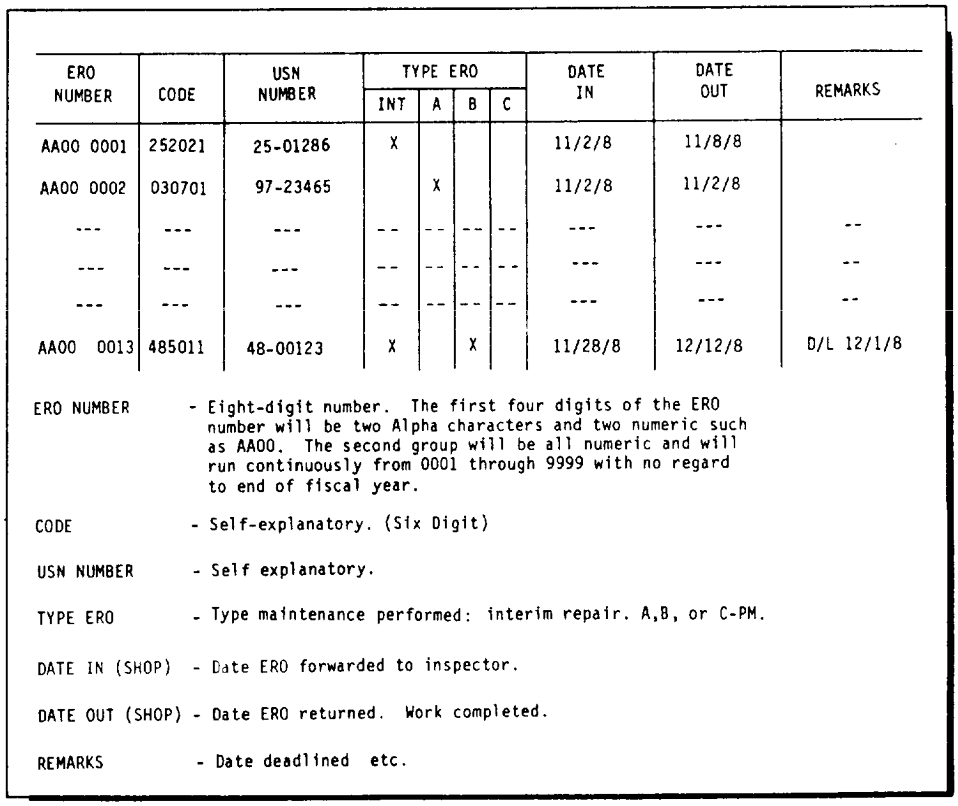
ORGANIZATIONAL MAINTENANCE

The first, or organizational, level of maintenance is divided into two categories: operator maintenance and preventive maintenance (PM). Operator maintenance, sometimes called first-echelon maintenance, is the maintenance that every operator is required to do to maintain CESE in a clean, safe, and serviceable condition. It includes daily inspections, lubrications, and adjustments necessary to ensure early detection of malfunctions of CESE. Figures 2-11 and 2-12 show preventive maintenance forms that the operator can use as guides for a daily prestart inspection and as a trouble report in case of any defect or unsafe condition that needs to be reported to the dispatcher immediately.

The second part of organizational maintenance is preventive maintenance, which goes beyond the inspections, lubrications, and adjustments of operator maintenance. Its prime objective is to maximize equipment availability and to minimize unnecessary repair costs. Whenever feasible, operators should participate in this type of maintenance.

INTERMEDIATE MAINTENANCE

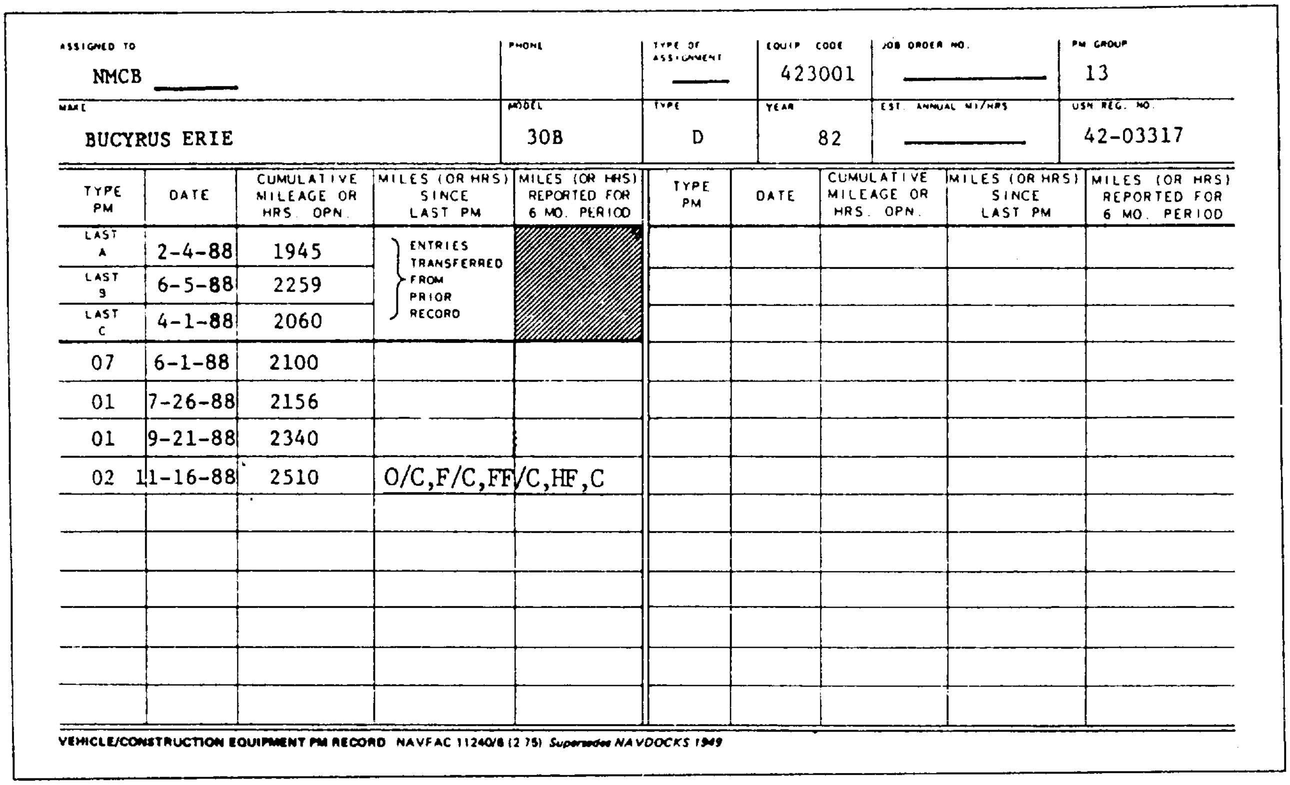
Intermediate maintenance, which every shop has the responsibility to perform, encompasses the removal, replacement, repair, alteration, calibration, modification, rebuilding, and overhaul of assemblies, subassemblies, and components. Although the rebuild and overhaul of major assemblies are included, only essential



ERO NUMBER	CODE	USN NUMBER	TYPE ERO				DATE IN	DATE OUT	REMARKS
			INT	A	B	C			
AA00 0001	252021	25-01286	X				11/2/8	11/8/8	
AA00 0002	030701	97-23465		X			11/2/8	11/2/8	
---	---	---	--	--	--	--	---	---	--
---	---	---	--	--	--	--	---	---	--
---	---	---	--	--	--	--	---	---	--
AA00 0013	485011	48-00123	X		X		11/28/8	12/12/8	D/L 12/1/8

ERO NUMBER	- Eight-digit number. The first four digits of the ERO number will be two Alpha characters and two numeric such as AA00. The second group will be all numeric and will run continuously from 0001 through 9999 with no regard to end of fiscal year.
CODE	- Self-explanatory. (Six Digit)
USN NUMBER	- Self explanatory.
TYPE ERO	- Type maintenance performed: interim repair. A,B, or C-PM.
DATE IN (SHOP)	- Date ERO forwarded to inspector.
DATE OUT (SHOP)	- Date ERO returned. Work completed.
REMARKS	- Date deadlined etc.

Figure 2-4.—Equipment Repair Order Log Sheet.

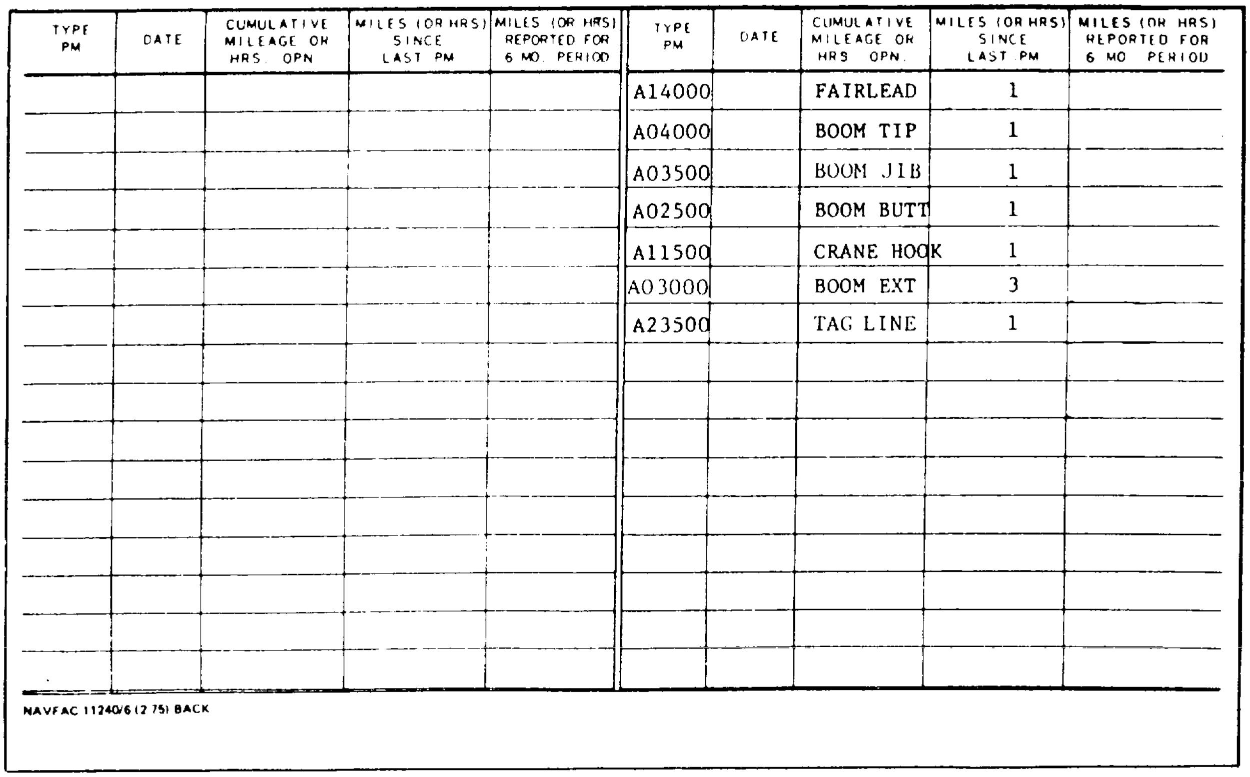


ASSIGNED TO NMCB ______	PHONE	TYPE OF ASSIGNMENT ______	EQUIP. CODE 423001	JOB ORDER NO. ______	PM GROUP 13
MAKE BUCYRUS ERIE	MODEL 30B	TYPE D	YEAR 82	EST. ANNUAL MI/HRS ______	USN REG. NO. 42-03317

TYPE PM	DATE	CUMULATIVE MILEAGE OR HRS. OPN.	MILES (OR HRS) SINCE LAST PM	MILES (OR HRS) REPORTED FOR 6 MO. PERIOD	TYPE PM	DATE	CUMULATIVE MILEAGE OR HRS. OPN.	MILES (OR HRS) SINCE LAST PM	MILES (OR HRS) REPORTED FOR 6 MO. PERIOD
LAST A	2-4-88	1945	} ENTRIES TRANSFERRED FROM PRIOR RECORD	▨					
LAST B	6-5-88	2259		▨					
LAST C	4-1-88	2060		▨					
07	6-1-88	2100							
01	7-26-88	2156							
01	9-21-88	2340							
02	11-16-88	2510	O/C,F/C,FF/C,HF,C						

VEHICLE/CONSTRUCTION EQUIPMENT PM RECORD NAVFAC 11240/6 (2 75) *Supersedes NAVDOCKS 1949*

Figure 2-5.—PM Record Card, NAVFAC 11240/6.



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

NAVFAC 11240/6 (2 75) BACK

Figure 2-6.—PM Record Card, NAVFAC 11240 /6 (back).

repairs shall be accomplished to ensure safe and serviceable equipment. Intermediate maintenance requires a higher degree of skill than organizational maintenance, a larger assortment of repair parts, more precision tools, and more complex testing equipment. Prior approval is required by COMCBPAC, COMCBLANT, or CESO before purchasing expensive parts or components for any CESE requiring extensive repairs or numerous assembly rebuilds. For further guidance see COMCBPAC/COMCBLANTINST 11200.1 series, section 2, paragraph 3201.

DEPOT MAINTENANCE

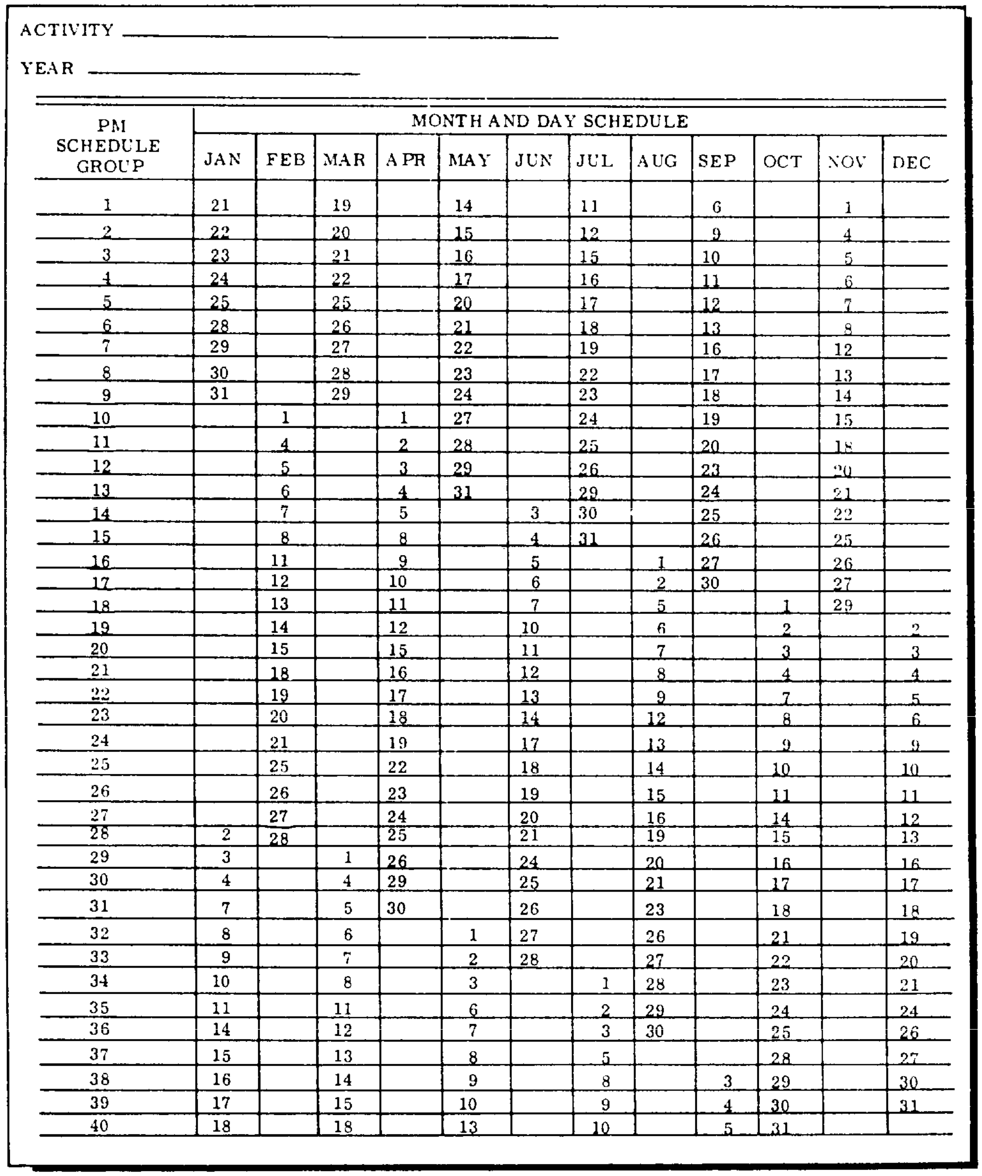
The third level of maintenance is depot maintenance. This is performed on equipment that requires major overhaul or restoration to the degree necessary to restore the unit to a like-new condition. This level of maintenance is not normally performed by field units, NMCBs, ACBs, and the like. Depot maintenance is performed by designated overhaul facilities, such as construction equipment departments located at CBC Port Hueneme, California, CBC Gulfport, Mississippi, and CBC Davisville, Rhode Island.

SCHEDULING MAINTENANCE

The standard interval between preventive maintenance service inspections for NCF CESE is 40 working days. This interval is established initially by grouping all assigned CESE into 40 separate PM groups. The CESE is distributed evenly among the PM groups so that only the minimum number of similar units is out of service at any one time.

It is the responsibility of the maintenance supervisor to determine whether the PM interval for any unit of CESE should be reduced. To maintain reliability, increased working tempo demands increased preventive maintenance. The maintenance supervisor may decrease the interval by assigning specific CESE to more than one PM group or reducing the total number of PM groups. The maintenance supervisor is not authorized to extend the standard interval between PM service inspections beyond 40 working days.

To establish a deployment schedule of PM due dates, the maintenance supervisor records the working days of the month consecutively beside the PM group numbers. See the sample schedule, figure 2-7.



ACTIVITY ______________________

YEAR ______________

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

Figure 2-7.—PM Schedule.

A PM Record Card (fig. 2-5) is maintained for each item of assigned CESE to help the PM clerk prepare the ERO. The following information is taken from the completed ERO and entered on a PM Record Card:

Type of service performed

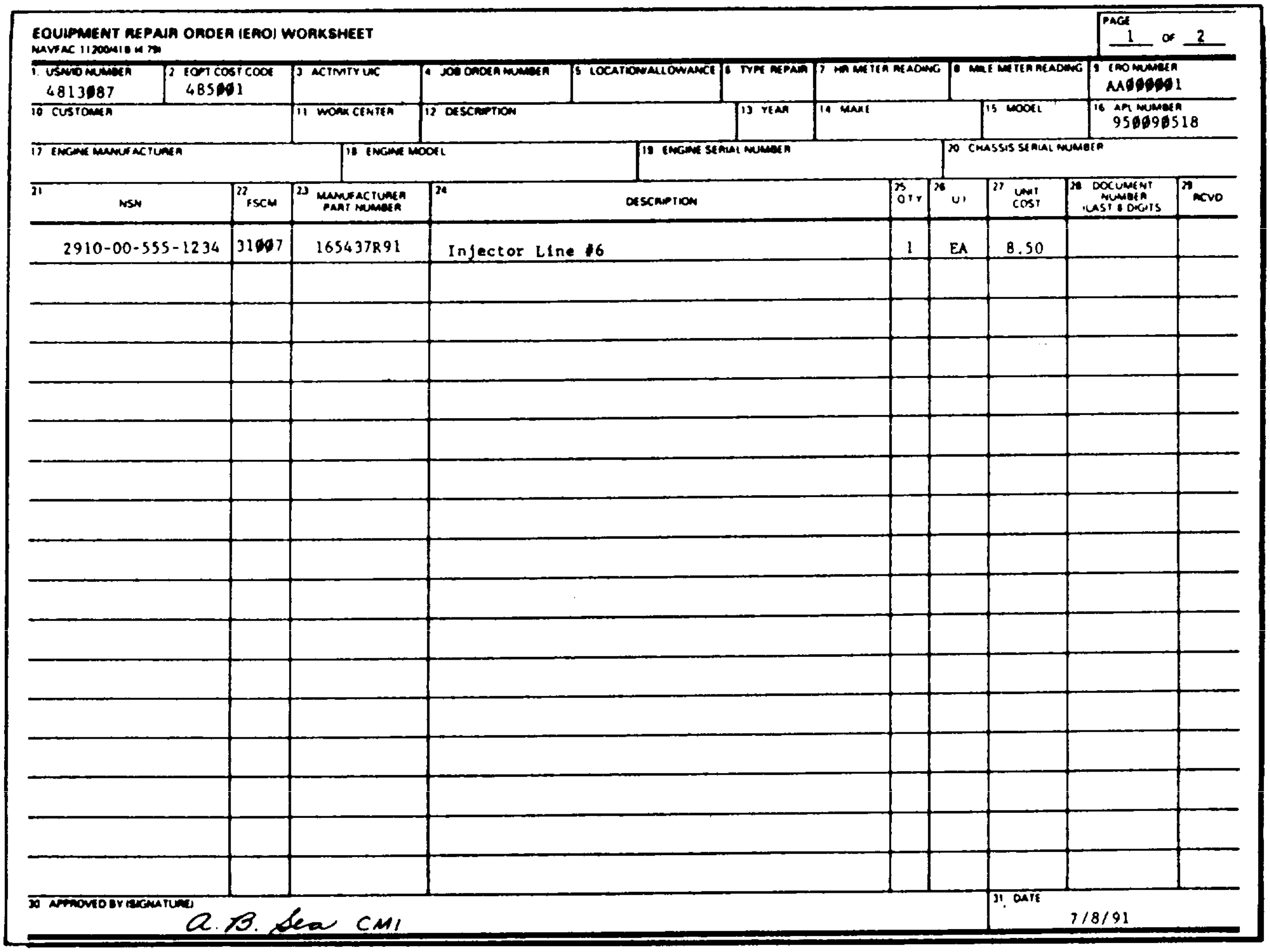
Date performed

Cumulative mileage/hours

Whether oil or filter was changed (shown by the abbreviation O/C or F/C)

PM record cards are maintained by the PM group in a tickler file, which the maintenance supervisor reviews at least once a month. When a vehicle is transferred, the PM Record Cards that pertain to that vehicle are placed in the history jacket.

The reverse side of the PM Record Card (fig. 2-6) is convenient for listing attachments for each USN. This will aid the inspector in locating the proper attachments for PM.



EQUIPMENT REPAIR ORDER (ERO) WORKSHEET
NAVFAC 11200/41B (4 79)

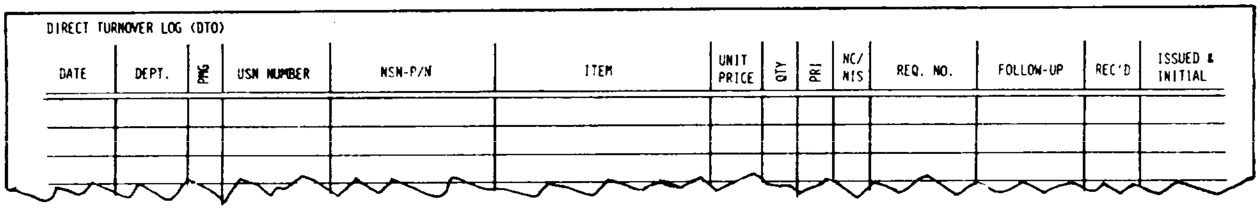
PAGE 1 OF 2

1. USN/ID NUMBER 4813087
2. EQPT COST CODE 485001
3. ACTIVITY UIC
4. JOB ORDER NUMBER
5. LOCATION/ALLOWANCE
6. TYPE REPAIR
7. HR METER READING
8. MILE METER READING
9. ERO NUMBER AA000001
10. CUSTOMER
11. WORK CENTER
12. DESCRIPTION
13. YEAR
14. MAKE
15. MODEL
16. APL NUMBER 950090518
17. ENGINE MANUFACTURER
18. ENGINE MODEL
19. ENGINE SERIAL NUMBER
20. CHASSIS SERIAL NUMBER

21 NSN	22 FSCM	23 MANUFACTURER PART NUMBER	24 DESCRIPTION	25 QTY	26 UI	27 UNIT COST	28 DOCUMENT NUMBER (LAST 8 DIGITS)	29 RCVD
2910-00-555-1234	31007	165437R91	Injector Line #6	1	EA	8.50		

30. APPROVED BY (SIGNATURE) A. B. Sea CM1
31. DATE 7/8/91

Figure 2-8.-Equipment Repair Oder Worksheet. NAVFAC 11200/41B.



DIRECT TURNOVER LOG (DTO)

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

Figure 2-9.—Direct Turnover (DTO) Log.

The types of PM inspection are defined and given as follows:

Type A Inspections

This type of inspection is given at intervals of 40 working days, using the appropriate PM service and inspection guide. They are performed on scheduled PM due dates. After having received two Type A PMs, the vehicle qualifies for a Type B inspection.

Type B Inspections

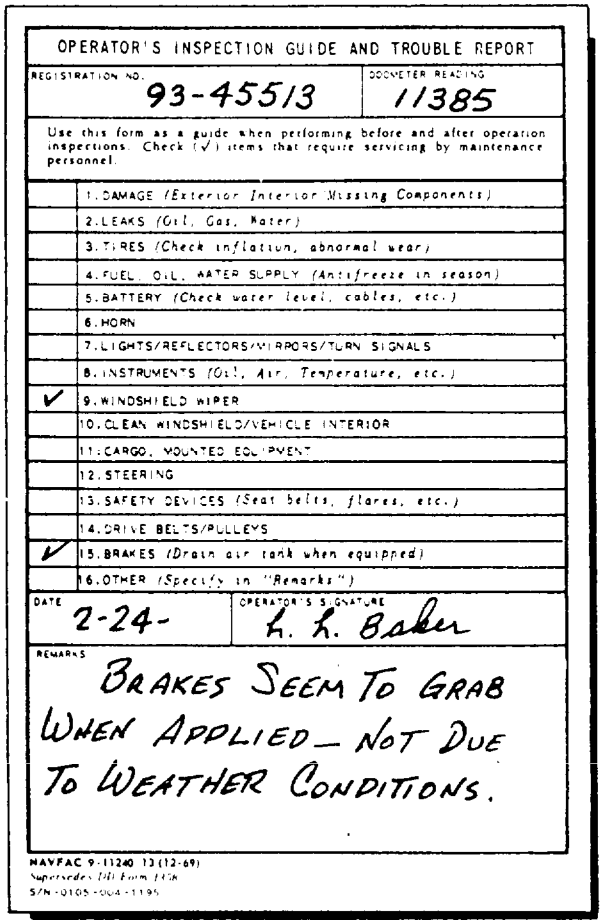
The Type B PM inspection is performed after two consecutive Type A inspections, using the appropriate PM service and inspection guide.

REPAIR PARTS SUMMARY SHEET

PM Group 23
Code 485001 USN 48-00123

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

Figure 2-10.—Repair Parts Summary Sheet Sample



OPERATOR'S INSPECTION GUIDE AND TROUBLE REPORT

REGISTRATION NO. 93-45513

ODOMETER READING 11385

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

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

DATE 2-24-

OPERATOR'S SIGNATURE L. L. Baker

REMARKS
BRAKES SEEM TO GRAB WHEN APPLIED— NOT DUE TO WEATHER CONDITIONS.

NAVFAC 9-11240 13 (12-69)
Supersedes [illegible]
S/N-0105-004-1195

Figure 2-11.—Operator's Inspection Guide and Trouble Report, NAVFAC 9-11240/13.

Type C Inspections

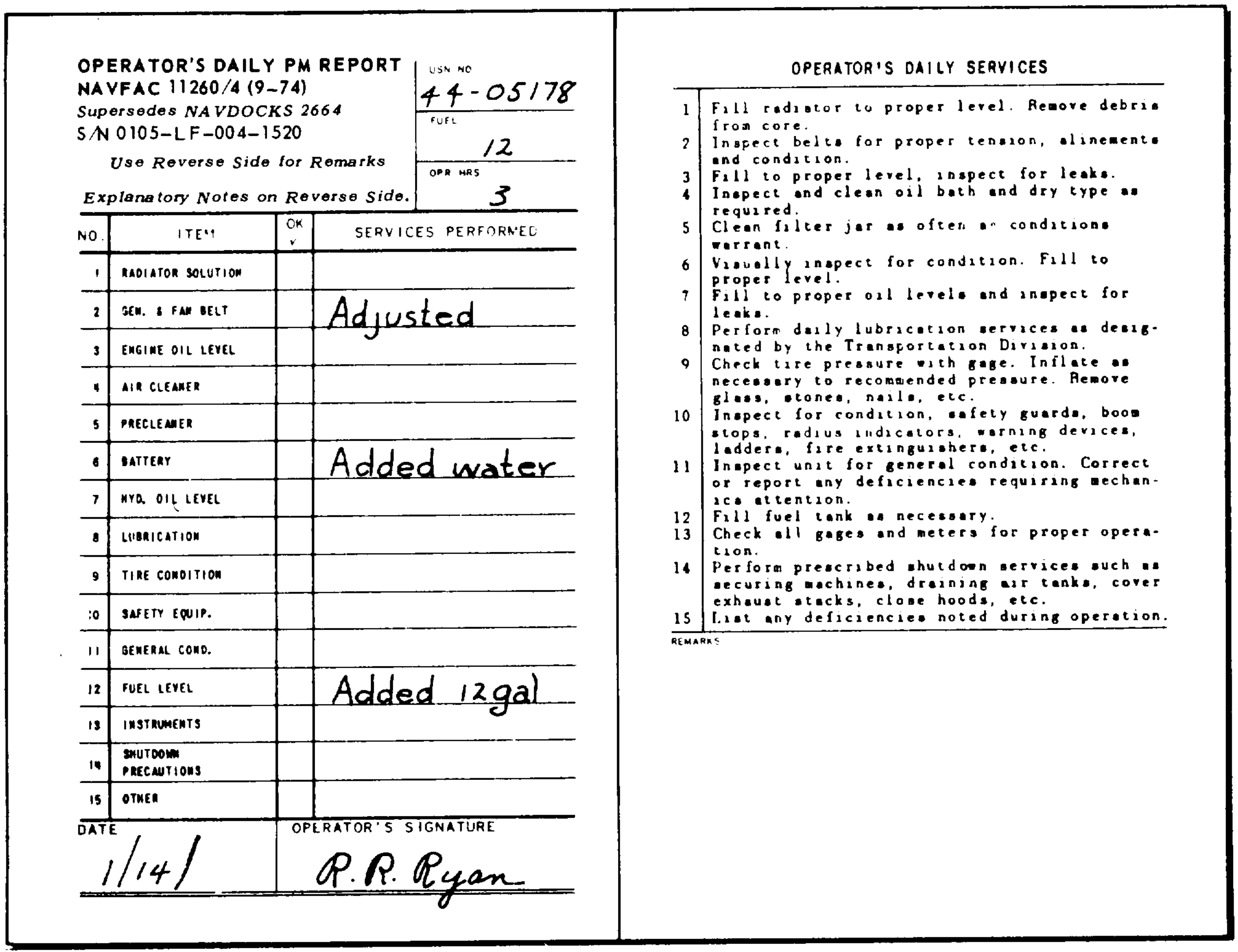
Consult COMCBPAC/COMCBLANTINST 11200.1 series for guidance regarding frequency of Type C PM scheduling.

NOTE

> Cost and availability of repair parts, as well as resources and working conditions, must be considered along with CESE commitments and conditions.

EQUIPMENT REPAIR ORDER AND CONTINUATION SHEET

The Equipment Repair Order (ERO) (figs. 2-1 and 2-2) and the continuation sheet (fig. 2-3) are used in the NCF to record costs of repairs, hours required for repairs, and total time that equipment is out of service. The data will help the NCF in budget planning, determining life expectancies of equipment, and predicting future equipment and training requirements. The Naval Facilities Engineering Command Systems Office (FACSO), Port Hueneme, California, also uses the data to compile cost and utilization figures on each piece of USN-numbered equipment. Therefore, the data must be complete, accurate, and neatly recorded according to NAVFAC P-404 and COMCBPAC/COMCBLANTINST 11200 series.



OPERATOR'S DAILY PM REPORT
NAVFAC 11260/4 (9–74)
Supersedes NAVDOCKS 2664
S/N 0105–LF–004–1520
Use Reverse Side for Remarks
Explanatory Notes on Reverse Side.

USN NO 44-05178
FUEL 12
OPR HRS 3

NO.	ITEM	OK ✓	SERVICES PERFORMED
1	RADIATOR SOLUTION		
2	GEN. & FAN BELT		Adjusted
3	ENGINE OIL LEVEL		
4	AIR CLEANER		
5	PRECLEANER		
6	BATTERY		Added water
7	HYD. OIL LEVEL		
8	LUBRICATION		
9	TIRE CONDITION		
10	SAFETY EQUIP.		
11	GENERAL COND.		
12	FUEL LEVEL		Added 12gal
13	INSTRUMENTS		
14	SHUTDOWN PRECAUTIONS		
15	OTHER		

DATE 1/14/
OPERATOR'S SIGNATURE R.R. Ryan

FRONT

OPERATOR'S DAILY SERVICES

1 Fill radiator to proper level. Remove debris from core.
2 Inspect belts for proper tension, alinements and condition.
3 Fill to proper level, inspect for leaks.
4 Inspect and clean oil bath and dry type as required.
5 Clean filter jar as often as conditions warrant.
6 Visually inspect for condition. Fill to proper level.
7 Fill to proper oil levels and inspect for leaks.
8 Perform daily lubrication services as designated by the Transportation Division.
9 Check tire pressure with gage. Inflate as necessary to recommended pressure. Remove glass, stones, nails, etc.
10 Inspect for condition, safety guards, boom stops, radius indicators, warning devices, ladders, fire extinguishers, etc.
11 Inspect unit for general condition. Correct or report any deficiencies requiring mechanica attention.
12 Fill fuel tank as necessary.
13 Check all gages and meters for proper operation.
14 Perform prescribed shutdown services such as securing machines, draining air tanks, cover exhaust stacks, close hoods, etc.
15 List any deficiencies noted during operation.

REMARKS

BACK

Figure 2-12.—Operator's Daily PM Report, Construction and Allied Equipment, NAVFAC 11260/4.

The Equipment Repair Order Worksheet (fig. 2-8) is used solely to list repair parts used. It is used by the mechanic and shop supervisor to ensure that all supply documents are attached to the ERO. The cost control supervisor and the maintenance supervisor use this form to record the cost of repair parts properly.

The ERO is the sole authority to perform work on equipment, whether the work is performed in the field or in the shop. An ERO is required each time labor time exceeds 1.0 hour or materials are expended on scheduled PM, interim repairs, modernization or alteration of equipment, or deadline cycling or preservation of equipment. The ERO Log Sheet (fig. 2-4) is one means for keeping track of the status of the EROS.

REPAIR PARTS

Any NCF unit has a wide variety of CESE assigned to it. Large quantities of repair parts are required to keep CESE in top operating condition. Because of this, a Construction Mechanic is assigned to supply to work in the repair parts outlet to identify repair parts, to provide counter help, and to act as a warehouseman. He or she also acts as an interface between supply and the maintenance supervisor. The Construction Mechanic assigned to this position is required to attend Shops Stores Procedure Class, given by NCTC Port Hueneme, California, to learn the full scope of his or her responsibilities. (See COMCBPAC/COMCBLANTINST 4400.3 series for the NCTC SSPC course number.)

COSAL SUPPORT

NAVFAC-funded initial outfitting repair parts allowances required by the NCF for support of its assigned equipment are listed in Consolidated SEABEE Allowance Lists (COSALs). The COSAL establishes the support for assigned organic and augment equipment based on USN-numbered listings. COSALs are published under the authority contained in the NAVFAC/NAVSUP program support agreement by Naval Ships Parts Control Center (SPCC), Mechanicsburg, Pennsylvania. COSALs are both technical and supply documents. They are technical documents in that equipment nomenclature, operating characteristics, technical manuals, and so on, are described in Allowance Parts Lists. They are supply documents in that they list all parts by manufacturer's code and part number, national stock number, unit of issue, and price and quantity authorized by NAVFAC maintenance policy. Repair parts allowances are designed to provide a 90 percent effectiveness for 1,800 construction hours or 90 days support. This 90-day period is defined as a 3-month utilization period for vehicles or equipment in new or like-new condition. Selection of parts included in the COSAL is made after identification; usage and insurance items are coded by maintenance capability according to NAVFAC Lead Allowance Parts Lists. Maintenance codes are used to control the allowed item range for each of the various organizational maintenance capabilities. The definition and application of maintenance codes are contained in appendix C of the COSAL introduction. There are two basic categories of repair parts: parts peculiar—NAVSUP modifier code 98 and parts common—NAVSUP modifier code 97. These are published in two separate COSALs. Parts peculiar are applicable only to specific makes or models of equipment. Parts common are the general repair type of items, (appendix G of the COSAL introduction) and are not referenced to any specific equipment. Military and commercial operators, manuals, parts manuals, and maintenance manuals are listed in the parts peculiar COSAL. A descriptive account showing the method of entry and how to use the COSAL is contained in appendix F of the COSAL instruction.

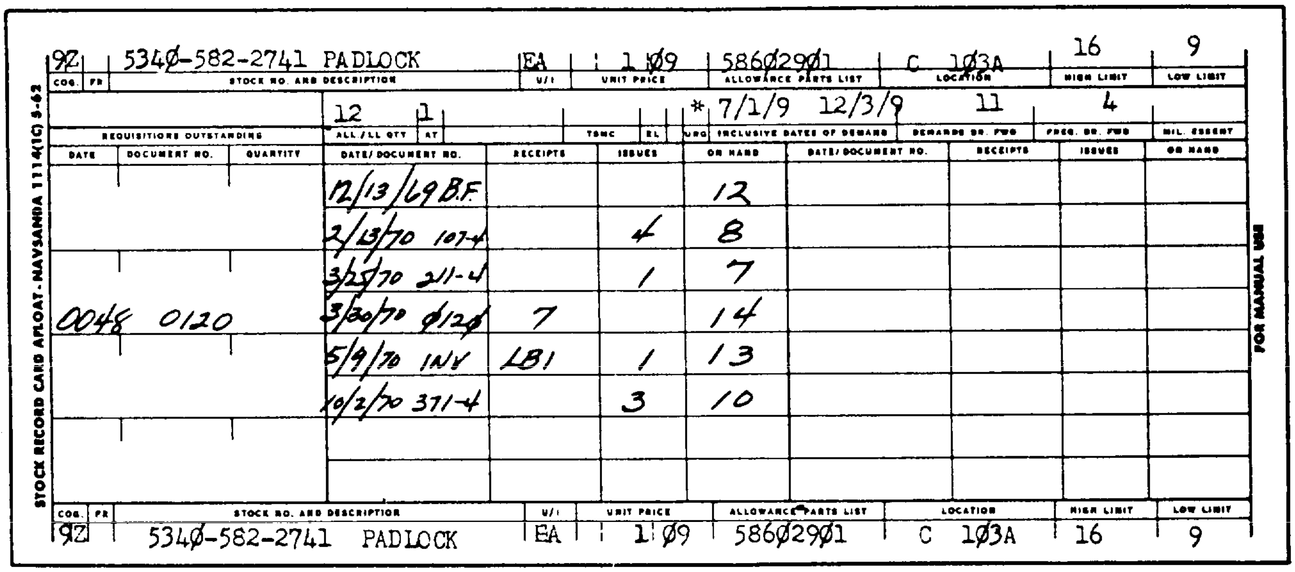
A third category of repair parts has been added to the battalion's allowance. The NAVSUP modifier 96 is a minimodifier 97 for use with the air detachment or an extended detachment.

SUPPLY AIDS

The following supply aids have been developed and are distributed with each COSAL to assist personnel in the repair parts program:

NAVSUP Form 1114 (fig. 2-13)—Stock Record Card Afloat.

Add Item Listing—Repair parts provided by a Naval Construction Battalion Center (NCBC) to support new equipment not previously supported.



STOCK RECORD CARD AFLOAT - NAVSANDA 1114(1C) 5-62

COG.	FR	STOCK NO. AND DESCRIPTION	U/I	UNIT PRICE	ALLOWANCE PARTS LIST	LOCATION	HIGH LIMIT	LOW LIMIT
92		5340-582-2741 PADLOCK	EA	1 09	58602901	C 103A	16	9

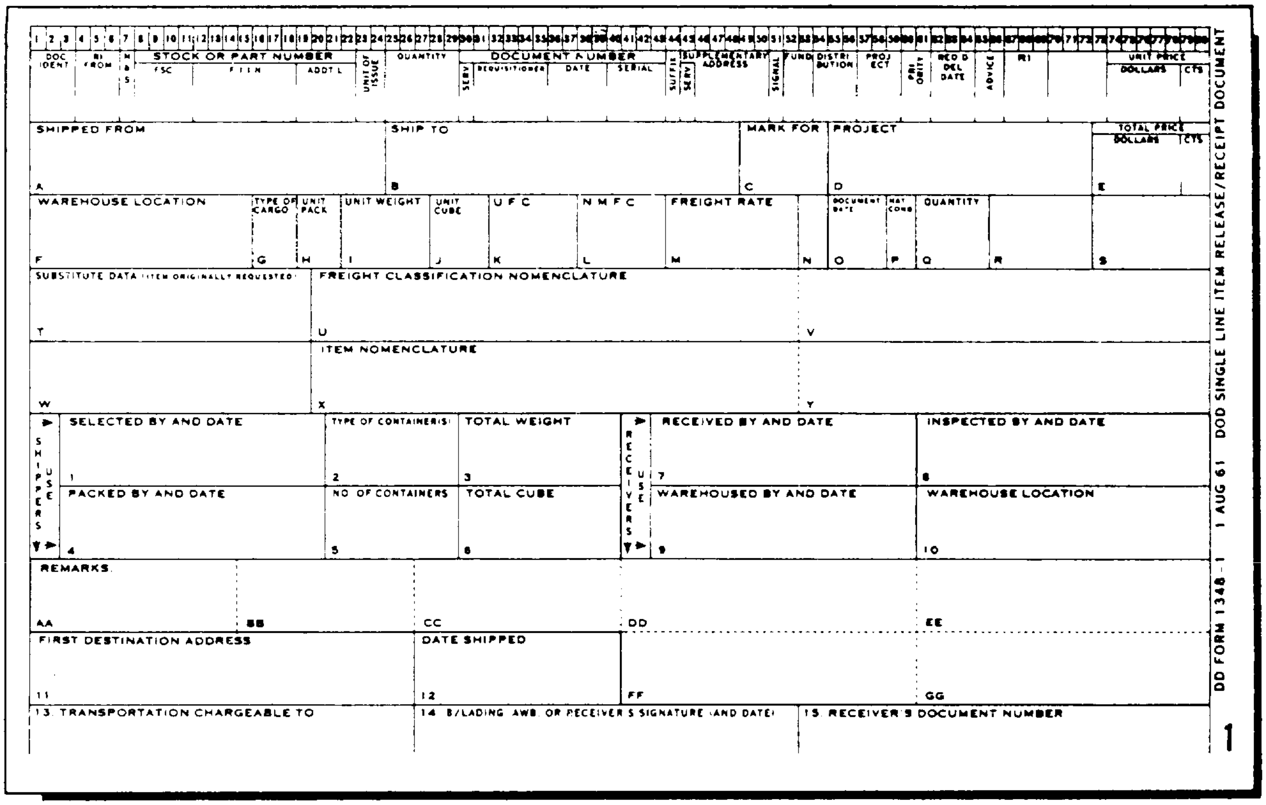
REQUISITIONS OUTSTANDING	ALL./LL QTY	AT		TSMC	EL	URC	INCLUSIVE DATES OF DEMAND	DEMANDS PR. FWD	FREQ. PR. FWD	MIL. ESSENT
	12	1				*	7/1/9 12/3/9	11	4	

DATE	DOCUMENT NO.	QUANTITY	DATE/DOCUMENT NO.	RECEIPTS	ISSUES	ON HAND	DATE/DOCUMENT NO.	RECEIPTS	ISSUES	ON HAND
			12/13/69 B.F.			12				
			2/13/70 107-4		4	8				
			3/25/70 211-4		1	7				
0048	0120		3/20/70 0120	7		14				
			5/9/70 INV	LB1	1	13				
			10/2/70 371-4		3	10				

COG.	FR	STOCK NO. AND DESCRIPTION	U/I	UNIT PRICE	ALLOWANCE PARTS LIST	LOCATION	HIGH LIMIT	LOW LIMIT
92		5340-582-2741 PADLOCK	EA	1 09	58602901	C 103A	16	9

FOR MANUAL USE

Figure 2-13.—Stock Record Card Afloat, NAVSUP Form 1114.



1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

DOC IDENT | RI FROM | M & S | STOCK OR PART NUMBER: FSC, FIIN, ADDT'L | UNIT OF ISSUE | QUANTITY | DOCUMENT NUMBER: SERV, REQUISITIONER, DATE, SERIAL | SUFFIX | SERV | SUPPLEMENTARY ADDRESS | SIGNAL | FUND | DISTRIBUTION | PROJECT | PRIORITY | REQ'D DEL DATE | ADVICE | RI | UNIT PRICE: DOLLARS, CTS

SHIPPED FROM A | SHIP TO B | MARK FOR C | PROJECT D | TOTAL PRICE: DOLLARS, CTS E

WAREHOUSE LOCATION F | TYPE OF CARGO G | UNIT PACK H | UNIT WEIGHT I | UNIT CUBE J | U F C K | N M F C L | FREIGHT RATE M | N | DOCUMENT DATE O | NAT COND P | QUANTITY Q | R | S

SUBSTITUTE DATA (ITEM ORIGINALLY REQUESTED) T | FREIGHT CLASSIFICATION NOMENCLATURE U | V

W | ITEM NOMENCLATURE X | Y

SHIPPERS USE: SELECTED BY AND DATE 1 | TYPE OF CONTAINER(S) 2 | TOTAL WEIGHT 3

PACKED BY AND DATE 4 | NO OF CONTAINERS 5 | TOTAL CUBE 6

RECEIVERS USE: RECEIVED BY AND DATE 7 | INSPECTED BY AND DATE 8

WAREHOUSED BY AND DATE 9 | WAREHOUSE LOCATION 10

REMARKS AA | BB | CC | DD | EE

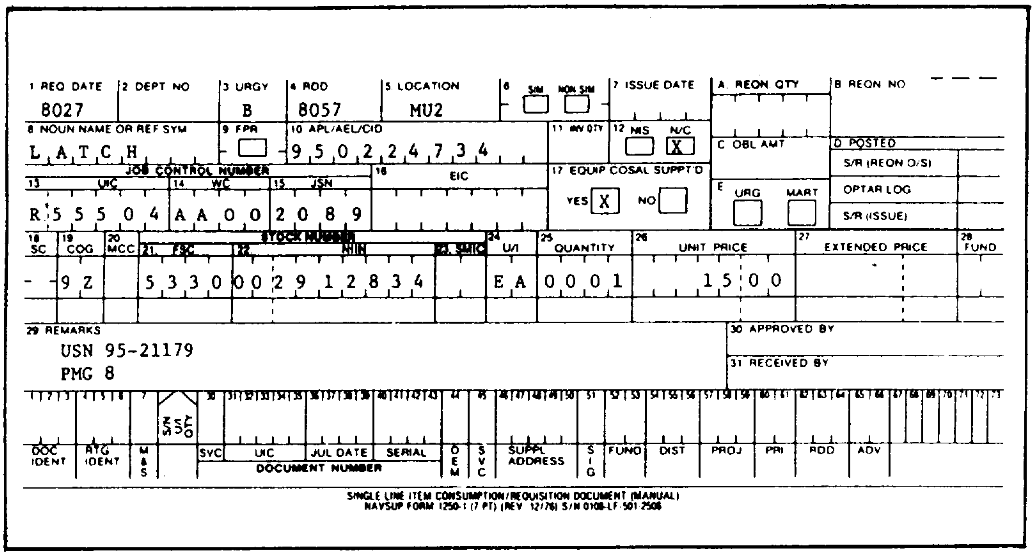
FIRST DESTINATION ADDRESS 11 | DATE SHIPPED 12 | FF | GG

13 TRANSPORTATION CHARGEABLE TO | 14 B/LADING AWB OR RECEIVER'S SIGNATURE (AND DATE) | 15 RECEIVER'S DOCUMENT NUMBER

DD FORM 1348-1 1 AUG 61 DOD SINGLE LINE ITEM RELEASE/RECEIPT DOCUMENT

1

Figure 2-14.—Single-Line Item Release/Receipt Document, DD Form 1348-1.



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

8 NOUN NAME OR REF SYM: LATCH | 9 FPR ☐ | 10 APL/AEL/CID: 950224734 | 11 INV QTY | 12 MIS ☐ N/C ☒ | C OBL AMT | D POSTED

JOB CONTROL NUMBER: 13 UIC: R 5 5 5 0 4 | 14 WC: A A 0 0 | 15 JSN: 2 0 8 9 | 16 EIC | 17 EQUIP COSAL SUPPT'D YES ☒ NO ☐ | E URG ☐ MART ☐ | S/R (REQN O/S) | OPTAR LOG | S/R (ISSUE)

18 SC: - | 19 COG: 9 Z | 20 MCC | STOCK NUMBER: 21. FSC: 5 3 3 0 | 22. NIIN: 0 0 2 9 1 2 8 3 4 | 23. SMIC | 24 U/I: E A | 25 QUANTITY: 0 0 0 1 | 26 UNIT PRICE: 15.00 | 27 EXTENDED PRICE | 28 FUND

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

1 2 3 4 5 6 7 | SIM UOI QTY | 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73

DOC IDENT | RTG IDENT | M & S | SVC | UIC | JUL DATE | SERIAL (DOCUMENT NUMBER) | DEM | SVC | SUPPL ADDRESS | SIG | FUND | DIST | PROJ | PRI | RDD | ADV

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

Figure 2-15.—Single-Line Item Consumption/Management Document (Manual), NAVSUP Form 1250-1.

Delete Item Listing—Repair parts provided by a previous COSAL that are no longer required.

DD Form 1348-1 (fig. 2-14)—Single-Line Item Release/Receipt Document.

Transfer Item Listing—A list showing previous COSAL items that must be transferred to other locations because of equipment transfer.

Summary Item List—A composite list of all items required by the old COSAL.

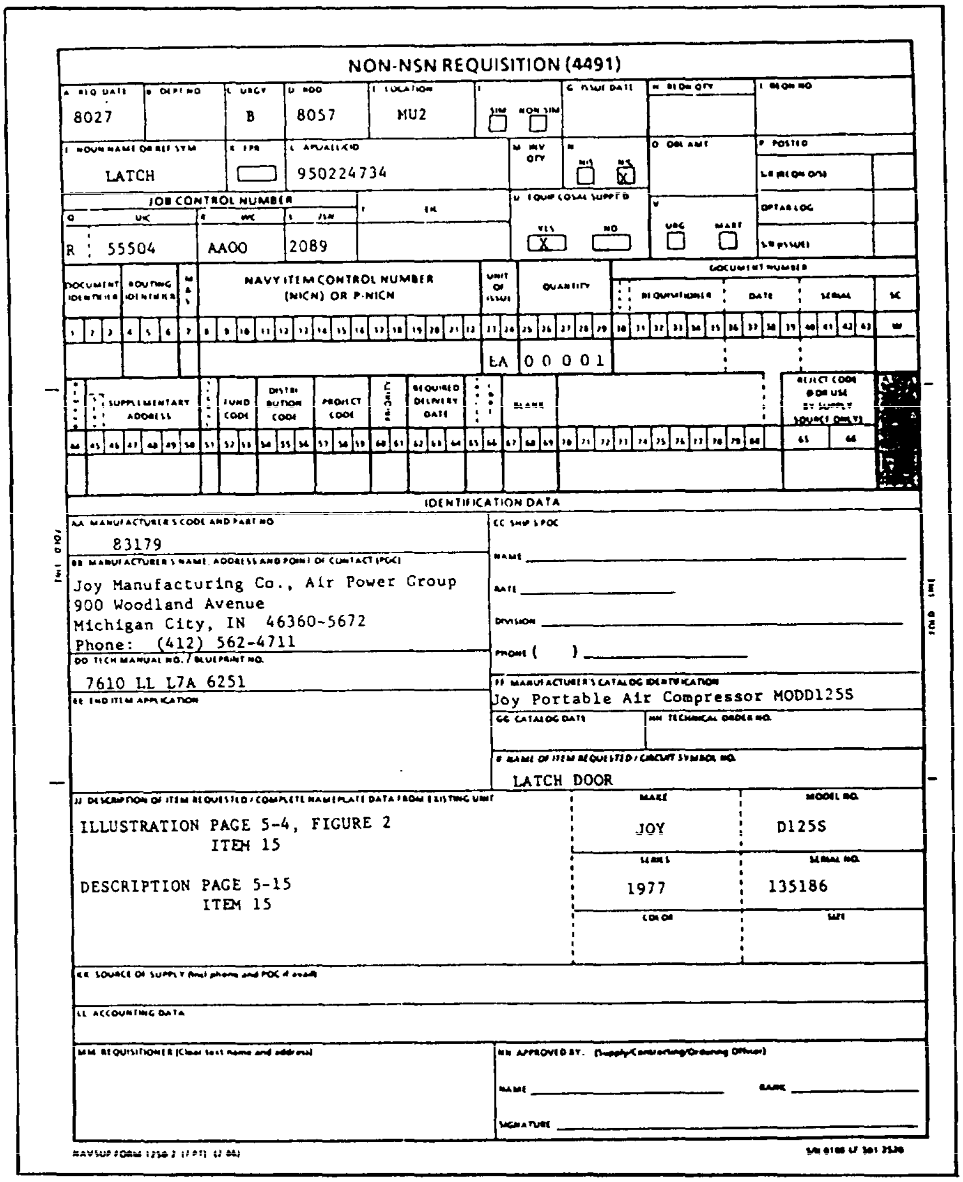
Stock Number Changes—Two listings: old-to-new national stock number (NSN) and new-to-old (NSN) which show changes in the stock number listed in the old COSAL and updated by the new COSAL.

TECHNICAL LIBRARY

An effective CESE management program needs technical data and guides for each item of CESE. Within the NCF, operator manuals, lubrication charts, parts manuals, and shop repair manuals are included in each parts peculiar COSAL. Civil Engineer Support Office (CESO) administers the technical manual support program. Inadequate or deficient TMs are reported to CESO.

REQUESTING REPAIR PARTS

NAVSUP Forms 1250-1 (fig. 2-15) and 1250-2 (fig. 2-16) are used as authorization for drawing



NON-NSN REQUISITION (4491)

8027

B

8057

MU2

SIM ☐ NON SIM ☐

LATCH

950224734

☐ ☒

JOB CONTROL NUMBER

R 55504

AA00

2089

YES ☒ NO ☐

NAVY ITEM CONTROL NUMBER (NICN) OR P-NICN

UNIT OF ISSUE: EA

QUANTITY: 00001

DOCUMENT NUMBER

SUPPLEMENTARY ADDRESS

FUND CODE

DISTRIBUTION CODE

PROJECT CODE

REQUIRED DELIVERY DATE

BLANK

IDENTIFICATION DATA

AA MANUFACTURER'S CODE AND PART NO

83179

BB MANUFACTURER'S NAME, ADDRESS AND POINT OF CONTACT (POC)

Joy Manufacturing Co., Air Power Group
900 Woodland Avenue
Michigan City, IN 46360-5672
Phone: (412) 562-4711

CC SHIP'S POC

NAME

DATE

DIVISION

PHONE ( )

DD TECH MANUAL NO./BLUEPRINT NO.

7610 LL L7A 6251

EE END ITEM APPLICATION

FF MANUFACTURER'S CATALOG IDENTIFICATION

Joy Portable Air Compressor MODD125S

GG CATALOG DATE

HH TECHNICAL ORDER NO.

II NAME OF ITEM REQUESTED/CIRCUIT SYMBOL NO.

LATCH DOOR

JJ DESCRIPTION OF ITEM REQUESTED/COMPLETE NAMEPLATE DATA FROM EXISTING UNIT

ILLUSTRATION PAGE 5-4, FIGURE 2
ITEM 15

DESCRIPTION PAGE 5-15
ITEM 15

MAKE: JOY

MODEL NO.: D125S

SERIES: 1977

SERIAL NO.: 135186

COLOR

SIZE

LL ACCOUNTING DATA

NAME

SIGNATURE

Figure 2-16.—NAVSUP Form 1250-2.

or ordering repair parts. The appropriate shop supervisor is responsible for ensuring that they are prepared according to COMCBPAC/COMCBLANTINST 4400.3 series.

Repair Parts Available from Stock

After the shop supervisor or higher authority authenticates the request, the cost control clerk submits the form to the repair parts storeroom with the ERO, After receiving the required part, the receiver signs NAVSUP Form 1250-1 (fig. 2-1 5) in data block 31. The repair parts person then enters the NSN quantity and price on the ERO worksheet and verifies the issue by initials.

Repair Parts Not in Stock (NIS), Not Carried (NC), or Procured from Salvage or Local Manufacture

If the repair part requested is NIS or NC, the storeroom storekeeper marks an "X" in the appropriate box in data block 12 and verifies data entries.

The request for an NIS/NC repair part will be attached to the ERO and returned to the cost control office for review by the maintenance supervisor and assignment of the urgency-of-need designator. The ERO, with NAVSUP Form 1250-1 or 1250-2 attached, is then passed to the cost control clerk, who records the information in the DTO log and DTO Summary Sheet. The cost control clerk pulls the yellow copy of the ERO and files it with the DTO Parts Summary Sheet. Nonoperational ready supply (NORS)/anticipated nonoperational ready supply (ANORS) entries in the DTO log are annotated in red ink.

Requests for repair parts with an urgency-of-need designator "B" in data block 3 require the approval signature of the ALFA FOUR or designated assistant in data block 30. All urgency-of-need designator "A" requests require the approval signature of the ALFA SIX.

The supply department orders the NIS/NC repair part and returns the yellow copy of NAVSUP Form 1250-1 or 1250-2 (fig. 2-16) within 72 hours after assigning the Julian date and serial number in data block B (fig. 2-15). The Julian date and serial number, referred to as the requisition number, are entered in the DTO log and will always be used for reference whenever a request is made for the requisition status of an outstanding order.

When any NIS/NC repair part is received, the item is given to the DTO clerk. The DTO clerk notates the part received on the DTO log and the appropriate DTO Summary Sheet. The yellow copy of the NAVSUP 1250-1 or 1250-2 (figs. 2-15 and 2-16) is taken from the file and attached to the part, which is then stored in the DTO bin according to the PM group of the equipment for which it was ordered. Any DTO part received for a deadline piece of equipment must be brought to the attention of the maintenance supervisor for disposition.

Repair parts from salvage or local manufacture (fabrication within the unit) may not involve procurement or issue action through the repair parts storeroom but must be documented for purposes of cost control and historical demand.

NON-NSN Requisition, NAVSUP Form 1250-2 (fig. 2-16), is processed in the same manner as NAVSUP Form 1250-1 (fig. 2-15).

Job Control Number (JCN)

The job control number consists of fourteen alphanumeric characters. The first six characters are the service designator (R, V, or N) and unit identification code (UIC). The next four characters are the work center (WC) code (for example, "AAOO") as defined in COMCBPAC/COMCBLANTINST 4400.3 series. The last four-character group is a locally assigned job sequence number (JSN).

WRONG PARTS!

Each year millions of dollars are wasted by ordering wrong parts. As a maintenance supervisor, you are responsible for ensuring that the Construction Mechanics assigned to the technical library are researching and ordering repair parts accurately. Strict adherence to proper supply procedures and a strong working relationship with your supply department will help prevent waste, save the government thousands of dollars, and curb unnecessary CESE downtime.

REPAIR PARTS TURN-IN

In the event, for one reason or another, that "the wrong parts" arrive at your site, do NOT ignore the problem. Such actions as hiding or burying them, giving them away, or destroying them are all illegal, and severe disciplinary action can be taken against you. Leaving these parts "on the shelf in case of need" is also in conflict with supply instructions, and it clogs up your storeroom or shop. The proper procedure is to turn these parts in to your supply department and let supply dispose of the parts properly. Proper procedures may be obtained from the supply officer of your unit.

BATTALION EQUIPMENT EVALUATION PROGRAM (BEEP)

The reliability of equipment is one of the main factors in the ability of an NMCB to perform its assigned mission. Before you take a look at this program from the maintenance viewpoint, you should familiarize yourself with current COMCBPAC/COMCBLANTINST 11200.1 series. This instruction establishes uniform procedures to be followed during a battalion's on-site relief and equipment turnover.

The purpose of the battalion equipment evaluation program (BEEP) is threefold: (1) to pass on all special knowledge of CESE maintenance and operations techniques; (2) to provide the relieving battalion with a realistic and in-depth condition evaluation of CESE allowance, facilities, tools and materials; and (3) to use the full expertise and efforts of the two equipment forces to provide the relieving battalion and detachments with the best possible' 'A" Company operation to conduct a successful deployment.

RESPONSIBILITIES OF THE RELIEVING BATTALION

Before arriving on the site, the incoming battalion is responsible for the following:

1. Notify COMCBPAC Equipment Office, Port Hueneme, California; COMCBLANT Detachment, Gulfport, Mississippi; and the battalion being relieved of the commencement date of the BEEP at least 30 days before commencement date. It is recommended that the BEEP start at least 10 days before the arrival of the main body.
2. Provide information, as required, to COMCBPAC/COMCBLANT equipment representatives for the completion of the BEEP report.
3. Ensure that all personnel required for the BEEP (see COMCBPAC/COMCBLANTINST 11200.1 series, chapter 3, for personnel requirements) are assigned to the advance party.
4. Have sufficient supplies of NMCB decals for organic and augment equipment on hand.
5. Ensure that required documents and supplies accompany the advance party.

RESPONSIBILITIES OF THE BATTALION BEING RELIEVED

Before and during the BEEP, the battalion being relieved is responsible for the following:

1. Coordinate the BEEP commencement date with the incoming battalion.
2. Assign counterparts to personnel arriving with the incoming battalion, and ensure that these personnel remain on site until completion of the BEEP. Personnel should not be assigned to other duties that would conflict with their participation in the BEEP.
3. Make available all necessary tools and shop equipment with which to evaluate and repair the equipment.
4. Clean and make available all equipment for evaluation and repair.
5. Coordinate the scheduling of equipment for inspection with the incoming battalion.

NOTE

> The recommended procedure is to schedule the equipment by PM group, using the appropriate number of PM groups to enable the BEEP to be completed within 10 working days.

6. Ensure that an ERO is prepared for each item of equipment with a copy of the Equipment Evaluation Inspection Guide (figs. 2-17 and 2-18) and also a copy of the Attachment Evaluation Inspection Guide (fig. 2-19), when appropriate.
7. Have two full workdays of CESE precleaned and staged before the commencement of the BEEP.

JOINT RESPONSIBILITIES

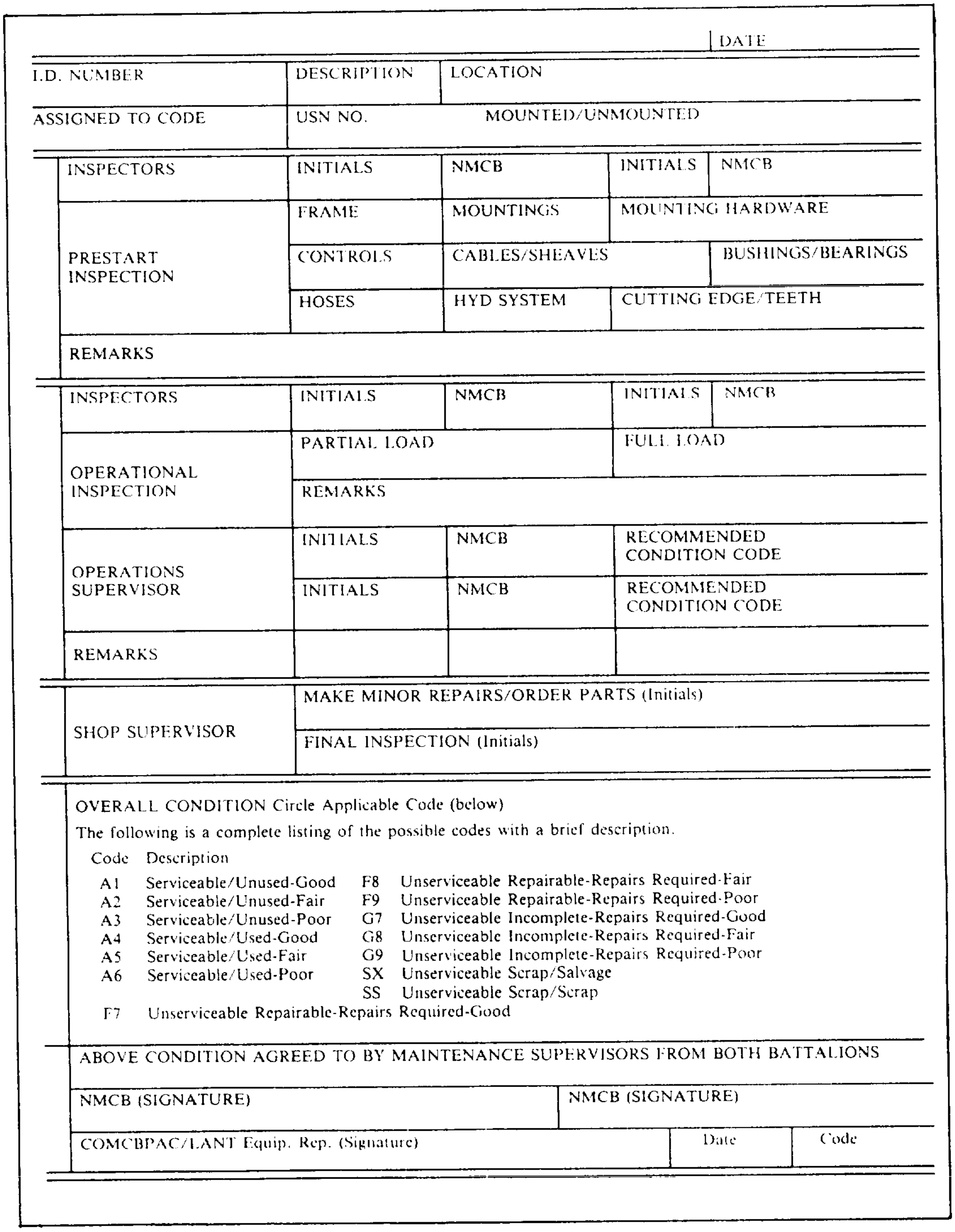
The following tasks are accomplished jointly by the battalions during the BEEP:

1. An inspection of all maintenance records, noting accuracy and deficiencies and updating as required.
2. A review and accountability of all maintenance correspondence that is pending final action.

DATE

CODE		USN NO.	MILEAGE	HOURS	ENGINE SERIAL NO.
PRESTART INSPECTION	INSPECTORS	INITIALS	NMCB	INITIALS	NMCB
	COOLING SYSTEM	LEVEL	LEAKS	CONDITION	
	LUBRICATION SYSTEM	LEVEL	LEAKS	CONDITION	
	CHARGING SYSTEM	BATTERY LEVEL	BELTS	CABLES	CONNECTIONS
	LIGHTING SYSTEM	HEADLIGHTS	TAILLIGHTS	BLACK OUT	INSTRUMENTS
		CLEARANCE	REFLECTORS	REMARKS	
	FUEL SYSTEM	LEVEL	LEAKS	CONDITION	
	TIRES	SIZE	TYPE TREAD	CONDITION	INFLATION
		MOUNTED SPARE SIZE		CONDITION	INFLATION
	TRACKS	RAILS	PINS	SHOES	SPROCKETS
		IDLERS	REMARKS		
	MISCELLANEOUS	AUTO TRANS FLUID		MIRRORS	LUG NUTS
		CONTROLS	CABLES	DOORS	GLASS
		UPHOLSTERY		BODY CONDITION	
	REMARKS				
ENGINE RUNNING	INSPECTORS	INITIALS	NMCB	INITIALS	NMCB
	ACCESSORIES	INSTRUMENTS	WARNING DEVICES HORN		
		W/S WIPERS	BRAKES	CLUTCH	HAND BRAKE
	LEAKS	ENGINE	TRANSMISSION		TRANSFER CASE
		DIFFERENTIALS	BRAKES	STEERING	WINCH
	ENGINE PERFORMANCE	STARTING	IDLING	FULL LOAD	
		PARTIAL LOAD		REMARKS	
	VEHICLE PERFORMANCE	STEERING	BRAKES	CLUTCH	TRANSMISSION
		DIFFERENTIALS	TRANSFER CASE	PTO	WINCH
		HYD SYSTEM	DRIVE SHAFTS	UNUSUAL NOISE/MOTION	
	REMARKS				

Figure 2-17.—Equipment Evaluation Inspection Guide.



		DATE
I.D. NUMBER	DESCRIPTION	LOCATION
ASSIGNED TO CODE	USN NO.	MOUNTED/UNMOUNTED

INSPECTORS	INITIALS	NMCB	INITIALS	NMCB
PRESTART INSPECTION	FRAME	MOUNTINGS	MOUNTING HARDWARE	
	CONTROLS	CABLES/SHEAVES		BUSHINGS/BEARINGS
	HOSES	HYD SYSTEM	CUTTING EDGE/TEETH	
REMARKS				

INSPECTORS	INITIALS	NMCB	INITIALS	NMCB
OPERATIONAL INSPECTION	PARTIAL LOAD		FULL LOAD	
	REMARKS			
OPERATIONS SUPERVISOR	INITIALS	NMCB	RECOMMENDED CONDITION CODE	
	INITIALS	NMCB	RECOMMENDED CONDITION CODE	
REMARKS				

SHOP SUPERVISOR	MAKE MINOR REPAIRS/ORDER PARTS (Initials)
	FINAL INSPECTION (Initials)

OVERALL CONDITION Circle Applicable Code (below)

The following is a complete listing of the possible codes with a brief description.

Code	Description
A1	Serviceable/Unused-Good
A2	Serviceable/Unused-Fair
A3	Serviceable/Unused-Poor
A4	Serviceable/Used-Good
A5	Serviceable/Used-Fair
A6	Serviceable/Used-Poor
F7	Unserviceable Repairable-Repairs Required-Good
F8	Unserviceable Repairable-Repairs Required-Fair
F9	Unserviceable Repairable-Repairs Required-Poor
G7	Unserviceable Incomplete-Repairs Required-Good
G8	Unserviceable Incomplete-Repairs Required-Fair
G9	Unserviceable Incomplete-Repairs Required-Poor
SX	Unserviceable Scrap/Salvage
SS	Unserviceable Scrap/Scrap

ABOVE CONDITION AGREED TO BY MAINTENANCE SUPERVISORS FROM BOTH BATTALIONS

NMCB (SIGNATURE)	NMCB (SIGNATURE)	
COMCBPAC/LANT Equip. Rep. (Signature)	Date	Code

Figure 2-18.—Equipment Evaluation Inspection Guide—Continued.

	INSPECTORS	INITIALS	NMCB	INITIALS	NMCB
INVENTORY	COLLATERAL EQUIPAGE INVENTORY	DISCREPANCIES/SHORTAGES			
	OPERATIONS SUPERVISORS	INITIALS	NMCB	RECOMMENDED CONDITION CODE	
		INITIALS	NMCB	RECOMMENDED CONDITION CODE	
	REMARKS				

SHOP INSPECTION AND REPAIR	INSPECTORS	INITIALS	NMCB	INITIALS	NMCB
	MOUNTING BOLTS	ENGINE	TRANSMISSION	AXLES	TRANSFER CASE
		SPRINGS	BODY	CAB	FENDERS
		FUEL TANKS	REMARKS		
	MISCELLANEOUS	EXHAUST SYSTEM	SPRINGS	SHOCKS	TIE RODS
		DRAG LINK	IDLER ARM	CONTROL LINKAGE	
	AIR INTAKE SYSTEM	CLEANER COND.	PIPING CONNECT	TURBOCHARGER, BLOWER	
	FRONT WHEELS	BRAKE LINING	BEARING ASSEMBLIES		SEALS
		BOOTS	DRUMS	CYLINDERS	BACKING PLATE
		SHOE MOUNT	ADJUST MECH	REMARKS	
	REAR WHEELS	BRAKE LINING	BEARING ASSEMBLIES		SEALS
		BOOTS	DRUMS	CYLINDERS	BACKING PLATE
		SHOE MOUNT	ADJUST MECH	REMARKS	
	SHOP SUPERVISOR	MAKE MINOR REPAIRS/ORDER PARTS (Initials)			
		FINAL INSPECTION (Initials)			

OVERALL CONDITION Circle Applicable Code (below)

The following is a complete listing of the possible codes with a brief description.

Code	Description		
A1	Serviceable/Unused-Good	F8	Unserviceable Repairable-Repairs Required-Fair
A2	Serviceable/Unused-Fair	F9	Unserviceable Repairable-Repairs Required-Poor
A3	Serviceable/Unused-Poor	G7	Unserviceable Incomplete-Repairs Required-Good
A4	Serviceable/Used-Good	G8	Unserviceable Incomplete-Repairs Required-Fair
A5	Serviceable/Used-Fair	G9	Unserviceable Incomplete-Repairs Required-Poor
A6	Serviceable/Used-Poor	SX	Unserviceable Scrap/Salvage
		SS	Unserviceable Scrap/Scrap
F7	Unserviceable Repairable-Repairs Required-Good		

ABOVE CONDITION AGREED TO BY MAINTENANCE SUPERVISORS FROM BOTH BATTALIONS

NMCB (SIGNATURE)	NMCB (SIGNATURE)	
COMCBPAC/LANT Equip. Rep. (Signature)	Date	Code

Figure 2-19.—Attachment Evaluation Inspection Guide.

3. An inventory and inspection of all permanent ALFA Company shop equipment, noting condition and deficiencies.

4. A preventive maintenance inspection to the BPM level on each nonpreserved item of USN-numbered equipment assigned, using the Equipment Evaluation Inspection Guide. Accomplish all repairs possible, dependent upon the work force, space, and repair parts available as determined jointly by both maintenance supervisors.

5. A preventive maintenance inspection of all equipment attachments, using an Attachment Evaluation Inspection Guide. Accomplish all repairs possible, dependent upon the work force, space, and repair parts available as determined jointly by both maintenance supervisors.

6. A visual inspection of each preserved item of assigned USN-numbered equipment, using an Equipment Evaluation Inspection Guide. The equipment is not depreserved for testing unless visual inspection shows major discrepancies.

The equipment condition codes as defined below are used in completing the parts of figures 2-18 and 2-19 that describe the overall condition of the equipment being BEEPed. Complete definitions of the codes are as follows:

A-Serviceable. New, used, repaired or reconditioned equipment that is serviceable for its intended function.

1-Unused-Good. Unused equipment that is usable without repairs and is ready for use.

2-Unused-Fair. Unused equipment that is usable without repairs, ready for use, but somewhat deteriorated.

3-Unused-Poor. Unused equipment that is usable without repairs but has considerable deterioration or damage.

4-Used-Good. Used equipment that is usable without repairs and most of its useful life remains.

5-Used-Fair. Used equipment that is usable without repairs but is somewhat worn or deteriorated and may soon require repairs.

6-Used-Poor. Used equipment that may be used without repair but is considerably worn or deteriorated. Remaining utility is limited or major repairs will soon be required.

F-Unserviceable (Repairable). Economically repairable equipment that requires repair or reconditioning.

G-Unserviceable (Incomplete). Equipment requiring additional parts or components to complete before issue. Also includes items with a long lead time, additional part requirement.

7-Repairs Required-Good. Required repairs are minor and should not exceed 15 percent of the replacement cost.

8-Repairs Required-Fair. Required repairs are considerable and are estimated to range from 16 percent to 40 percent of replacement cost.

9-Repairs Required-Poor. Required repairs are major and are estimated to range from 41 percent to 65 percent of replacement cost.

S-Unserviceable (Scrap). Equipment that has no value except for its basic material.

X-Salvage. Property that has some value, but repair or rehabilitation to use for the intended purpose is clearly impractical. Cannibalization of parts is possible.

X-Scrap. Material that has no value except for its basic material cost.

NOTE

Repair costs by percentage of replacement as set forth in numerical coding will pertain to deadlined equipment only.

COMCBPAC/COMCBLANT RESPONSIBILITIES

Representatives from COMCBPAC or COMCBLANT will be present at each BEEP and will remain on board until all phases of the BEEP have been completed. The primary duty of the representives is to present guidelines to personnel from both battalions that they are to cover and adhere to during the BEEP. (These guidelines are listed in the COMCBPAC/COMCBLANTINST 11200.1 series, page 157, paragraph 3702.) Specific responsibilities of the COMCBPAC/ COMCBLANT representatives are as follows:

1. Provide technical assistance during the BEEP.

2. Authenticate all NAVSUP Form 1250-1s and 1250-2s generated during the BEEP.
3. Assign all final CESE condition codes.
4. Conduct a post-BEEP critique for appropriate personnel of both battalions.
5. Prepare and submit a BEEP completion report to COMCBPAC or COMCBLANT, with copies to appropriate addresses.

KEEP IN MIND THAT SAFETY WILL BE PARAMOUNT THROUGHOUT THE ENTIRE BEEP

REPAIR PARTS

The repair parts portion of the BEEP will be accomplished according to COMCBPAC/COMCBLANTINST 4400.3 series, appendix C.

EMBARKATION

As indicated in the name, mobility is a major portion of the tasking of each Mobile Construction Battalion. The battalion maintains a staff that preplans for given situations. They work with the air detachment, air echelon, and sea echelon scheduling for ships or planes. The embarkation staff determines and adjusts load requirements to fit the type of units doing the transporting. As a CM1, you will be tasked to communicate with the embark staff through your chain of command. This communication will include changes in types of equipment available, deadlined units designated as air detachment or air echelon, and parts requirements changes.

SCHEDULING

Scheduling of equipment through the shop during embarkation depends on which equipment is to be embarked, the number of mechanics available, and time allowed. All equipment must be thoroughly cleaned, and time must be allotted for this operation. Air detachment equipment will receive top priority. As a shop supervisor, you will find that your input and knowledge of the mechanic's capabilities will be vitally important.

INSPECTING

Equipment to be embarked should have minor repairs accomplished before embarkation. These units must be capable of operating for some time without breakdown. Deadlined units on the sea echelon may be repaired under way. Equipment to be transported aboard aircraft will be delayed if fuel, oil, and water leaks are not detected during your inspection and corrected while in the shop.

PREPARING

Coordinated preplanned efforts between the mechanics, wash rack personnel, collateral equipment, and Equipment Operators are essential for a successful embark. All collateral equipment has to accompany the unit for which it was intended; spare tires have to be mounted. Depending on the method of transporting, dump truck headache boards need to be removed and secured in the bed, tops removed, windshields put down and taped, and exhaust stacks loosened. It is often required that the buckets and counterweights of front-end loaders be removed. Detailed data for each unit will be coordinated between the embark staff and the transporting unit.

STAGING

After the equipment has undergone the shop requirements, it might need to be loaded with designated equipment. All air-transported units must be weighed and the center of balance marked in the configuration in which it is to be loaded. After this has been accomplished, it maybe staged for convoy or movement in a place that is not congested and does not interfere with continued progress of equipment in process.

TRANSPORTING

Often a convoy movement is required to reach the transporting unit. This operation may be used to arrange equipment in load-number order if it was not done during the staging phase. Loading and tie-down are normally under the directions of the loadmaster of the aircraft or the boatswain of the ship.

HAZARDOUS MATERIALS

WARNING

Materials required to operate a maintenance organization are often toxic, corrosive, explosive, or highly flammable. These materials (paints, gases, acids, fuels, lubricants, and so on) are to be located where they are convenient to the users, secured safely (locked up), and at a safe distance to minimize injury in the event of a mishap. Warning signs pertaining to hazardous materials are required to be posted. The shop safety petty officer is to be aware of all of the locations of these materials in the maintenance shop. All shop personnel have to be briefed and are to understand fully countermeasures to take in the event of an accident. Complete safety instructions for hazardous materials storage are listed in the U. S. Army Corps of Engineers *Safety and Health Requirements Manual,* EM 385-1-1.

STORAGE

Fuels may be stored in underground tanks, fuel bladders, or properly equipped fuel tankers. The method of disbursing fuels depends on whether the site is temporary or not. At a temporary site, drummed fuels may be used. When selecting a fueling site, consider the accessibility of vehicles requiring fuel. Tracklaying equipment and automotive equipment are usually fueled in separate areas to avoid congestion.

Paints and lubricants are inventoried by the supply department. However, you are responsible for storing those in use or drawn in large quantities. **Storing lubricants properly includes taking steps to prevent fire or contamination by water.** Paints should be stored away from flames. Provide a fire-resistant area for paints stored inside a building. A well-constructed metal CONEX box is generally suitable for small quantities. By using good housekeeping practices, you can help avoid accidents or fires.

Gases normally used by Construction Mechanics include oxygen, acetylene, MAPP-gas, helium, and butane. The U.S. Army Corps of Engineers *Safety and Health Requirements Manual,* EM 385-1-1 is the current reference for safe handling and storage of compressed gases.

WARNING

Oil and grease must NOT be allowed to come in contact with gases; if they do, they may explode or burn out of control.

Compressed gas containers will be segregated and stored in the manner prescribed at specific distances from each other and working areas.

Acid or electrolyte used in the battery shop is to be stored in an upright position on a stable platform. This space is to be well ventilated, A facility for quick drenching of the eyes is to be available in this area.

SPILLS AND CLEANUP

When spilled in the shop, fuels are hazardous. They cause fires and accidental falls and they contaminate air and water. Small spills can be cleaned with absorbents that must be disposed of properly. Good housekeeping means fewer accidents.

Spills at fueling stations are normally smaller than bulk fuel spills. They may be absorbed with sand or oil dry types of absorbents. These absorbents must be properly disposed of also.

Fueling spills spell fire! Hosing the affected area with water will dilute the fuel to a degree, but it will also spread the fuel over a larger area. Fuels may contaminate water systems as well as sewer systems. **Should a large quantity of volatile fuel enter a sewer system, notify proper authorities.**

Oil drums at fueling stations used by the Equipment Operators must have a catch trough for spillage. Oil caught in this way is placed in a container for waste oil. Waste oil from service stations, shops, and lubrication areas is disposed of by re-refining when possible.

Using waste oil as a dust or weed control agent is prohibited, because this oil often washes into water systems during heavy rains. Burning of waste oil contributes to air pollution and is prohibited. Re-using or burning waste oils is allowed in large power plants that can separate contaminates or blend the waste with fuel properly.

Field repair personnel are responsible for collecting oils and fuels drained during repair operations. **Spilled lubricants penetrate the soil and could reach the groundwater table.** Contaminating the groundwater table may harm local drinking water. Immobilize a ground spill by adding dry soil to soak up the spill. To prevent contamination of the water table, collect the waste lubricants and return them to a collection point for disposal. You must develop contingency plans in case of a hazardous material spill. OPNAVINST 4110.2 (series), *Hazardous Material Control and Management,* and OPNAVINST 5090.1 (series), *Environment and Natural Resources Protection Manual* provide detailed information.

DEFENSE REUTILIZATION AND MARKETING OFFICE (DRMO)

Do not let your maintenance area become the ALFA Company junk yard. Unneeded materials and CESE that have no further use, worn-out CESE components, batteries, tires, and so on, are to be turned in to the Defense Reutilization and Marketing Office (DRMO) to "clean house." Contact your supply officer and local DRMO for proper turn-in procedures.

CESE DISPOSAL

Disposition instructions for CESE assigned to an NMCB come from COMCBPAC Equipment Office in Port Hueneme, California, or COMCBLANT DET, Gulfport, Mississippi. Only upon receipt of these instructions may disposal be initiated.

A. Follow the procedures outlined in the disposal letter/message.

B. Remove all unit decals and stencils from the equipment.

C. On or before the predetermined date in the disposal letter/message, using a DoD Form 1348-1 as a turn-in document, deliver the equipment, its attachments, and its history jacket to the nearest DRMO. (List on the 1348-1 all attachments accompanying the unit to DRMO.)

NOTE

Unless otherwise directed, all collateral equipage and attachments assigned to that particular unit will accompany the unit to DRMO.

D. Upon completion of action, forward a copy of the disposal letter/message with a copy of the signed DD Form 1348-1 turn-in document as an enclosure to COMCBPAC Equipment Office or COMCBLANT DET within 15 days of disposal action.

E. Adjust your CESE inventory records, status boards, DTO files, DTO room, and so forth. Notify supply and the dispatch supervisor of your actions.

NOTE

Disposal letters/messages are not blanket cannibalization authority. If your shop needs parts from a piece of CESE going to DRMO, request authority from COMCBPAC Equipment Office or COMCBLANT DET to remove such parts.

HAZARDOUS MATERIALS DISPOSAL

Hazardous materials have special turn-in procedures. For instance, batteries must be drained of all electrolyte before turn-in. The electrolyte is turned in separately in a separate container. Both items, electrolyte and batteries, are to be palletized and marked "HAZARDOUS" before turn-in. If in doubt of any hazardous material turn-in procedures, contact your local DRMO office.

ASSIGNMENT 2

Textbook Assignment: “Battalion Equipment Company Shops Supervisor,” pages 2-1 through 2-23.

2-1. What sections constitute the equipment maintenance branch of an NMCB?

1. Administration and automotive repair only
2. Heavy equipment repair and support shops only
3. Automotive repair and support shops only
4. Administration, automotive repair, heavy equipment repair, and support shops

2-2. The equipment maintenance branch is normally under the overall supervision of which of the following personnel?

1. An EQCM
2. A CMCS
3. A civil service employee
4. A CMC

2-3. The shop supervisor in a maintenance branch is normally which of the following individuals?

1. An EQCM
2. A CMCS
3. A CM1
4. A CM2

2-4. In planning for the location of a maintenance shop, you should consider which of the following factors?

1. Nearness to transportation facilities
2. Room for expansion
3. Size of the parking area
4. Each of the above

2-5. Where should heaters be located in a maintenance shop?

1. Where the heat is most needed
2. By the doorways
3. In the center of the main shop

2-6. Doors at the front and rear of the shop, and windows that can be opened, will normally enable enough air to enter the shop and remove exhaust gases.

1. True
2. False

2-7. Before stationary gasoline or diesel engines are used in a maintenance shop, which of the following features must be provided?

1. Exhaust outlets
2. Natural ventilation
3. Forced air intake for the prime mover
4. Noise suppression

2-8. When deciding what type of tools and equipment to have on hand, you should consider which of the following factors?

1. Goals and limitations set by the regiment
2. Layout of the shop and the qualifications of your mechanics
3. Operational needs of the battalion and the cost of having work performed at an overhaul facility
4. Cost plus factor and the expediency of the commercial facility

2-9. Deciding that work can be done more economically at a component overhaul facility than in the maintenance branch is based solely on what factor(s)?

1. Cost plus factor
2. Availability of the facility
3. Facts and figures in transportation maintenance management reports
4. Desires and goals of the regimental transportation officer

2-10. Drill presses, bench grinders, and other common power tools used for repairing many kinds of equipment should be installed in which of the following locations?

1. In or near the main shop area
2. In an area where ON-OFF switches are reached easily
3. In an area where water is accessible, in case of fire
4. In any section of the equipment maintenance branch

2-11. You should install the master switch that controls all power in the maintenance shop in which of the following locations?

1. A room that can be secured easily
2. A space that is in full view of all shop personnel
3. An area that can be controlled by a supervisor
4. A location that can be reached quickly in an emergency

2-12. In an area where welding equipment is used, you should take which of the following safety precautions?

1. Have the area screened and equipped with fire-fighting equipment
2. Locate the area away from the rest of the shop areas
3. Have the area posted with hazard warning signs
4. All of the above

2-13. Tire repair equipment should be located near one of the shop’s entrances for what reason?

1. To eliminate the need for duplicate equipment
2. To enable it to be used by patrons of the hobby shop after workinq hours
3. To enable civil service employees, as well as CMs, to use it
4. To allow the EOs to use it as readily as the CMs

2-14. You can reduce pressure drops in a maintenance shop air pressure system in which of the following ways?

1. By installing condensation traps
2. By keeping the air lines as short as possible
3. By lengthening the air lines

2-15. Condensation traps should be drained at least how often?

1. Each shift
2. Daily
3. Every other day
4. Weekly

2-16. When you have battery-charging equipment in your maintenance branch, you must take which of the following precautions?

1. Locate the equipment in a well-ventilated space
2. Install an exhaust fan near the equipment
3. Have a water supply near the equipment
4. Each of the above

2-17. Safe working practices must be emphasized to such a point that they become routine.

1. True
2. False

2-18. To help prevent shop accidents, a supervisor should make sure the mechanics observe qood housekeeping and safe working practices.

1. True
2. False

2-19. Accidents and injury may be reduced or cut to zero if you take which of the following actions?

1. Practice good housekeeping
2. Crack down on bad habits
3. Conduct daily safety lectures
4. All of the above

2-20. The overall responsibility for ensuring proper maintenance and repair of all automotive, construction, and materials-handling equipment assigned to an NMCB belongs to what person?

1. The maintenance supervisor
2. The automotive shop supervisor
3. The heavy equipment shop supervisor
4. The support section supervisor

2-21. When working with shop supervisors, inspectors need to use tact and maturity for which of the following reasons?

1. The shop supervisors are older
2. The shop supervisors are often militarily senior
3. The inspectors report to the maintenance supervisor
4. Each of the above

2-22. The automotive repair supervisor has direct control and supervision over the personnel in his section. Which of the following is NOT a duty of this supervisor?

1. Providing technical leadership
2. Providing the field maintenance crew
3. Maintaining records and reports
4. Ensuring timely and quality work performance

2-23. It is worthwhile for the heavy equipment repair shop supervisor to shortchange himself as to shop personnel in which of the following situations?

1. When furnishing additional personnel to the support section
2. When providing experienced field maintenance mechanics
3. When providing technical assistance to the logistic section with regard to repair parts

2-24. Furnishing the tools and equipment that field mechanics require is the responsibility of whom?

1. The senior mechanic
2. The automotive shop supervisor
3. The heavy equipment shop supervisor
4. The maintenance supervisor

2-25. An injector shop is normally attached to which of the following shops?

1. The heavy shop
2. The 5000 shop
3. The light shop
4. The support shop

2-26. Companies within the battalion requesting the services of the Alfa company machine shop must route their request through which of the following persons?

1. The support shop supervisor
2. The operations officer
3. The maintenance shop supervisor
4. The Alfa company commander

2-27. An updated inventory list for the machine shop trailer may be obtained from which of the following locations?

1. COMCBLANT Det, Gulfport
2. COMCBPAC equipment officer
3. Both 1 and 2 above
4. CESO

2-28. A repair shop mechanic needs to use a tool that is not in his custody. How should he obtain this tool?

1. By giving the tool issue room personnel the assigned job order number
2. By presenting an ERO to the toolroom personnel
3. By checking the tool out from the toolroom

2-29. The tire shop could require a separate air compressor because of the large volume of air used.

1. True
2. False

2-30. PM lube racks should be located some distance from the other shop areas for which of the following reasons?

1. To make lubrication services easy to perform
2. To make it easy to inspect and clean equipment
3. To guard against fire
4. To provide shelter to increase PM efficiency

2-31. What person is normally responsible for updating the equipment computer program?

1. The maintenance supervisor
2. The cost control clerk
3. The cost control supervisor
4. The company clerk

2-32. Which of the following persons should notify the dispatcher in advance of equipment coming into the shop?

1. The DTO clerk
2. The PM clerk
3. The cost control supervisor
4. The cost control clerk

2-33. Summarizing the total cost of repair parts and labor expended on an ERO is the responsibility of what person?

1. The cost control clerk
2. The DTO clerk
3. The PM clerk
4. The shop supervisor

2-34. Guidance in establishing the inventory and checkout procedures of a technical library is provided in which of the following COMCBPAC/COMCBLANT instructions?

1. 1040.2 series
2. 4400.3 series
3. 5100.3 series
4. 5600.1 series

2-35. What is the basic objective of the preventive maintenance program?

1. To provide a thorough inspection of each piece of equipment
2. To make sure each piece of equipment is painted when required
3. To keep records to obtain a complete history of the equipment
4. To keep the equipment operating and to detect minor problems before they become major ones

2-36. Organizational maintenance of equipment includes which of the following tasks?

1. Operator and preventive maintenance
2. Daily inspection, lubrication, and adjustments
3. Mechanics weekly inspections, lubrications, and adjustments

2-37. Any defect or unsafe condition found by any operator should be reported immediately to which of the following persons?

1. The senior mechanic
2. The shop supervisor
3. Any shop supervisor
4. The dispatcher

2-38. Organizational maintenance is followed by what type of work?

1. Interim repair
2. Preventive maintenance
3. Breakdown maintenance
4. Safety inspections

2-39. The overhaul of equipment assemblies, subassemblies, and components is the responsibility of the maintenance shops at which level of the battalion maintenance program?

1. Organizational
2. Depot
3. Intermediate

2-40. What is the standard interval (in working days) between PM service inspections for NCF equipment?

1. 30
2. 40
3. 50
4. 60

2-41. Which of the following actions is a step in establishing the initial standard between PM service inspections?

1. Group all similar types of equipment
2. Group all assigned equipment into 30 separate PM groups
3. Distribute all assigned PM groups evenly among 40 separate PM groups
4. Divide the number of pieces of equipment into the number of workdays per month

2-42. Determining whether the PM interval for a piece of equipment should be reduced is the responsibility of which of the following personnel?

1. The operator
2. The mechanic
3. The shop supervisor
4. The maintenance supervisor

2-43. To make sure the PM program is being performed as prescribed, the maintenance supervisor should review the PM Record Card file at least how often?

1. Once a month
2. Every other month
3. Three times a year
4. Quarterly

2-44. The PM Record Cards should be maintained in what order?

1. Alphabetically by type of vehicle
2. Numerically by type of vehicle
3. By PM group in a tickler file
4. By date of scheduled PMs

2-45. What action should be taken with a PM Record Card for a vehicle that is transferred?

1. It should be destroyed immediately
2. It should be held for 1 year, then destroyed
3. It should be placed in the equipment history jacket
4. It should be sent to the equipment records division at Port Hueneme

2-46. At intervals of 40 working days, a piece of NCF equipment is given which of the following inspections?

1. 01 or 02
2. 04 or 06
3. 07 or 09
4. 012 or 013

2-47. A Type B inspection is performed at which of the following intervals?

1. 2,000 miles
2. 120 hours
3. After two consecutive 01 inspections
4. Each of the above

2-48. Which of the following entries is NOT recorded on EROs and their continuation sheets?

1. Cost of repairs
2. Types of repairs
3. Hours required for repairs, as well as the total time that an item of equipment is out of service
4. Next PM service required

2-49. The accumulation of data from the EROs and their continuation sheets provides information for which of the following reasons?

1. Budget planning
2. Determining economical life expectancies
3. Predicting equipment and training requirements
4. Each of the above

2-50. What difference, if any, is there between the authority to perform work in the field and the authority to do work in the shops?

1. An ERO must be filled out for work in the shops but not in the field
2. An ERO must be filled out for work in the field but not in the shops
3. An ERO and SRO must be filled out for work in the shops but not in the field
4. None

2-51. The ERO Log Sheet, figure 2-4 in your textbook, shows a dozer receiving an interim repair and Type 02 PM. What type PM, if any, is it scheduled for next?

1. An 01
2. An 02
3. An 03
4. None

2-52. Who, if anyone, acts as an interface between the supply officer and the maintenance supervisor?

1. The CM assigned to repair parts
2. The cost control supervisor
3. The technical librarian
4. No one

2-53. The Consolidated SEABEE Allowance Lists (COSALS) establish the support for which of the following assigned types of equipment based on USN-numbered listing?

1. Vehicular
2. Materials-handling
3. Organic and augment
4. Construction or weight-handling

2-54. Repair parts allowances are normally designed to provide what percentage of effectiveness for 90-day support of vehicles or equipment in new or like-new condition?

1. 100 percent
2. 90 percent
3. 80 percent
4. 75 percent

2-55. General repair type of items are referenced in the COSALs as parts peculiar.

1. True
2. False

2-56. What are the respective high and low limits established for the stock items carried on the Stock Record Card of figure 2-13 in your textbook?

1. 11 and 4
2. 12 and 1
3. 14 and 7
4. 16 and 9

IN ANSWERING QUESTIONS 2-57 THROUGH 2-60, SELECT FROM COLUMN B THE DESCRIPTION OF THE SUPPLY AID IN COLUMN A. RESPONSES IN COLUMN B MAY BE USED ONCE, MORE THAN ONCE, OR NOT AT ALL.

	A. SUPPLY AIDS		B. DESCRIPTIONS
2-57.	Surmmary item list	1.	Repair parts no longer required by a previous COSAL
2-58.	NAVSUP 1114	2.	A printed stock record card
2-59.	Delete item listing	3.	An item release or receipt document
2-60.	DD Form 1348-1	4.	Items required by the old COSAL

2-61. Which of the following materials should be in a technical library?

1. Manufacturer's parts manuals and operator's manuals
2. History jackets for assigned equipment
3. Administrative supplies
4. All of the above

2-62. If a repair part was issued, which data block of figure 2-15 in your textbook should indicate this?

1. Block 5
2. Block 7
3. Block 12
4. Block 17

2-63. Which of the following forms should you use as authorization for drawing or ordering repair parts?

1. NAVSUP 1250-1
2. NAVFAC 11210/4
3. NAVDOCK 1250–1
4. DD 120

2-64. Who authorizes placing a part on order that is not in stock and assigns a priority to the requisition?

1. The shop supervisor
2. The shop inspector
3. The senior mechanic
4. The maintenance supervisor

2-65. When parts are being placed on order, what action, if any, is taken by the cost control clerk?

1. Assigning a department order number for each part not in stock (NIS)
2. Assigning a deparment order number for each group of similar items
3. Recording the information in the DTO log and the DTO summary sheet
4. None

2-66. After assigning a Julian date and serial number, the supply department normally returns the yellow copy of the 1250-1 or 1250-2 to cost control within what maximum period of time?

1. 1 working day
2. 24 hours
3. 72 hours
4. 1 week

2-67. Repair parts manufactured locally or acquired from salvage must be documented through the supply system for which of the following reasons?

1. To manage DTO parts
2. For cost purposes
3. For historical demand purposes
4. Both 2 and 3 above

2-68. What is indicated by the last four digits on the ERO?

1. Unit identification
2. Job sequence number
3. Shop identification number
4. Deployment site identification number

2-69. In your unit, proper excess repair parts turn-in instructions may be obtained from which of the following sources?

1. The supply officer
2. The maintenance supervisor
3. The cost control supervisor
4. The material logistics officer

2-70. When should the Battalion Equipment Evaluation Program (BEEP) establish the uniform procedures that are to be carried out?

1. During a battalion's on-site relief and equipment turnover
2. During the original equipping of a battalion before an overseas assignment
3. At an inspection conducted 3 months after the battalion arrives at a station
4. Each of the above

IN ANSWERING QUESTIONS 2-71 THROUGH 2-75, ASSUME THAT NAVAL MOBILE CONSTRUCTION BATTALION 40 IS SCHEDULED TO BE RELIEVED BY NAVAL MOBILE CONSTRUCTION BATTALION 133. SELECT FROM COLUMN B THE BATTALION(S) RESPONSIBLE FOR ACCOMPLISHING, DURING THE BEEP, THE TASK GIVEN IN COLUMN A. RESPONSES IN COLUMN B MAY BE USED MORE THAN ONCE.

A. TASKS	B. BATTALIONS
2-71. Reviewing maintenance correspondence not yet acted upon	1. NMCB 133 2. NMCB 40 3. NMCB 133 and NMCB 40
2-72. Notifying higher authority of BEEP commencement date	
2-73. Providing tools and shop equipment for evaluation and repair of CESE	
2-74. Coordinating the scheduling of CESE for inspection	
2-75. Conducting a PM inspection of all CESE and CESE attachments	

CHAPTER 3

ENGINE TROUBLESHOOTING AND OVERHAUL

The engine of any piece of equipment is taken for granted as long as it runs smoothly and efficiently. But all engines lose power sooner or later from normal wear. When this happens, the mechanic must be able to determine the cause and know what is needed to correct the trouble.

Generally speaking, it is not the supervisor's job to perform engine repairs, but it is the supervisor's job to see that these repairs are performed correctly and to assist and instruct those doing the work.

Since the SEABEEs use many models of internal combustion engines, it is impossible to specify the detailed overhaul procedures for all the engines. However, here are several basic principles that apply to all engine overhauls.

1. Consult the detailed repair procedures given in the manufacturers' instruction and maintenance manuals. Study the appropriate manuals and pamphlets before attempting any repair work. Pay particular attention to tolerances, limits, and adjustments.
2. Observe the highest degree of cleanliness in handling engine parts during overhaul.
3. Before starting repair work, be sure all required tools and replacements for known defective parts are available.
4. Keep detailed records of repairs, such as the measurements of parts, hours of use, and new parts installed. An analysis of these records will indicate the hours of operation that may be expected from the various engine parts and help in determining when a part should be renewed to avoid a failure.

Since maintenance cards, manufacturers' technical manuals, and various instructions contain repair procedures in detail, this chapter will be limited to general information on some of the troubles encountered during overhaul, their causes, and methods of repair.

HORSEPOWER AND HORSEPOWER RATINGS

Horsepower is a unit for measuring work per unit of time. One horsepower is equivalent to 33,000 foot-pounds of work per minute. Horsepower is determined by either measuring mechanically or computing mathematically.

Maintenance manuals should be consulted for engine performance data and specifications. These manuals will also have additional horsepower designations and the many different horsepower ratings used by manufacturers in describing the equipment. The method used in measuring power and the purpose for which it is intended account for the variety of horsepower and horsepower ratings.

INDICATED HORSEPOWER

INDICATED HORSEPOWER is the theoretical power that an engine would deliver if all frictional losses were eliminated. It is used mainly by experimental engineers in designing new and more efficient engines. Indicated horsepower may be computed from the following formula:

$$\text{Indicated HP} = \frac{PLANK}{33{,}000}$$

Where

P = Mean effective pressure in pounds per square inch (This is the average pressure on the piston during the power stroke minus the average pressure during the other three strokes.)

L = Length of stroke in feet

A = Area of piston head in square inches

N = Working strokes per minute

K = Number of cylinders in the engine

33,000 = The equivalent of one horsepower in foot-pounds per minute

Of all the factors given in this formula, only cylinder pressure (P) and engine rpm (N) can be changed during the normal operation of the engine. The remaining factors are constant.

BRAKE HORSEPOWER

BRAKE HORSEPOWER is the actual amount of power that an engine can deliver at a certain speed with a wide-open throttle. The term *brake horsepower* is derived from the braking device (usually a dynamometer) that is applied to measure the horsepower an engine develops. The dynamometer consists of a resistance-creating device, such as an electric armature revolving in a magnetized field. A paddle wheel revolving in a fluid may also be used to absorb the energy.

An ENGINE DYNAMOMETER maybe used to test an engine that has been removed from the vehicle it drives. If the engine does not develop the manufacturer's recommended horsepower and torque at specific rpms, the engine must be tuned up or repaired.

The CHASSIS DYNAMOMETER can give a quick report on engine conditions by measuring output at various speeds and loads. It is useful in shop testing and adjusting automatic transmissions.

On the chassis dynamometer (fig. 3-1), the driving wheels of the vehicle are placed on rollers. The engine drives the wheels, and the wheels drive the rollers. By loading the rollers varying amounts and by running the engine at different rpms, nearly all normal driving conditions can be simulated. The tests and checks can be made without the interference of body noises, as happens when the vehicle is driven on the road.

FRICTION HORSEPOWER

FRICTION HORSEPOWER is the difference between indicated horsepower and brake horsepower. Actually, it is the power required to overcome friction within the engine, such as friction between engine parts, resistance in driving accessories, and, among other things, loss due to pumping action of the pistons. The latter maybe compared to the effort required to raise the handle of a hand-operated tire pump. It may be difficult to define friction horsepower properly, but with proper maintenance, it can be reduced to improve the mechanical efficiency of the engine.

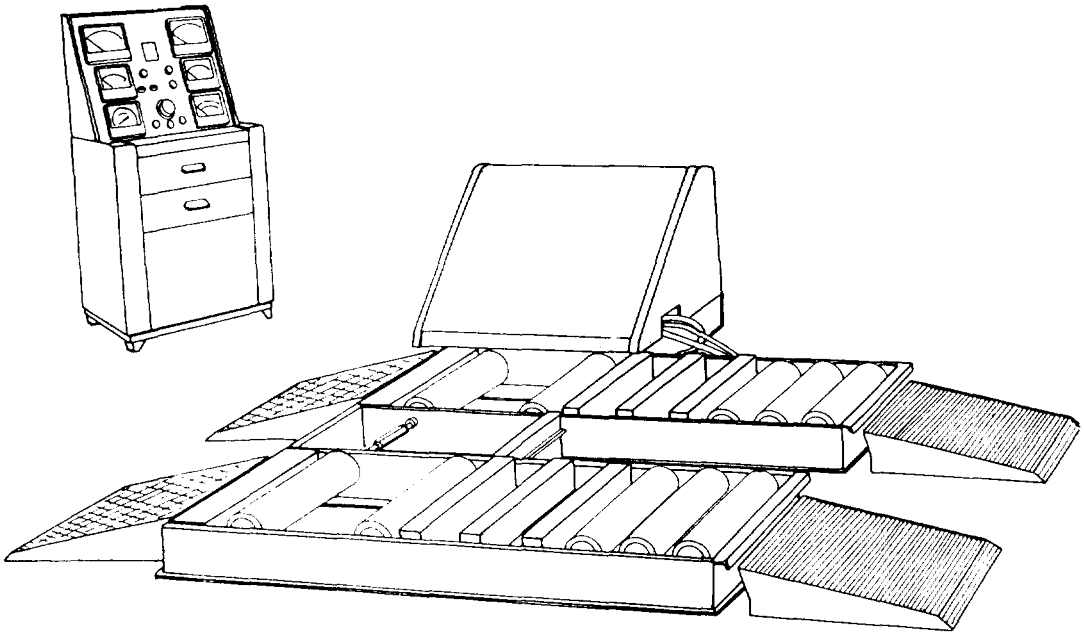


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Figure 3-1.—Chassis dynamometer.

DRAWBAR AND BELT HORSEPOWER

There are two kinds of horsepower commonly used by manufacturers in rating the power of construction vehicles: drawbar and belt horsepower.

DRAWBAR HORSEPOWER is the power that can be exerted in pulling a load. Specifications of the Caterpillar D-8 H series with a D-342 engine, for example, rate the drawbar horsepower at 180.

BELT HORSEPOWER is equivalent to the rated engine power except in cases where the belt pulley is driven through a gear train. In that case, there is a slight loss of power caused by gear friction. Also, while there may be some belt-pulley slippage, it is disregarded in arriving at the belt horsepower rating.

The national Automotive Chamber of Commerce has developed a simplified method of determining taxable horsepower based on the bore of the engine and the number of cylinders. This specification is listed in most manufacturers' manuals, but it does not truly represent the actual horsepower of modern high-speed, high-compression engines. It is used for licensing purposes only in some states.

GRAPHS AND DIAGRAMS

Graphs and diagrams are abbreviated methods of recording operational and maintenance data.

Manufacturers' operational and maintenance manuals often contain graphs and diagrams. The technical bulletins, prepared chiefly for tune-up mechanics, may use a particular graph or diagram to eliminate pages of written description that otherwise would be necessary.

PERFORMANCE CURVES

Figures 3-2 and 3-3 are examples of graphs that describe engine performance in terms of brake horsepower and fuel consumption. Dynamometer tests provide the data used in plotting the performance curves for each engine.

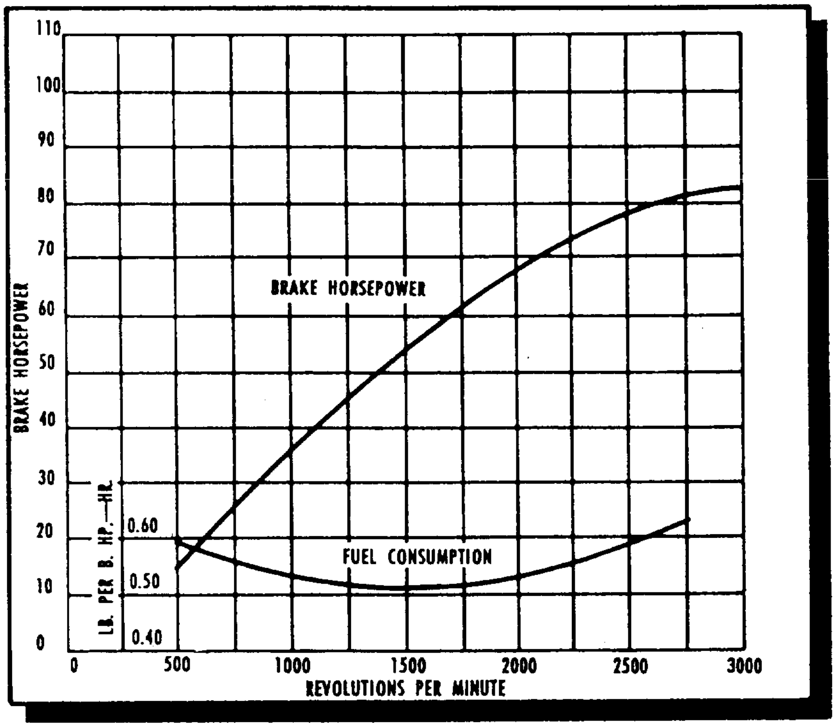


Figure 3-2.—Performance curves of a typical six-cylinder gasoline engine.

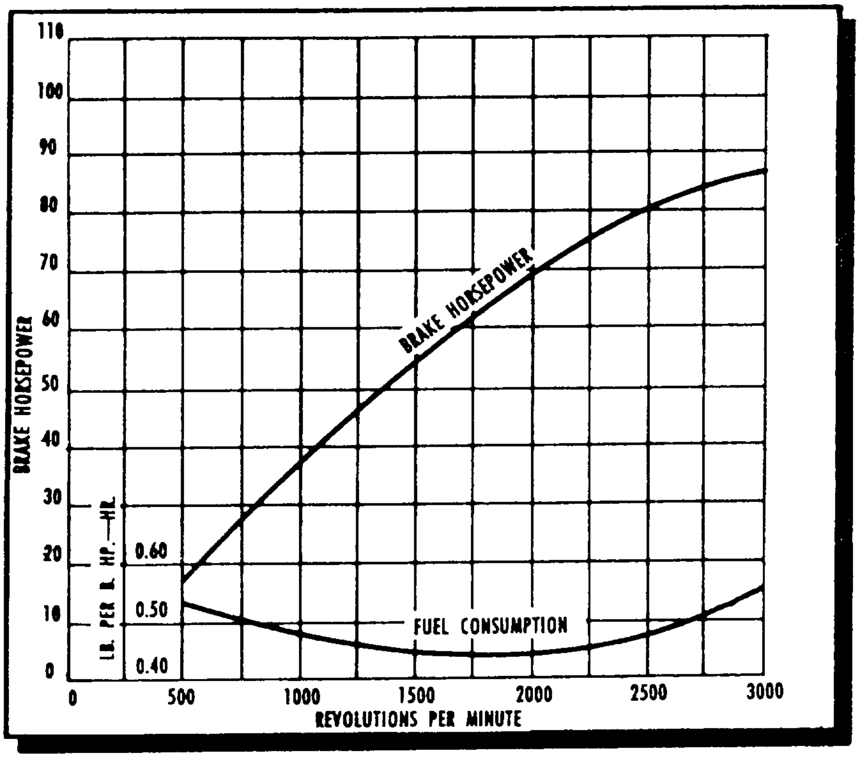


Figure 3-3.—Performance curves of a typical six-cylinder diesel engine.

Figure 3-4 is another example of a graph. It shows that the amount of torque an engine produces varies with its speed. The relationship between torque and horsepower is shown in figure 3-5.

Horsepower is related to both torque and speed. When both are increasing, as they do between 1,200 and 1,600 rpm, then horsepower goes up sharply. As torque reaches maximum and begins to taper off, horsepower continues to rise to maximum. The horsepower starts to decline beyond rated speed where torque falls off sharply.

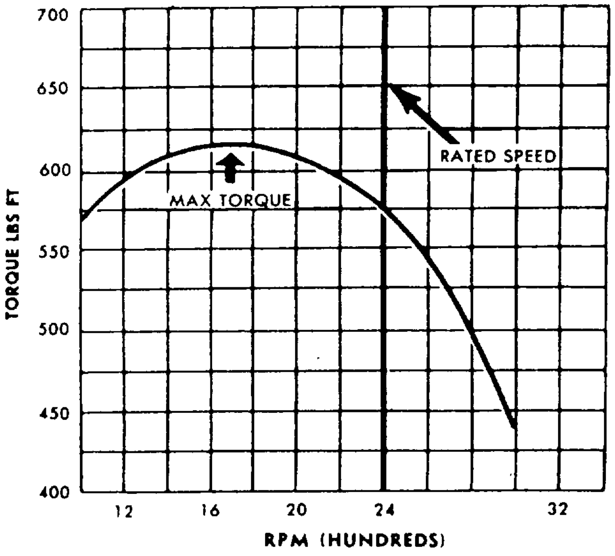


Figure 3-4.—Graph showing relationship between torque and speed.

TIMING DIAGRAMS

Engine timing is largely a matter of opening and closing valves or ports and of adjusting ignition or fuel injection so that these events occur at the proper time in the cycle of engine operation. Timing diagrams picture these events in relation to each other and in relation to top dead center (TDC) and bottom dead center (BDC). They are useful to the CM for quick and easy reference. However, before timing diagrams can be useful, the mechanic must recall a few facts about engine cycles.

The four-stroke-cycle engine makes two complete crankshaft revolutions in one cycle

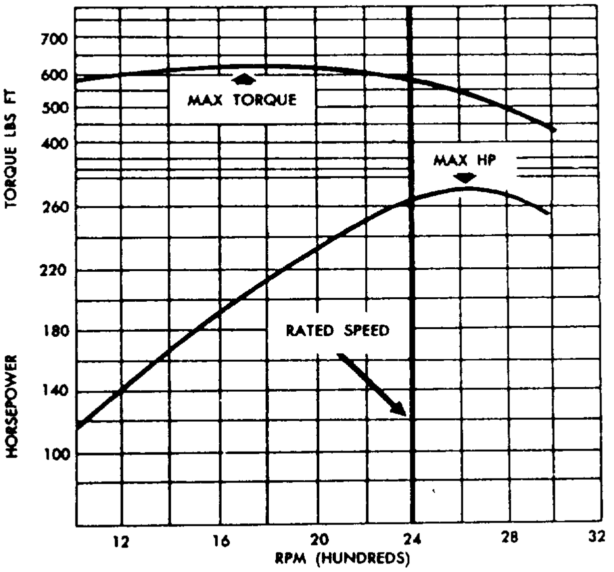


Figure 3-5.—Relationship between torque and horsepower.

(intake, compression, power, and exhaust). The two-stroke-cycle engine completes a cycle with just one crankshaft revolution. With diesel engine cycles (two- and four-stroke), the event of fuel injection will be shown on the timing diagram instead of spark ignition, which is common to gasoline engine operating cycles.

Four-Stroke-Cycle Engine Timing

Figure 3-6 shows a typical timing diagram for a four-stroke-cycle diesel engine. The actual length of the strokes shown and the beginning of fuel injection will vary a few degrees in either direction, depending on the specific manufacturer's recommendations. Follow the events in this cycle by tracing the circular pattern around two complete revolutions in a clockwise direction.

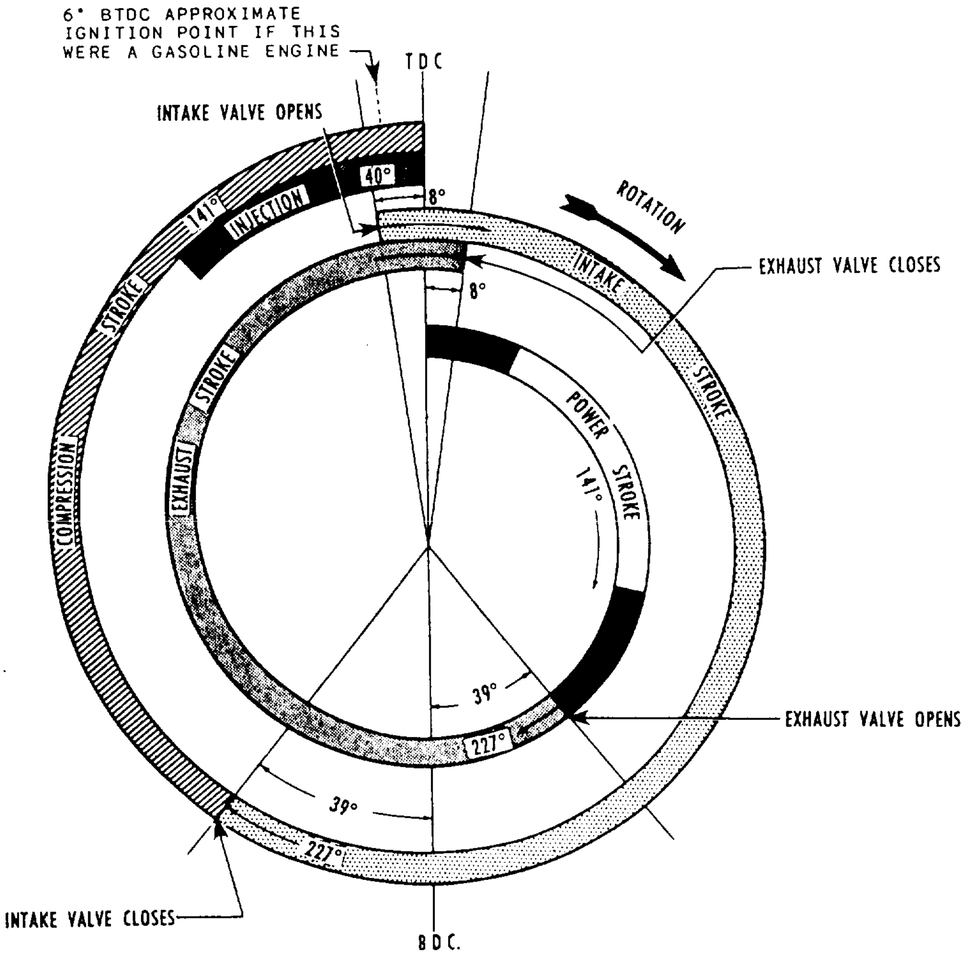


Figure 3-6.—Typical timing diagram of a four-stroke-cycle diesel engine.

Start TDC with the beginning of the POWER STROKE. Compression is at its peak when fuel injection has been completed and combustion is taking place. Power is delivered to the crankshaft as the piston is driven downward by the expanding gases in the cylinder. Power delivery ends when the exhaust valve opens.

After the exhaust valve opens, the piston continues downward to BDC and then upward in the EXHAUST STROKE. The exhaust gases are pushed out of the cylinder as the piston rises to TDC, and the exhaust valve closes a few degrees after TDC to ensure proper scavenging. The crankshaft has made a complete revolution during the power and exhaust strokes.

The intake valve opens a few degrees before TDC near the end of the upward exhaust stroke to aid in scavenging the cylinder. As the crankshaft continues to rotate past TDC, the INTAKE STROKE begins. The intake stroke continues for the whole downward stroke and part of the next upward stroke to take advantage of the inertia of the incoming charge of fresh air.

The rest of the upward stroke is the COMPRESSION STROKE, which begins at the instant of intake valve closing and ends at TDC FUEL INJECTION may begin as much as 40° before TDC and continue to TDC, thus completing the power cycle and the second complete revolution of the engine.

By showing an approximate ignition point in place of fuel injection, figure 3-6 could easily represent a timing diagram for a typical gasoline engine.

For additional information on diesel fuel injection system tests that can be made both in the shop and in the field, refer to the manufacturer's service manual.

Two-Stroke-Cycle Engine Timing

Figure 3-7 shows a timing diagram of a two-stroke-cycle diesel engine. This engine is typical of the General Motors series, which uses a blower to send fresh air into the cylinder and to clear out the exhaust gases. The movement of the piston itself does practically none of the work of intake and exhaust, as it does in a four-stroke-cycle engine. This fact is important to the mechanic in detecting two-stroke-cycle diesel engine power losses.

Beginning at TDC (fig. 3-7), the fuel has been injected, and combustion is taking place. The piston is driven down, and the power is delivered to the crankshaft until the piston is just a little more than halfway down. The exhaust valves (two in each cylinder) open 92 1/2° after TDC. The exhaust gases blow out through the manifold, and the cylinder pressure drops off rapidly.

At 132° after TDC (48° before BDC), the intake ports are uncovered by the downward movement of the piston. Scavenging air under blower pressure swirls upward through the cylinder and clears the cylinder of exhaust gases. This flow of cool air also helps to cool the cylinder and the exhaust valves. Scavenging continues until the piston reaches 44 1/2° after BDC. At this point, the exhaust valves are closed. The blower continues to send fresh air into the cylinder for just a short time (only 3 1/2° of rotation), but it is sufficient to give a slight supercharging effect.

The intake ports are closed at 48° after BDC, and compression takes place during the remainder of the upward stroke of the piston. Injection begins at about 22 1/2° before TDC and ends about 5° before TDC, depending on the engine speed and load.

The whole cycle is completed in one revolution of the crankshaft, and the piston is ready to deliver the next power stroke.

Multiple-Cylinder Engines

Theoretically, the power stroke of a piston continues for 180° of crankshaft rotation on a four-stroke-cycle engine. Best results can be obtained, however, if the exhaust valves are opened when the power stroke has completed about four-fifths of its travel. Therefore, the period that power is delivered during 720° of crankshaft rotation, or one four-stroke cycle, will be 145° multiplied by the number of cylinders in the engine. This may vary slightly according to the manufacturers' specifications. If an engine has two cylinders, power will be transmitted for 290° of the 720° necessary to complete the four events of the cycle. The momentum of the flywheel rotates the crankshaft for the remaining 430° of travel.

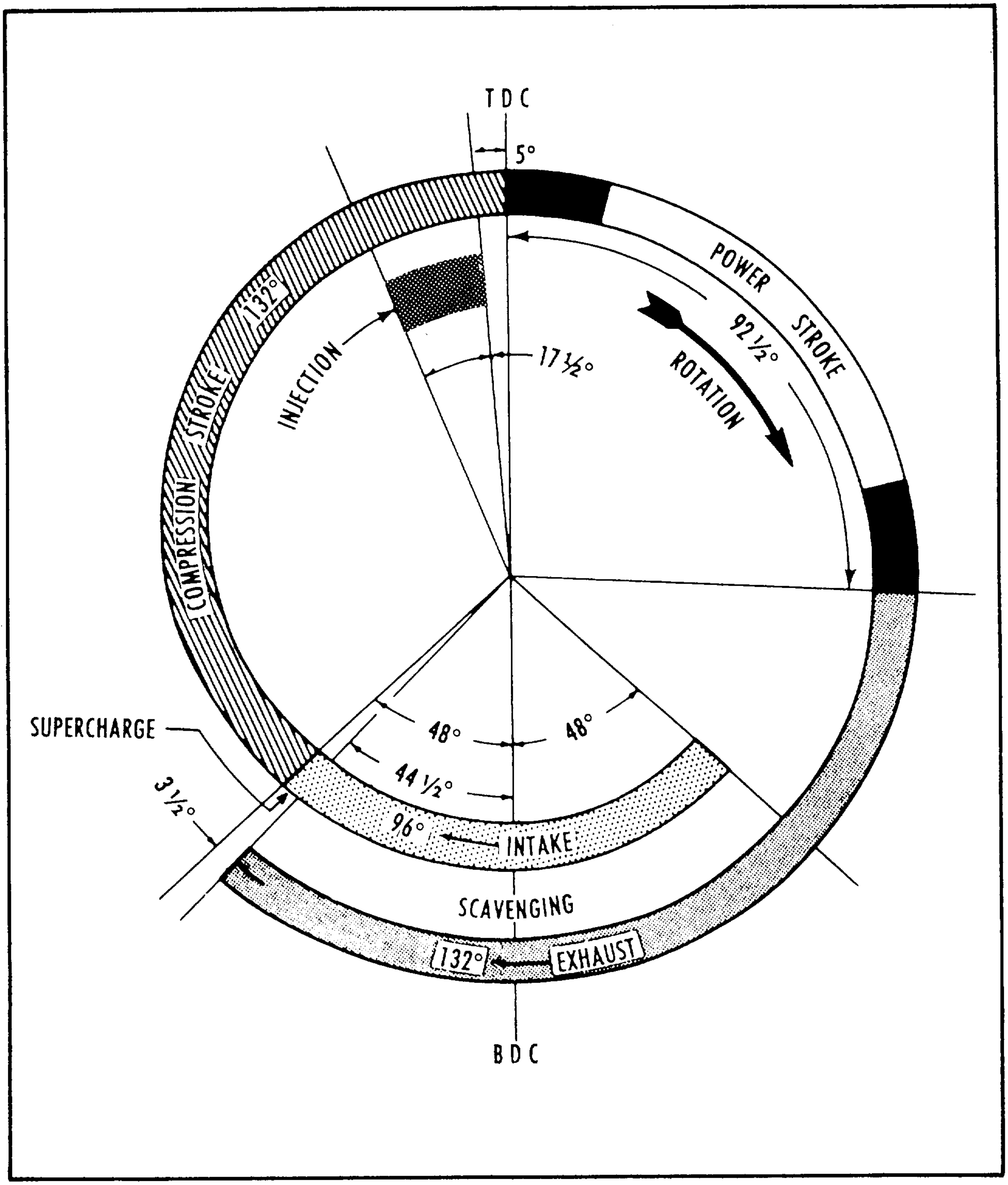
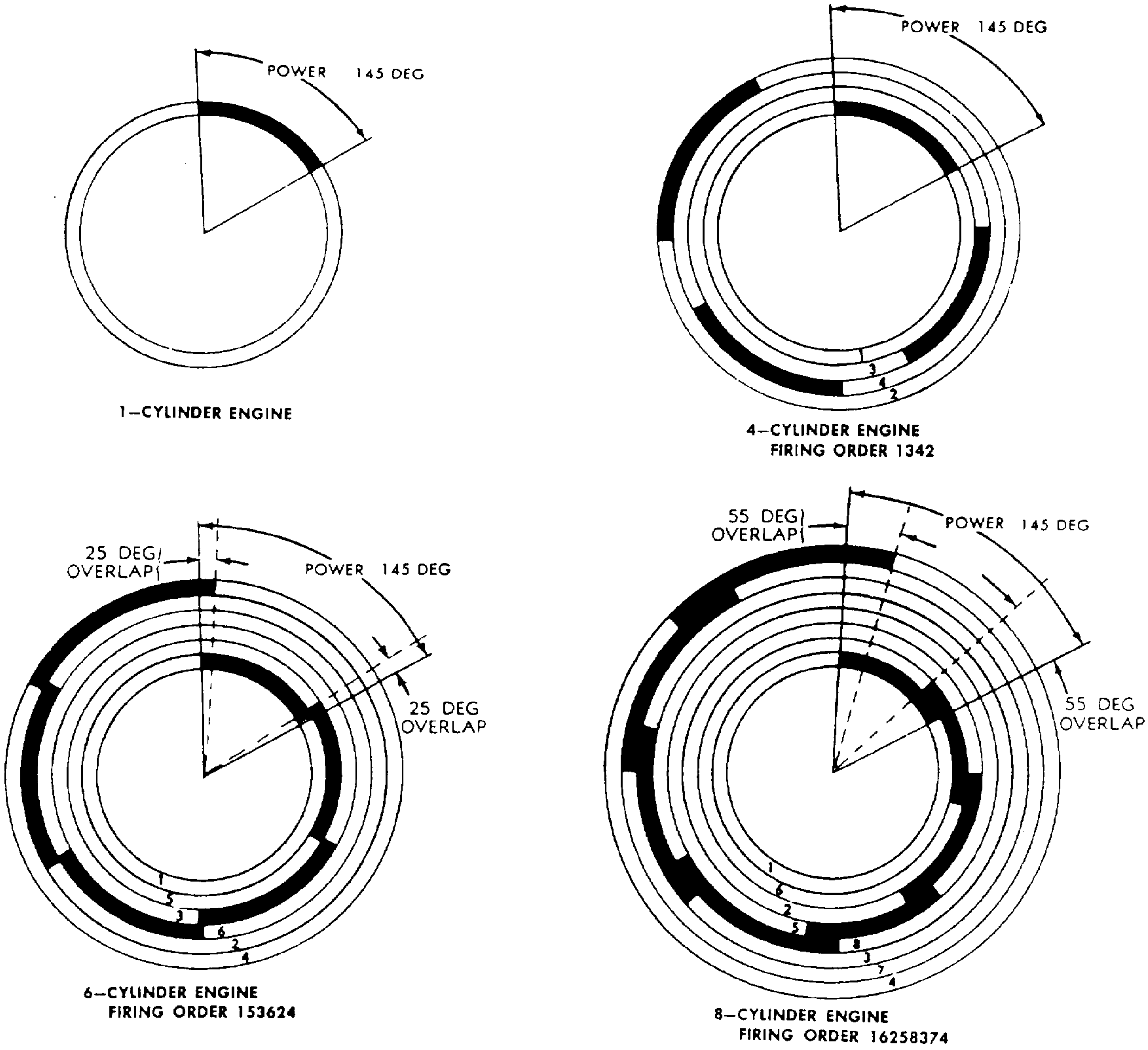


Figure 3-7.—Timing diagram of a two-stroke-cycle diesel engine.

As cylinders are added to an engine, each one must complete the four steps of the cycle during two revolutions of the crankshaft. The number of power impulses for each revolution also increases, producing smoother operation. If there are more than four cylinders, the power strokes overlap, as shown in figure 3-8. The length of overlap increases with the number of cylinders. The diagram for the six-cylinder engine shows a new power stroke starting each 120° of crankshaft rotation and lasting 145°. This provides an overlap of 25°. In the eight-cylinder engine, a power stroke starts every 90° and continues for 145°, resulting in a 55° overlap of power. Because the cylinders fire at regular intervals, the power overlap will be the same regardless of firing order and will apply to either in-line or V-type engines.

POWER LOSSES AND FAILURE

Power failures can result from minor troubles, such as loose or bare wires and disconnected or damaged fuel lines. When reported by the



NOTE.-THE CIRCLES SHOWN ABOVE REPRESENT 720 DEG NOT 360 DEG BECAUSE THE CRANKSHAFT MUST ROTATE THROUGH 720 DEG TO COMPLETE THE CYCLE ONCE FOR ALL CYLINDERS

Figure 3-8.-Power strokes in one-, four-, six-, and eight-cylinder engines.

Equipment Operator, these troubles are easy to detect without too much checking and testing. The supervisor must, however, make the mechanics aware that there probably was, in addition, an actual or contributing cause to the power failure. The supervisor must train the mechanics to look for this cause while making repairs. Unless eliminated, this may be the cause of major trouble later on.

Too often, troubles concerned with power loss occur within the engine and are not easily found. It is these hard-to-find troubles, with little or no visual indication, that keep the CMs busy. An operator may notice a decided power loss in the equipment and, because there is excessive smoke coming from the exhaust, report the trouble as improper carburetion, or, in the case of a diesel engine, as injector trouble.

An inexperienced mechanic may notice an increased engine temperature in addition to the exhaust smoke and diagnose the loss of power as improper valve action or as trouble in the cooling system. The diagnoses are comparatively simple through visual indications. But, as a CM1, you know that there are many causes of power loss that have little or no visual indications. Examples are incorrect ignition timing, faulty coil or condenser, defective mechanical or vacuum spark advance, worn distributor cam, or slipping clutch. Any of them can cause a power loss.

After a deficiency has been located in an engine, it is usually easy to make the necessary corrections to eliminate the conditions causing the deficiency. Careful analysis and straight thinking, however, are often needed to find the cause of engine deficiencies. If a supervisor has a thorough knowledge of the basic engineering and operating principles of an engine, his or her job of training the mechanics will be easier and more interesting. In diagnosing engine deficiencies, the supervisor must never jump to conclusions and make a decision on the nature of repairs to be made before being sure that what will be done will eliminate the trouble. The mechanics must be able to interpret the engine instrument indications as well as use the proper testing devices. Furthermore, they must be able to road test the equipment to determine whether repairs have been made satisfactorily and whether a part or several parts should be adjusted or replaced. Besides, the mechanic must know when and how to make emergency adjustments for every unit on the engine.

It may seem that some of the qualifications required of a good mechanic point to the know-how of an automotive engineer. However, no one person can know all about engines and also be an expert in repairing all kinds of powered equipment used by the SEABEEs. For instance, if the checks or instrument tests indicate some internal trouble in a magneto, carburetor, or fuel injection unit, the repairs should be made by mechanics who have experience or have been specially trained to use the equipment to do the particular job at hand. It is the supervisor who will be expected to have the answers to all the questions asked by less experienced mechanics.

The three basic factors that affect an internal combustion engine's power are as follows: COMPRESSION, IGNITION, and CARBURETION. In the diesel engine, fuel is injected into each cylinder, and ignition depends on the heat of compression; in the gasoline engine, ignition and carburetion are independent. In both engines, of course, proper action and timing of all three factors are necessary for the engine to produce its rated power.

It is obvious then that an engine runs and develops rated power only if all of its parts function or operate as they should. If any of these parts wear or break, requiring replacement or adjustment, the performance charts and engine specifications are "tools" that will help the mechanic to bring those parts back to their original relationship to each other.

There are more factors NOT directly associated with engine working parts that must be considered in correcting engine power losses.

OPERATING CONDITIONS can affect engine power. For example, the usable horsepower of an engine is reduced by the number of accessories it must operate. If the engine is required to provide power for lifting operations at the same time it is delivering power to wheels or tracks, the engine may be overloaded and may not be able to develop its rated rpm; consequently, the rated horsepower would NOT be reached.

The effect of ALTITUDE on engine power must also be considered. As a rule, 2 1/2 percent of the output of an engine is lost for every 1,000-foot increase in elevation above sea level. Overheated air entering the cylinders has the same effect on engine power as an increase in altitude. In computing horsepower output, engineers will deduct as much as 1 percent for each 10°F rise in the intake air temperature above a "normal" temperature of 70°F.

ENGINE TROUBLESHOOTING

"Diagnosing" may be defined as a systematic means of identifying a problem by using all available information and facts. Usually, the Equipment Operator will be able to tell the symptoms, such as the engine lacks power, uses excessive oil, has low oil pressure, or makes certain noises.

Some internal engine problems may be found by listening for unusual noises and knocks or by examining the exhaust gases for indications of incomplete combustion. Then too, placing an artificial load on an engine can emphasize certain noises; for example, applying the brakes and partially engaging the clutch with the vehicle transmission in high gear. In this manner, the engine operating under a load can be heard without the interference of body noises.

There are also other tricks of the trade that a mechanic may use, such as feeling the oil or shorting out the spark plugs to get an idea of the source of trouble.

EXCESSIVE OIL CONSUMPTION

Excessive oil consumption would probably first be noted by the Equipment Operator who has to add oil to maintain the proper oil level. There are two main causes of excessive oil consumption: external leakage and burning in the combustion chamber.

External oil leaks can often be detected by inspecting the seals around the oil pan, valve covers, timing gear housing, and at the oil line and oil filter connections.

The burning of oil in the combustion chamber usually produces a bluish tinge in the exhaust gas. Oil may enter the combustion chamber in two ways: (a) through clearances caused by wear between the intake valve guides and stems and (b) around the piston rings.

Excessive oil consumption caused by worn valve guides or stems may be indicated by too much carbon on the undersides of the intake valve. In this case, it is usually necessary to install valve seals, new valve guides, or new valves. If excessive oil consumption is caused by worn rings or worn cylinder walls, the supervisor may have the mechanics do a complete engine overhaul.

LOW OIL PRESSURE

Low oil pressure often indicates worn engine bearings. Worn bearings can pass so much oil that the oil pump cannot maintain oil pressure. Other causes of low oil pressure include a weak relief-valve spring, a worn oil pump, a broken or cracked oil line, or a clogged oil line. Oil dilution, foaming, sludge, insufficient oil, incorrect oil, or oil made too thin by the engine overheating will also cause low oil pressure.

ENGINE NOISES

A variety of engine noises may occur, Although some noises have little significance, others can indicate serious engine trouble that will require prompt attention to prevent major damage to the engine.

A listening rod can be of help in locating the source of a noise. The rod acts somewhat like the stethoscope a doctor uses to listen to a patient's heartbeat or breathing. When one end is placed at the ear and the other end at some particular part of the engine, noises from that part of the engine will be carried along the rod to your ear. By determining the approximate source of the noise, you can, for example, locate a broken or noisy ring in a particular cylinder or a main bearing knock.

Valve and Tappet Noise

Valve and tappet noise is a regular clicking sound that increases in intensity as the engine speed increases. The cause is usually excessive valve clearance. A feeler gauge inserted between the valve stem and lifter or rocker arm will reduce the clearance, and the noise should decrease. If the noise does not decrease when the feeler gauge is inserted, it is probably caused by weak lifter springs, worn lifter faces, lifters loose in the block, a rough adjustment-screw face, a rough cam lobe, or possibly the noise is not from the valves at all.

A noisy hydraulic valve lifter maybe sticking because of dirt in the ball or disk valve. When this happens, you must disassemble the lifter and clean all the parts in a clean solvent. Then reassemble the lifter and fill it with clean, light engine oil.

Connecting Rod Noise

Connecting rod noise usually tends to give off a light knocking or pounding sound. The sound is more noticeable when the engine is "floating" (not accelerating or decelerating) or as the throttle is eased off with the vehicle running at medium speed. To locate a noise in the connecting rod, short out the spark plugs one at a time. The noise will be greatly reduced when the piston in the cylinder that is responsible is not delivering power.

Piston-Pin Knock

Piston-pin knock is identified more as a metallic double-knock rather than a regular clicking sound like that heard in valve and tappet noise. In addition, it is most noticeable during idle with the spark advanced. A check can be made by idling the engine with the spark advanced and then shorting out the spark plugs. Piston-pin noise coming from a cylinder will be reduced somewhat when the spark plug for that cylinder is shorted out. Causes of this noise are a worn or loose piston-pin, a worn bushing, and a lack of oil.

Piston-Ring Noise

Piston-ring noise is also similar to valve and tappet noise since it is identified by a clicking, snapping, or rattling sound. This noise is most noticeable on acceleration. Low-ring tension, broken or worn rings, or worn cylinder walls will produce this sound. To avoid confusing this sound with other engine noise, make the following test: remove the spark plugs and add an ounce or two of heavy engine oil to each cylinder. Crank the engine for several revolutions to work the oil down past the rings. Replace the spark plugs and start the engine, If the noise has decreased, it is probable that the rings are at fault.

Piston Slap

Piston slap may be detected by a hollow, bell-like knock and is due to the rocking back and forth of the piston in the cylinder. If the slap occurs only when the engine is cold, it is probably not serious. However, if it occurs under all operating conditions, a further examination is called for. The slap can be caused by worn cylinder walls, worn pistons, collapsed piston skirts, or misaligned connecting rods.

Crankshaft Knock

Crankshaft knock is a heavy, dull, metallic knock that is noticeable when the engine is under load or accelerating. When the noise is regular, it can be contributed to worn main bearings. When irregular and sharp, the noise is probably due to worn thrust bearings.

ENGINE TESTING

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

Four of the most widely used testing instruments are the cylinder compression tester, vacuum gauge, cylinder leakage tester, and tachometer.

Compression Test

As you have learned, engine power results from igniting a combustible mixture that has been compressed in the combustion chamber of an engine cylinder. The tighter a given volume of fuel mixture is squeezed in the cylinder before it is ignited, the greater the power developed. Unless approximately the same power is developed in each cylinder, the engine will run unevenly. The cylinder compression tester (fig. 3-9) is used to measure cylinder pressure in psi, as the piston moves to TDC on the compression stroke.

By measuring compression pressures of all cylinders with a compression gauge, then comparing them with each other and with the manufacturer's specifications for a new engine, you get an accurate indication of engine condition.

The compression pressures in the different cylinders of an engine may vary as much as 20 pounds. The variation is caused largely by the lack of uniformity in the volume of the combustion chamber. It is nearly impossible to make all the combustion chambers in a cylinder head exactly the same size. For example, in a given engine with

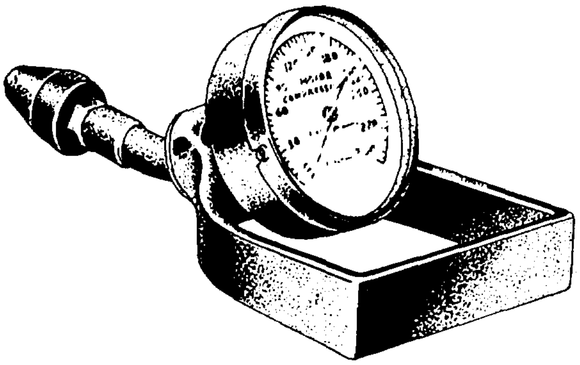


Figure 3-9.—Cylinder compression tester.

a 7 to 1 compression ratio with all combustion chambers the same volume, the compression pressure would be about 120 pounds in all cylinders. However, if one combustion chamber is 1/3 cubic inch too small, the pressure will be about 126 pounds, and if it is 1/3 cubic inch too large, the compression pressure would be about 114 pounds. This is a variation of 12 pounds. Also note that a carbon deposit will raise the compression pressure at any given ratio by reducing the combustion chamber volume—the greater the deposit, the higher the pressure.

To make a compression test, first, warm up the engine. Warming up will allow all the engine parts to expand to normal operating condition and will ensure a film of oil on the cylinder walls. Remember that the oil film on the walls of the cylinder helps the expanded piston rings to seal the compression within the cylinder. After the engine is warmed to operating temperature, shut it down and remove all the spark plugs. Removing all the plugs will make the engine easier to crank while you obtain compression readings at each cylinder. The throttle and choke should be in a wide-open position when compression readings are taken. Some compression gauges can be screwed into the spark plug hole. Most compression gauges, however, have a tapered rubber end plug and must be held securely in the spark plug opening until the highest reading of the gauge is reached.

Crank the engine with the starting motor until it makes at least four complete revolutions. Normal compression readings for gasoline engine cylinders are usually 100 psi or slightly higher. Compression testing is faster and safer when there are two mechanics assigned to the job. Remember that the compression test must be completed before the engine cools off.

Unless the compression readings are interpreted correctly, it is useless to make the tests. Any low readings indicate a leakage past the valves, piston rings, or cylinder head gaskets. Before taking any corrective action, make another check to try to pinpoint the trouble. Pour approximately a tablespoon of heavy oil into the cylinder through the spark plug hole, and then retest the compression pressure. If the pressure increases to a more normal reading, it means the loss of compression is due to leakage past the piston rings. If adding oil does not help compression pressure, the chances are that the leakage is past the valves. Low compression between two adjacent cylinders indicates a leaking or a blown head gasket. If the compression pressure of a cylinder is low for the first few piston strokes and then increases to near normal, a sticking valve is indicated. Near normal compression readings on all cylinders indicate that the engine cylinders and valves are in fair condition. Indications of valve troubles by compression tests may be confirmed by taking vacuum gauge readings.

Vacuum Gauge Test

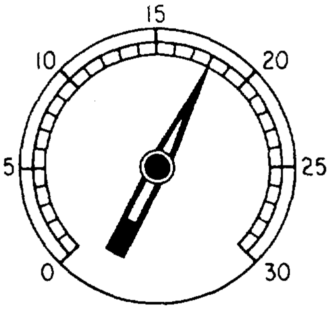
When an engine has an abnormal compression reading, it is likely that the cylinder head will have to be removed to repair the trouble. Nevertheless, the mechanics should test the vacuum of the engine with a gauge. The vacuum gauge provides a means of testing intake manifold vacuum, cranking vacuum, fuel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

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

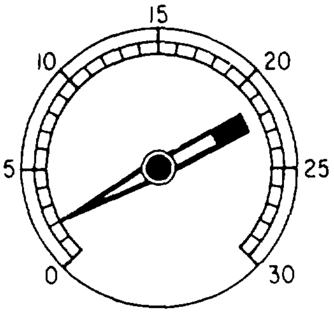
When a test is made at an elevation of 1,000 feet or less, an engine in good condition, idling at a speed of about 550 rpm, should give a steady reading of from 17 to 22 inches on the vacuum gauge. The average reading will drop approximately 1 inch of vacuum per 1,000 feet at altitudes of 1,000 feet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

When the throttle is opened and closed suddenly, the vacuum reading should first drop to about 2 inches with the throttle open, and then come back to a high of about 24 inches before settling back to a steady reading as the engine idles, as shown in figure 3-10. This is normal for an engine in good operating condition.

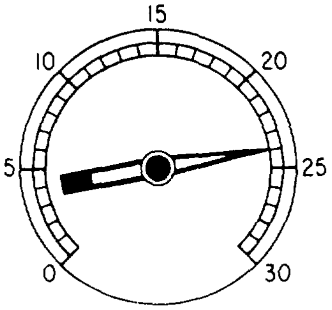
If the gauge reading drops to about 15 inches and remains there, it would indicate compression leaks between the cylinder walls and the piston rings or power loss caused by incorrect ignition timing, A vacuum gauge pointer indicating a steady 10, for example, usually means that the valve timing of the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



NORMAL IDLE



THROTTLE OPENED SUDDENLY



MAX READING AFTER
THROTTLE IS OPENED SUDDENLY

Figure 3-10.—Approximate vacuum gauge readings on a normal operating engine.

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

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

Vacuum gauge tests only help to locate the trouble. They are not always conclusive, but as you gain experience in interpreting the readings, you can usually diagnose engine behavior.

Cylinder Leakage Test

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

There are commercial cylinder leakage testers available, but actually the test may be conducted with materials readily available in most repair shops. In addition to the supply of compressed air, a device for attaching the source of air to the cylinder is required. For a gasoline engine, this device can be made by using an old spark plug of the correct size for the engine to be tested. By removing the insulator and welding a pneumatic valve stem to the threaded section of the spark plug, you will have a device for introducing the compressed air into the cylinder.

The next step is to place the piston at TDC or “rock” position between the compression and power strokes. Then you can introduce, the compressed air into the cylinder. Note that the engine will tend to spin. Now, by listening at the carburetor, the exhaust pipe, and the oil filler pipe (crankcase), and by observing the coolant in the radiator, when applicable, you can pinpoint the area of air loss. A loud hissing of air at the carburetor would indicate a leaking intake valve or valves. Excessive hissing of air at the oil filler tube (crankcase) would indicate an excessive air leak past the piston rings. Bubbles observed in the coolant at the radiator would indicate a leaking head gasket.

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

In making a cylinder leakage test, remove all the spark plugs so that each piston can be positioned without the resistance of compression of the remaining cylinders. The commercial testers, such as the one shown in figure 3-11, have a gauge indicating a percentage of air loss. The gauge is connected to a spring-loaded diaphragm. The source of air is connected to the instrument and counterbalances the action of the spring against the diaphragm. By adjusting the spring tension, you can calibrate the gauge properly against a variety of air pressure sources within a given tolerance.

Tachometer

The tachometer is a speed-indicating instrument that measures the rpms of a rotating shaft. It maybe either manually or electrically operated.

A manual tachometer (fig. 3-12) is held by its tip against the end of an exposed rotating shaft. Make sure the end of the shaft is clean and there is no slippage between the tip of the tachometer and the shaft. Read the speed directly on the tachometer dial, which is calibrated in revolutions per minute. No timing is necessary, as variations in speed will be reflected by movement of the pointer on the dial during the test.

When using the manual tachometer on a shaft, make sure that that shaft turns at the same speed as the crankshaft or you will not get an accurate reading of engine rpms. In many instances, it is easy to take manual tachometer readings from a camshaft or fuel pump shaft. On four-cycle engines, this shaft runs at one-half engine speed. Consequently, any manual tachometer reading taken from this shaft must be doubled to get the true engine speed.

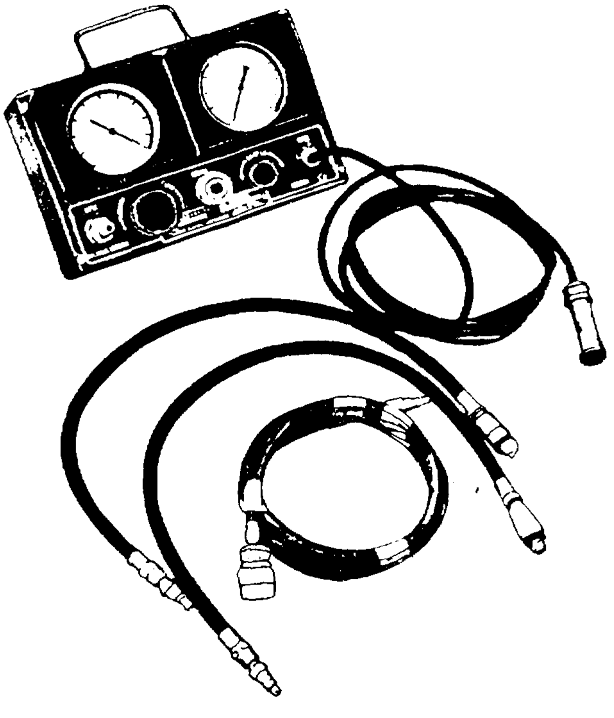


Figure 3-11.—Cylinder leakage tester.

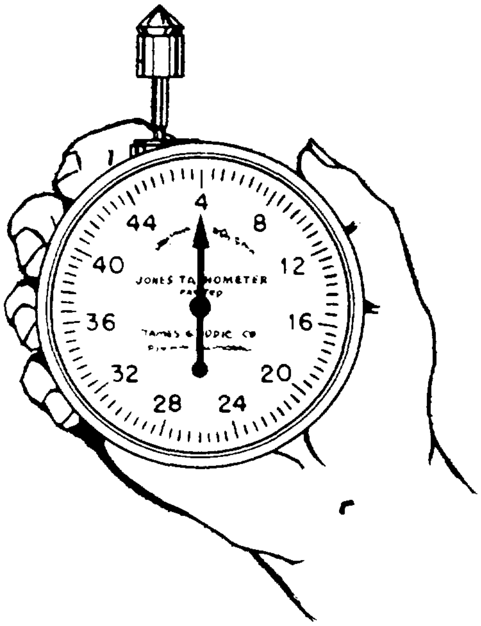


Figure 3-12.—Manually operated tachometer.

The electric tachometer is connected to the ignition primary circuit to measure the number of times per minute the primary circuit is interrupted. It then translates this information into engine speed.

The electric tachometer may have a selector switch on it that can be turned to correspond with the number of lobes on the distributor cam. The number of lobes will be the same as the number of cylinders in the engine. For the proper method of hooking up and using the electric tachometer, check the manufacturer's instructions for the tachometer you are using.

GAUGE CARE AND MAINTENANCE

As a CM1, you will probably be responsible for the care and maintenance of the engine testing equipment, such as cylinder compression tester, vacuum gauge, cylinder leakage tester, and tachometer. You, as the supervisor, must impress upon the mechanics that these gauges and testers are fragile instruments that can be damaged through improper use or rough handling. They should be kept in a safe place in the toolroom and should be returned there immediately after being used. Keeping the gauges and testers clean is about all the maintenance that is required. If they are dropped, broken, or jarred out of calibration, it is generally necessary to return them to the manufacturer for repairs or to replace them.

VALVES, VALVE MECHANISMS, AND CYLINDER HEADS SERVICING

When an engine has been properly maintained and serviced, the first major repair job it will need will normally involve the valves. A general procedure for servicing valves is described in the NAVEDTRA training manual for second class Construction Mechanics. Here, you will get more details on the servicing and troubleshooting of valves, valve mechanisms, and cylinder heads.

VALVE TROUBLES

Some of the common valve troubles that you may encounter in working with engines, and possible causes of these troubles, are indicated below.

- Sticking valves may be caused by gum or carbon deposits, worn valve guides, a warped valve stem, insufficient oil, cold engine operation, or overheating.

- Valve burning maybe caused by a sticking valve, insufficient valve tappet clearance, a distorted seat, overheated engine, lean fuel-air mixture, preignition, detonation, or valve seat leakge.

- Valve breakage may occur by valve overheating, detonation, excessive tappet clearance, seat eccentric to stem, cocked spring or retainer, or scratches on the stem caused by improper cleaning.

- Valve face wear maybe caused by excessive tappet clearance, dirt on the face, or distortion.

- Valve deposits may be produced by gum in the fuel, a rich fuel mixture, poor combustion, worn valve guides, dirty oil, or the use of a wrong oil.

VALVE ADJUSTMENTS

Proper and uniform, valve adjustments are required for a smooth running engine. Unless the clearance between valve stems and rocker arms or valve lifters is adjusted according to the manufacturer’s specifications, the valves will not open or close at the proper time, and engine performance will be affected. Too great a clearance will cause the valves to open late. Excessive clearance may also prevent a valve from opening far enough and long enough to admit a full charge of air or fuel mixture (with either a diesel or gasoline engine), or it will prevent the escape of some exhaust gases from the cylinder. A reduced charge in the cylinder obviously results in engine power loss. Exhaust gases that remain in the cylinder take up space, and when combined with the incoming charge, reduce the effectiveness of the mixture. Valves adjusted with too little clearance will overheat and warp. Warped valves cannot seat properly and will permit the escaping combustion flame to burn both the valve and valve seat.

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

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

Overhead Valves

Most overhead valves are adjusted “hot”; that is, valve clearance recommendations are given for an engine at operating temperatures. Before valve adjustments can be properly effected, the engine must be run and brought up to normal operating temperature.

To adjust a valve, remove the valve cover and measure the clearance between the valve stem and the rocker arm. Loosen the locknut and turn the adjusting screw in the rocker arm, in the manner shown in figure 3-13. On engines with stud-mounted rocker arms, make the adjustment by turning the stud nut.

Valves in Block

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

Valves within the block are generally adjusted "cold"; that is, recommended valve clearance are given for a cold engine. These valves have mechanisms quite similar to those of overhead valves. They are adjusted by removing the side plates, usually found beneath the intake manifold on the side of the engine block (fig. 3-14). Since you must stop this engine to adjust the valves, the piston in the cylinder to be adjusted must be on TDC of the compression stroke. You can determine this by watching the valves of the piston that is paired with the one that is being set. As the cylinder that is being positioned is coming up on the compression stroke, the paired cylinder will be coming up on the exhaust stroke. Therefore, an exhaust valve will be open. Just as the exhaust valve closes and the intake valve begins to open, the cylinder that is to be set will be on TDC of the compression stroke, and you can set the two valves. Once the No. 1 cylinder is positioned, follow through according to the firing order of the engine, as this makes the job easier and faster. You may also use this procedure when adjusting valves on overhead valve engines.

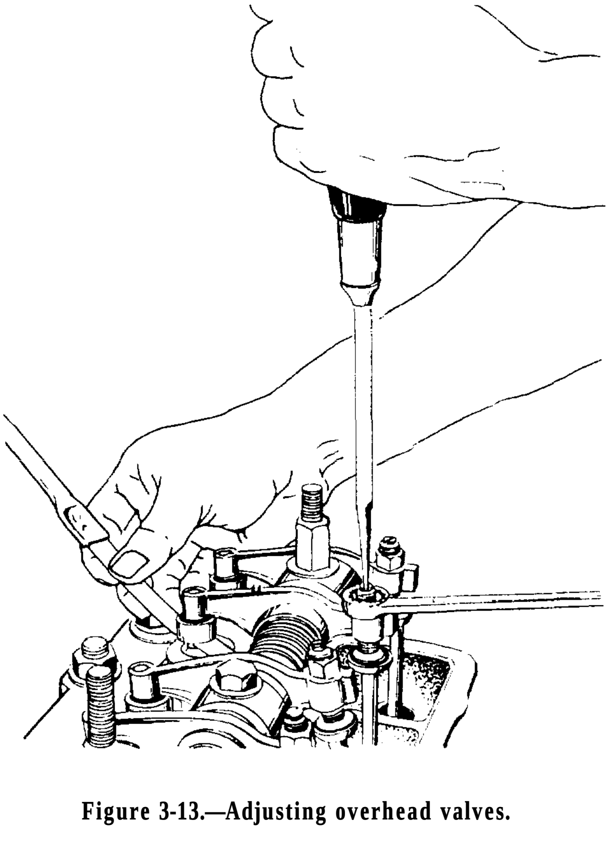


Figure 3-13.—Adjusting overhead valves.

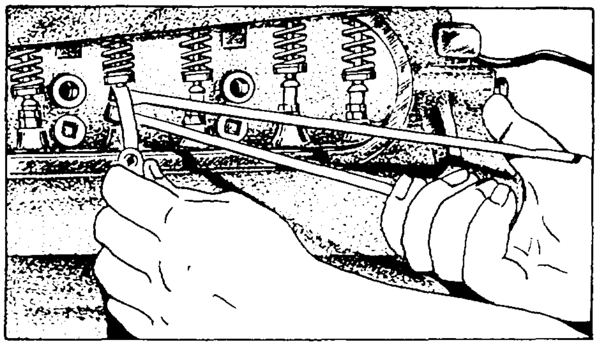


Figure 3-14.—Adjusting valve in block.

Hydraulically Operated Valves

On engines equipped with hydraulic valve lifters (fig. 3-1 5), it is not generally necessary to

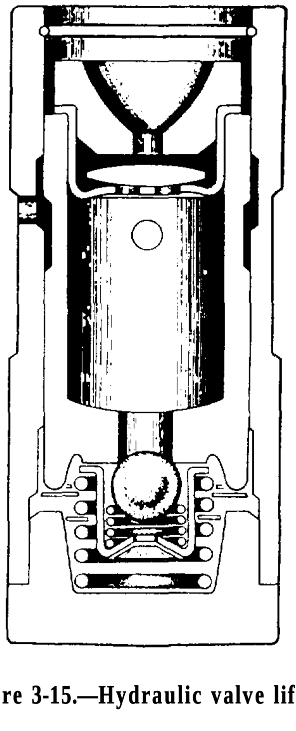


Figure 3-15.—Hydraulic valve lifter.

adjust the valves periodically. The engine lubrication system supplies a flow of oil to the lifters at all times. These hydraulic lifters operate at zero clearance and compensate for changes in engine temperature, adapt automatically for minor wear at various points, and thus provide ideal valve timing.

The first indication of a faulty hydraulic valve lifter is a "clicking" noise. In one method for locating a noisy valve lifter, you use a piece of garden hose. Place one end of the hose near the end of each intake and exhaust valve and the other end of the hose to your ear. In this way you can localize the sound, making it easy to determine which lifter is at fault. Another method is to place a finger on the face of the valve spring retainer. If the lifter is not functioning properly, a distinct shock will be felt when the valve returns to its seat.

Usually, where noise exists in one or more of the valve lifters, you should remove all lifter units, clean them in a solvent, reassemble them, and reinstall them in the engine. If dirt, carbon, or the like, is found in one unit, it more than likely is present in all of them; and it will be only a matter of time before the rest of the lifter units will give trouble.

VALVE REMOVAL

For such services as valve or valve seat grinding, valve seat insert replacement, and valve guide cleaning or replacement, you need to remove the cylinder head and valves from the engine. Avoid interchanging valves; each valve must be replaced in the valve port from which it was removed. A valve rack in which the valves may be placed in their proper order—along with their valve springs, retainers, and locks—is normally provided. Different tools and procedures for removal are used for different engines. Check the manufacturer's maintenance manual for your particular engine.

VALVE GRINDING

The first step in servicing valves after they have been removed from the engine is to rid them of carbon. The best method for doing this is cleaning them with a wire buffing wheel or brush.

WARNING

When using the wire buffing wheel, always wear goggles to protect your eyes from wire or carbon that may fly off the buffing wheel.

After the cleaning process, inspect each valve to determine whether it can be serviced and reused or must be replaced. The valve should be checked with a run-out gauge for eccentricity and inspected for worn valve stem and badly cracked, burned, or pitted valve face. Minor pits, burns, or irregularities in the valve face may be removed by grinding.

To grind valves, clamp the valve stem in the chuck of the valve-refacing machine so that the face of the valve will contact the grinding wheel. (See fig. 3-16.) Set the chuck at the proper angle to give the correct angle to the setting face. This angle must just match the valve seat angle. It is becoming common, however, in some engines to reface the valves at a slightly flatter angle than the seat, usually 1/4° to 1°, to provide what is known as an "interference angle." This angle provides greater pressure at the upper edge of the valve seat, which aids in cutting through any deposits that form and provides for better sealing. Some engines use the interference angle on the exhaust valve only, and others use it on both the intake and exhaust valves. Check the manufacturer's manual for the recommended angle for both valve and valve seat.

CAUTION

Because of the different angles between the valve and the valve seat, do NOT use grinding compound to finish the surface.

At the start of the grinding operation, make the first cut a light one. If metal is removed from only one-third or one-half of the valve face, check to make sure you have cleaned the valve stem and grinder chuck thoroughly and centered the valve

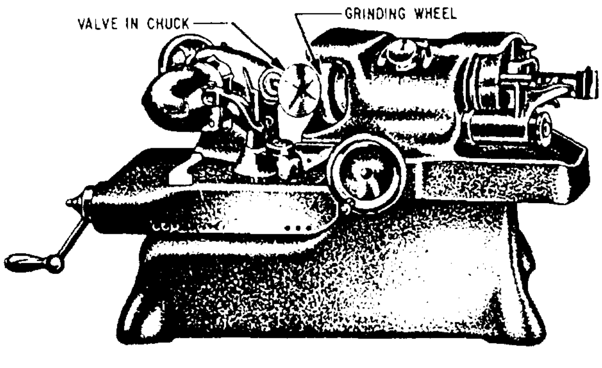


Figure 3-16.—Valve-refacing machine.

in the chuck. If the valve is centered properly, then the valve stem is bent and the valve must be replaced. Remove only the amount of metal necessary to true up the face and remove the pits. Make sure there is a proper margin of thickness, as shown in figure 3-17. If this margin cannot be retained after refacing, the valve must be discarded.

There are many different makes and models of valve-refacing machines. Make sure that you read and understand the instructions that apply to the machine you are using.

VALVE GUIDE SERVICING

When servicing valve guides, remember that the guides must be clean and in good condition for normal valve seating. If, after cleaning a valve guide, you find it worn, remove it and install a new one. To remove old or worn valve guides and install new ones, you need special guide removing and replacing tools.

One procedure for checking valve guide wear is as follows. Remove the cylinder head from the vehicle to a clean safe working area. Remove the valve springs and clean the valves and valve guides. Insert the valve into the guide, allowing the valve to remain off of its seat. Attach a dial indicator to the cylinder head with the gauge button just touching the edge of the valve head. Watch the dial indicator gauge face, and move the valve head sideways to determine the amount of valve guide wear.

Another checking procedure involves the use of a small hole gauge to measure the inside diameter of the guide and a micrometer to measure the valve stem; the difference in the readings will be the clearance. When the maximum clearance is exceeded, the valve guide needs further servicing before you can proceed. If the valve guide is of the integral type, you must ream it to a larger size and install a valve with an oversized stem. But if the guide is replaceable, you should remove it and install another one.

To remove valve guides, you will need a special puller. On many L-head engines, you can drive the guides down into the valve spring compartment and then remove them. You can use an arbor press to remove guides from the overhead type of engines.

To replace the guides, use a valve guide driver or a valve guide replacer except on overhead valve engines, where an arbor press is necessary. In any case, the guides must be installed to the proper depth in either the block or head, as specified by the manufacturer.

After the valve guides are serviced and the valve seats ground, check the concentricity of the two with a dial indicator. (See fig. 3-18.) Any irregularity in the seat will register on the dial.

VALVE SEAT GRINDING

Two general types of valve seat grinders are in use. One is a concentric grinder; the other, an eccentric grinder. Only the concentric grinder is discussed here because of its greater availability.

In the concentric valve seat grinder (fig. 3-19), a grinding stone of the proper shape and angle

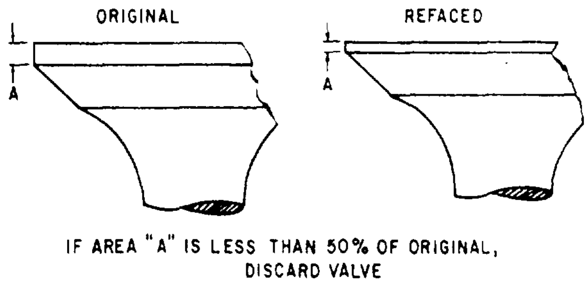


Figure 3-17.—Proper valve margin of thickness after refacing.

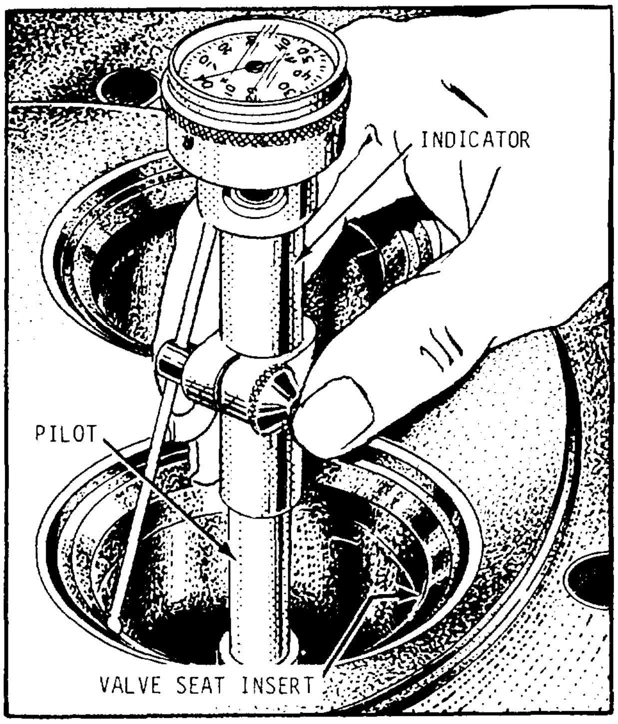


Figure 3-18.—Determining concentricity of the valve seat with a dial indicator.

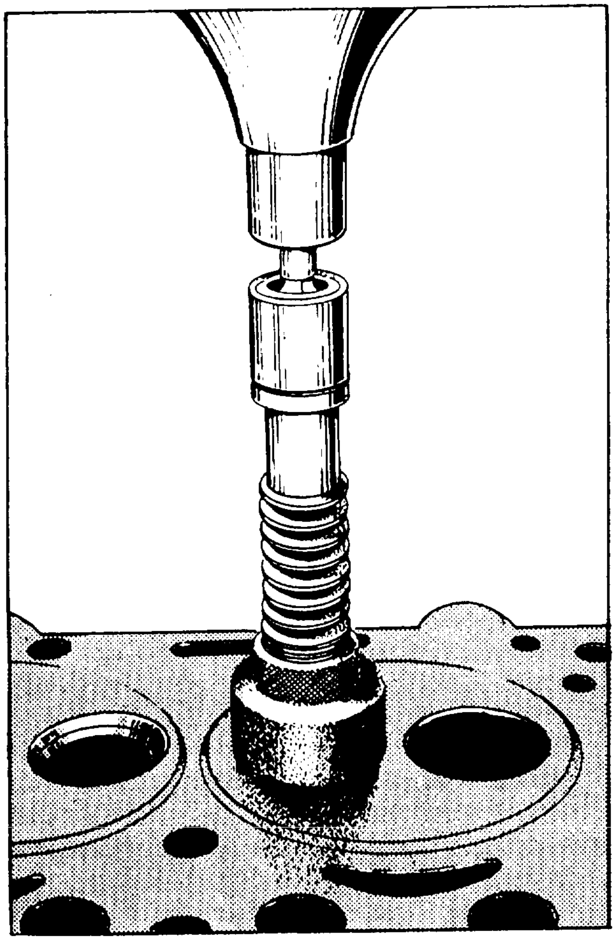


Figure 3-19.—Grinding valve seats using a concentric type of grinder.

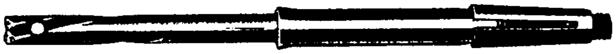


Figure 3-20.—Self-centering pilot.

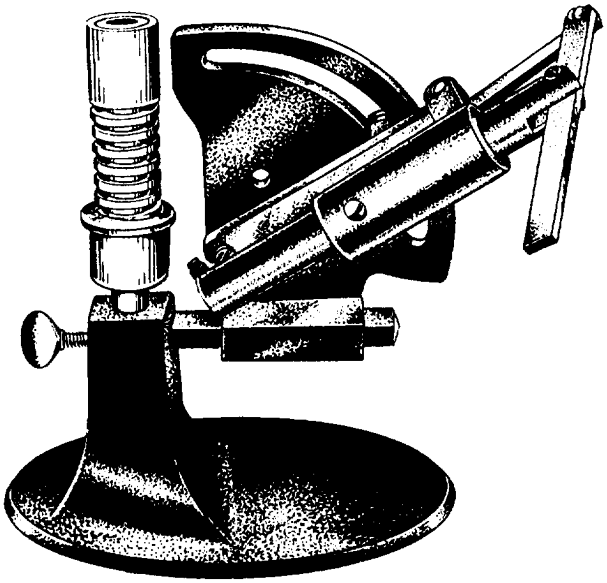


Figure 3-21.—Stone dresser.

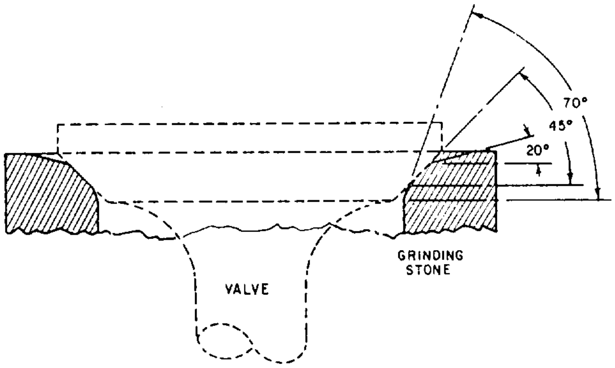


Figure 3-22.—Valve contact correction.

is rotated in the valve seat, The stone is kept concentric with the valve guide by means of a self-centering pilot (fig. 3-20), which is installed in the guide. Check the self-centering pilot for trueness before using, A damaged pilot will cause the seat position to move in relation to the valve guide. The valve guide must be kept clean and in good condition. Most of the concentric grinders of the Navy automatically lift the stone off the valve seat about once every revolution to allow the stone to clean itself of dust and grit by centrifugal action.

The abrasive stone must be dressed frequently with a diamond-tipped dressing tool, such as that shown in figure 3-21. Dressing the stone will ensure a uniform, even grinding of the valve seat.

After the seat is ground, it will be too wide. To narrow it, use upper and lower grinding stones to grind away the upper and lower edges of the seat. Figure 3-22 shows a typical valve seat that was ground at 45°, then narrowed at the top with a 20° grinding stone, and then ground at the bottom with a 70° grinding stone to narrow and center the valve seat.

To test the contact between the valve seat and the valve, mark lines with a soft pencil about one-fourth inch apart around the entire face of the valve. Next, put the valve in place and rotate, using a slight pressure, one-half turn to the right and then one-half turn to the left. If rotating removes the pencil marks, the seating is good.

Another method for checking the valve seating is to coat the valve face lightly with Prussian blue and turn it about one-fourth turn in the seat. If the Prussian blue transfers evenly to the valve seat, it is concentric with the valve guide. Be sure to wash all the Prussian blue from the seat and valve. Then lightly coat the valve seat with Prussian blue. If the blue again transfers evenly, this time to the valve when it is turned in the seat, you can consider the seating to be normal.

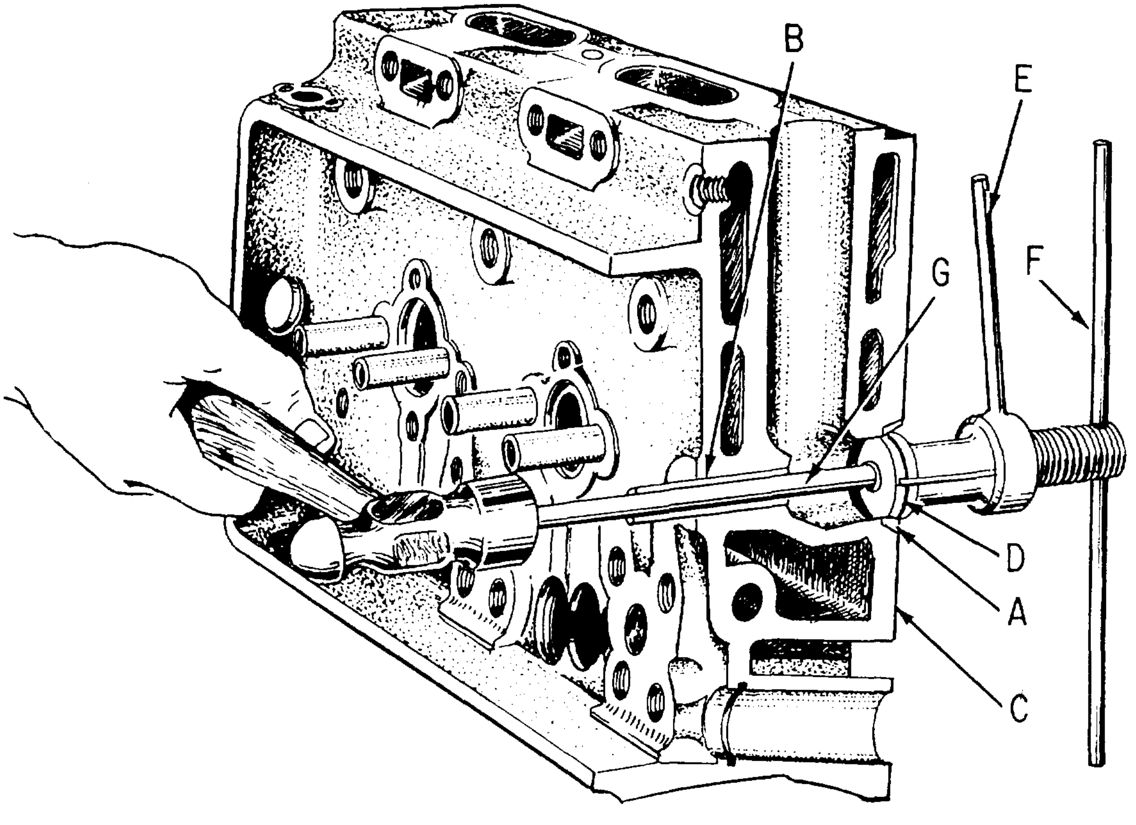
VALVE SEAT INSERT REPLACEMENT

Some engines are equipped with valve seat inserts that may be replaced when they are badly worn or burned or have been ground down to the point where there is not enough metal to permit another grind. You can remove the old valve seat by using a special puller, such as the one shown in figure 3-23. However, if a puller is not available, you can punch mark each side of the insert and then drill almost through. After drilling, take a hammer and chisel and break the insert into halves for easy removal.

Before installing a new insert, chill it for 15 minutes in dry ice or by any other chilling method. Chilling shrinks the insert so that it will fit in place. You may then drive it in place and grind the seat.

VALVE SPRING TESTING

Valve springs should be tested for uniform height and proper tension. To test for uniformity



A. Insert, Valve Seat
B. Guide, Exhaust Valve
C. Cylinder Head
D. Collet
E. Handle, Collet
F. T Handle
G. Bar, Drive

Figure 3-23.—Puller used in removing valve seat inserts.

of height, place the used springs on a level surface beside a new pair of springs. Use a straightedge to determine any differences in height. Unequal or cocked valve springs may cause faulty valve and engine performance.

The preferred method of testing valve springs for proper tension is by using a valve spring tester. The pressure required to compress the spring to the proper length is measured according to the manufacturer's specifications. Never use shims to compensate for a weak valve spring. Shims should be used to adjust the valve spring to the installed height only.

VALVE LIFTER SERVICING

There are two types of valve lifters: the solid type and the hydraulic type. Procedures for removing and servicing the two types are quite different.

Solid lifters are removed from the camshaft side on some engines. This requires removal of the camshaft. The lifters must be held up by clips or wires so that the camshaft can be extracted. Then the clips or wires are removed so that the lifters may be extracted. Most valve lifters may be extracted from the pushrod or valve side of the engine block, in which case extraction of the camshaft is not necessary. Be sure to keep the lifters in the proper order so that they may be replaced in the same bores from which they were removed.

If the lifter screw face is worn or pitted, it may be refaced on a valve-refacing machine. If the lifter bore in the block becomes worn, it maybe rebored by reaming; then oversized lifters must be installed.

Hydraulic lifters on some engines are tested by the leak-down-rate test. In testing, insert a feeler gauge between the rocker arm and the valve stem, and note the time it takes the valve lifter to leak enough oil to permit the valve to seat. As the valve seats, the feeler gauge becomes loose and signals the end of the test. If the leak-down-rate time is too short, the lifter is defective and must be replaced. In any case, be sure to follow the manufacturer's recommended procedures for performing this test.

To remove the hydraulic lifters, remove the pushrod. On engines with shaft-mounted rocker arms, the rocker arm may be moved by compressing the spring so that the pushrod can be removed. Thus, the rocker arm assembly does NOT have to be removed.

After the lifter has been removed, check the bottom or cam side to ensure that it is flat. To do this, place a straightedge across the lifter bottom. If light can be seen between the straightedge and the lifter, the lifter should be discarded.

When disassembling the lifter, be sure to clean all the parts in a cleaning solvent. Reassemble and fill the lifter with clean, light engine oil. Also, make sure that all lifters are replaced in the same bore from which they were removed. Work on one lifter at a time so that parts are not mixed between lifters.

ROCKER ARM SERVICING

After removing rocker arms, inspect them for wear or damage. Rocker arms that are equipped with bushings may be rebushed if the old bushing is only worn. As you know, the worn valve on slightly worn rocker arm ends can be ground down on a valve-refacing machine, whereas excessively worn rocker arms should be discarded.

When installing rocker arms and shafts in the cylinder head, make sure that the oil holes (in shafts so equipped) are on the underside so that they will feed oil to the rocker arms. If the springs and rocker arms are suitable for continued use, they should be reinstalled in their original positions in the head.

CAMSHAFT CHECKING

The camshaft must be checked for bearing-journal or cam wear and alignment. In checking alignment, place the camshaft in a set of V-blocks, and use a dial indicator to check the runout of the journals when the shaft is turned. Journals should be checked with a micrometer and the reading compared to the manufacturer's specifications. The cam wear should be measured with a micrometer; however, if wear shows across the full face of the cam, you can be almost certain that excessive wear has taken place.

CAMSHAFT BEARING REPLACEMENT

When camshaft bearings are worn or show excessive clearance, they should be replaced. Special tools are required to remove and replace cam bearings. When installing new bearings, be sure that the oil holes are aligned with those in the block. Also, make sure that new bearings are staked in the block if the old bearings were staked. On some engines that do not use precision-insert bearings, line reaming of the bearings is required after they have been installed.

VALVE TIMING

The relationship between the camshaft and the crankshaft determines the valve timing. Gears, drive chains, and reinforced neoprene belts are used to drive the camshafts that open and allow the valves to close in relation to the position of the pistons in the cylinders. The gears, drive sprockets, or cogs, as the case may be, of the camshaft and crankshaft are keyed in position so they cannot slip.

With directly driven timing gears (fig. 3-24), one gear usually has a mark on two adjacent teeth and the other, a mark on only one tooth. To time the valves properly, you need to mesh the gears so that the two marked teeth of the one gear straddle the single marked tooth of the other gear.

In chain-driven sprockets, you can obtain correct timing by having a certain number of chain teeth between the marks or by lining up the marks with a straightedge, as shown in figure 3-24.

Engines using a continuous neoprene belt have sprockets, or cogs, attached to the camshaft and crankshaft. The belt has square-shaped internal teeth that mesh with the teeth on the sprockets. All engines with this system use a timing belt tensioner. Timing marks on this system vary with each manufacturer.

Before setting the valve timing on any engine that you are overhauling, always check the manufacturer's specifications and instructions.

CRANKSHAFT SERVICING

Most modern engines have main and connecting rod bearings of the precision-insert type, which can be replaced without removing the crankshaft. However, if oil passages are blocked, journals are tapered out of round, or the crankshaft is bent, simply replacing the bearings will not correct the trouble.

If the bearings appear to have worn uniformly, probable the only requirements are crankshaft journal checks and bearing replacement. If bearing wear appears uneven, then the safest procedure is to remove the crankshaft from the engine and check it.

BEARING CAPS REMOVAL

When removing bearing caps, if they are not already marked, be sure to mark them so they will be replaced on the same journal from which they were removed. If bearing caps stick, carefully work them loose by using a soft-faced hammer,

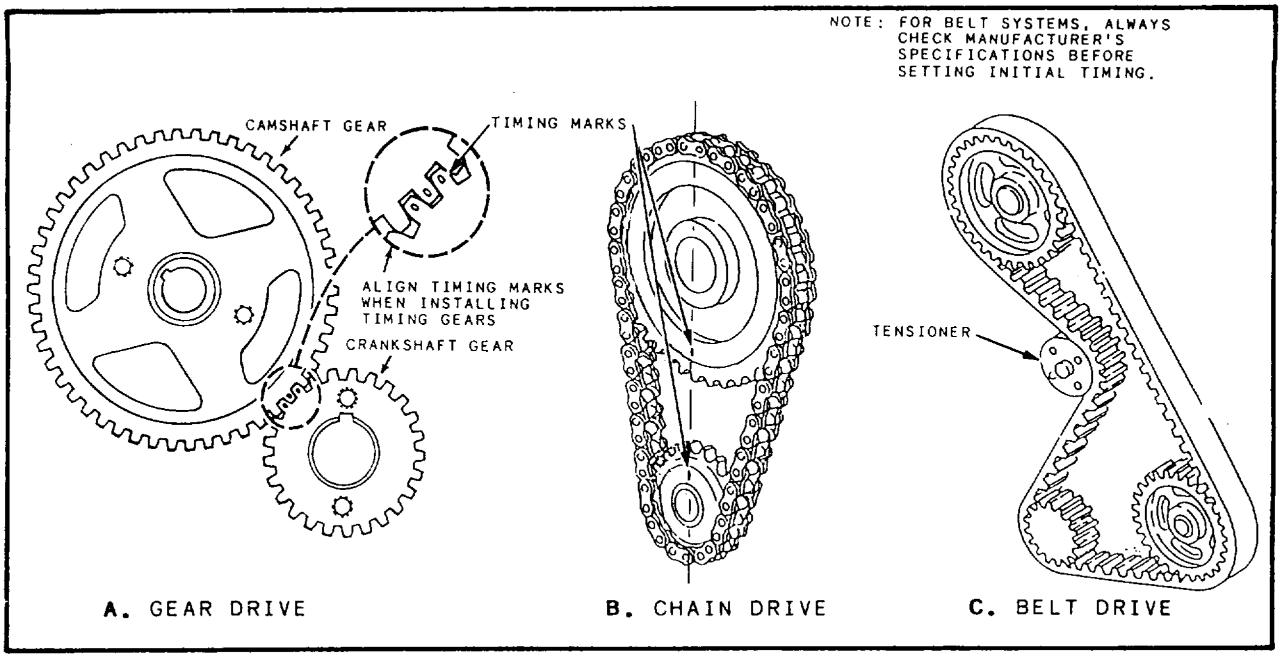


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Figure 3-24.—Driving the camshaft.

to avoid distorting them, and tapping the cap lightly on one side and then the other.

CRANKSHAFT REMOVAL

Once the bearing caps have been removed, lift the crankshaft out of the engine block. Usually one or two people do this seemingly simple operation by hand. With larger crankshafts, use a hoist (fig. 3-25), lifting above the center with a rope sling around two of the throws.

CAUTION

Do not bang the crankshaft around causing damage that will have to be repaired before the crankshaft may be put back in service.

CRANKSHAFT JOURNAL CHECK

The preferred method of measuring crankshaft journals is as follows. Remove the crankshaft from the engine block and clean the surfaces to be measured. Using the appropriate outside micrometer, measure the journals at several points around and across the bearing surface (fig. 3-26). Measurements around the journal will show if the journal is out of round. Those measurements across the surface show if the journal is tapered. Journals that are tapered or out of round more than .003 must be reground. BE SURE THAT YOU ALWAYS REFER TO MANUFACTURER'S SPECIFICATIONS WHEN PERFORMING ANY CRANKSHAFT WORK.

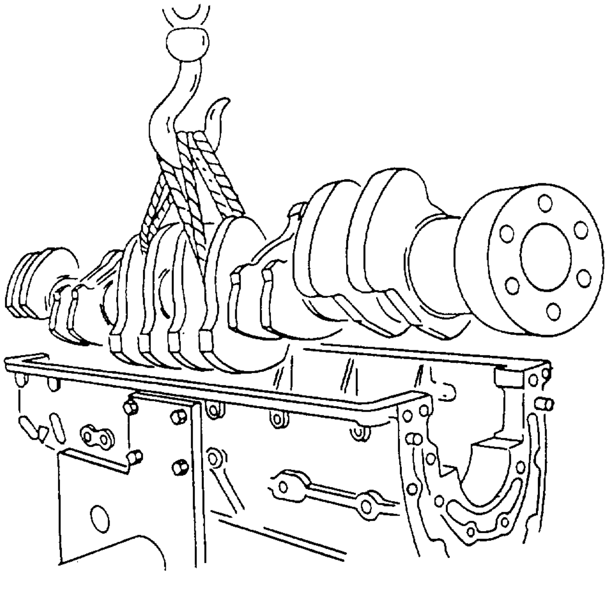


Figure 3-25.—Crankshaft removal using hoist.

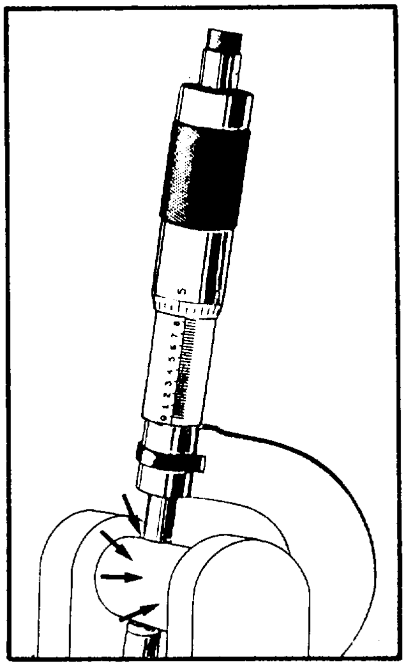


Figure 3-26.—Measuring the journals at different points around the diameter and along the length of the bearing surface.

CHECKING OF BEARING FIT

You should always check bearing fit or oil clearance when installing new bearings. When the bearing caps are off, you should measure the journals so that you can detect wear, out of roundness, or taper.

You can check bearing clearance with either feeler stock or Plastigage. Plastigage is a plastic material that is flattened by pressure. The amount it flattens indicates the amount of clearance.

Before checking bearing clearance with Plastigage, wipe the journal and the bearing clean of oil. Then place a strip of the Plastigage lengthwise in the center of the bearing cap (fig. 3-26). Install the cap next and tighten it into place. When the cap is removed, you can measure the amount of flattening of the strip with a special scale (fig. 3-26). Do NOT remove the flattened strip from the cap or the journal to measure the width, but measure it in place, as shown in figure 3-27. Not only does the amount of flattening measure bearing clearance, but uneven flattening also indicates a tapered or worn crankshaft journal or bearing.

CAUTION

Do not turn the crankshaft with the Plastigage in place.

When using feeler stock to check main bearing clearances, you should place a piece of stock of the correct size and thickness in the bearing cap after it is removed. The feeler stock should be coated lightly with oil. Then you should replace and tighten the bearing cap. Note the ease with which the crankshaft can be turned. As a word of caution, do not completely rotate the engine, which could damage the bearing. Turn it only about an inch in one direction or the other.

If the crankshaft is locked or drags noticeably after the bearing cap has been replaced and tightened, then the bearing clearance is less than the thickness of the feeler stock. If it does not tighten or drag, place an additional thickness of feeler stock on top of the first and again check the ease of crankshaft movement. Clearance normally should be about .002 inch. Be sure to check the engine manufacturer's shop manual for exact specifications.

CRANKSHAFT INSTALLATION

After preparing the engine block and crankshaft for reassembly, install the upper halves of the insert bearings into the engine block. Make sure all oil passages are aligned and open (fig. 3-28). Coat the bearings with lubricating oil and lower the crankshaft into place by hand or by the use of a hoist (fig, 3-25). Install the lower bearing inserts into the main bearing caps and fit them into place on the cylinder block. Tighten the main bearing caps, using proper sequence (fig. 3-29) and torque specifications. After the main bearings have been secured, the crankshaft should rotate without drag or binding.

CRANKSHAFT END PLAY CHECK

Crankshaft end play will become excessive if the thrust bearings are worn, producing a sharp, irregular knock. If the wear is considerable, the knock will occur each time the clutch is engaged or released; this action causes sudden endwise movement of the crankshaft. Crankshaft end play should only be a few thousandths of an inch. To measure this end play, force the crankshaft endwise as far as possible by using a pry bar, and then measure the clearance between the thrust bearing and the block with a feeler gauge.

CRANKSHAFT STORAGE

After the crankshaft has been removed from the engine, protect the crankshaft and prevent it

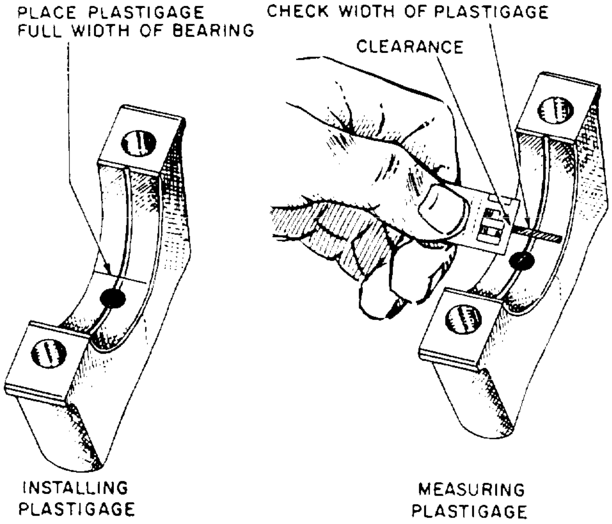


Figure 3-27.—Checking bearing clearance with Plastigage.

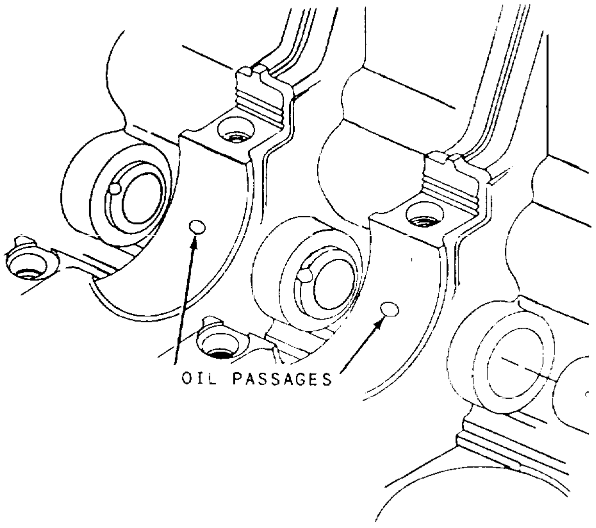


Figure 3-28.—Align these passages with passages in the cylinder block.

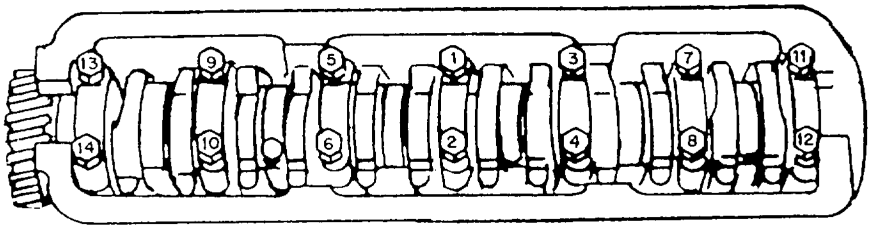


Figure 3-29.—Tighten bolts in proper sequence.

from becoming warped by storing it on end in a safe area.

CYLINDER SERVICING

There are certain limits to which cylinders may become tapered or out of round before they require refinishing. If they have only a slight taper or are only slightly out of round (consult the manufacturer's manual for the maximum allowable taper or out of round), new standard rings can be installed.

When cylinder wear goes beyond the point recommended in the engine manufacturer's specifications, loss of compression, high oil consumption, poor performance, and heavy carbon accumulations in the cylinder will result. In such cases, the only way to put the engine back into good operating condition is to refinish the cylinders and fit new pistons (or oversized pistons) and rings.

CYLINDER WALLS CHECK

As a first step in checking cylinder walls, wipe them clean and examine them carefully for scored places and spotty wear (which shows up as dark, unpolished spots on the walls). Holding a light at the opposite end of the cylinder from the eye will help in the examination. If scores or spots are found, you should refinish the cylinder walls.

Next, measure the cylinders for taper and oval wear. This can be done with an inside micrometer or by a special dial indicator, as shown in figure 3-30. As the dial indicator is moved up and down in the cylinder and turned from one position to another, any irregularities will cause the needle to move. This will indicate how many thousandths of an inch the cylinder is out of round or tapered.

The permissible amount of taper or out of roundness in a cylinder varies somewhat with different engines. Engine manufacturers issue recommendations based on experience with their own engine. When the recommendations are exceeded, the cylinders have to be refinished.

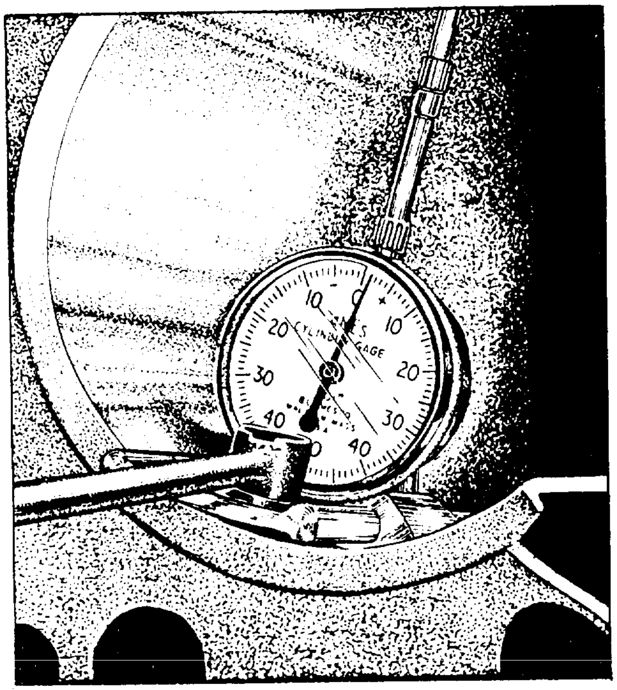


Figure 3-30.—Dial indicator for measuring cylinders.

CYLINDER REFINISHING

There are two methods of refinishing cylinders: honing and boring. Cylinders are refinished by honing when wear is not too great; otherwise, they are bored with a machine, and oversized pistons and rings are installed. This machine consists of a boring bar and cutting tool, and operating the boring machine will vary among different makes of equipment. Consult the manufacturer's operating manual for the procedures recommended.

In honing, two sets of stones—coarse and fine-are generally used along with honing oil or cutting fluid. If a lot of material must be removed, start with the coarse stones. You must leave sufficient material, however, so that the rough-honing marks can be removed with the fine stones. The final honed size must equal the size of the piston and rings to be installed.

During the final honing stage, occasionally clean the cylinder walls and check the piston size to guard against removing too much material or honing the cylinder oversize.

Honing is sometimes used to "break" or "crack" the glaze on cylinder walls when new rings are installed. The idea behind this is to remove the smooth glaze that has formed on the cylinder walls, thus giving the new rings a change to set quickly.

CYLINDER LINERS REPLACEMENT

Using replaceable cylinder liners can save time and costly machine work. First, determine the type of liners—wet or dry—that are used in the unit being rebuilt. Dry liners do not require a water seal and can simply be pulled out (fig. 3-31) and the new liner pressed into place. Wet liners have grooves cut into them (fig. 3-32) for fitting O-ring seals to prevent water leakage into the crankcase.

CAUTION

When installing the wet type of liners (fig. 3-33), use care to prevent damage to the O-ring seals.

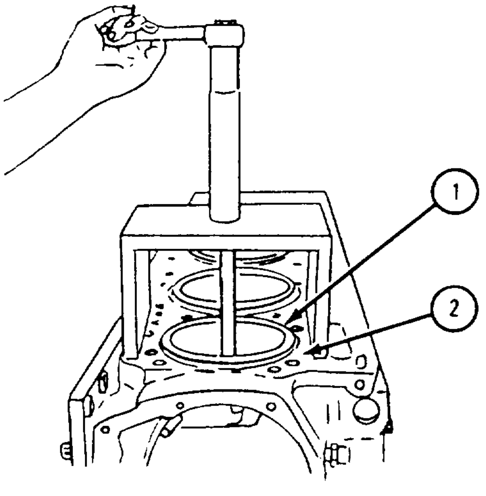


Figure 3-31.—Cylinder liner removal.

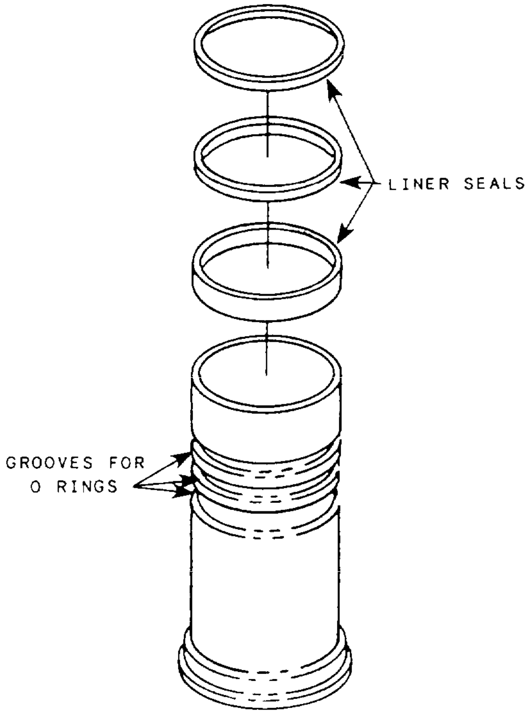


Figure 3-32.—Wet type of cylinder liner.

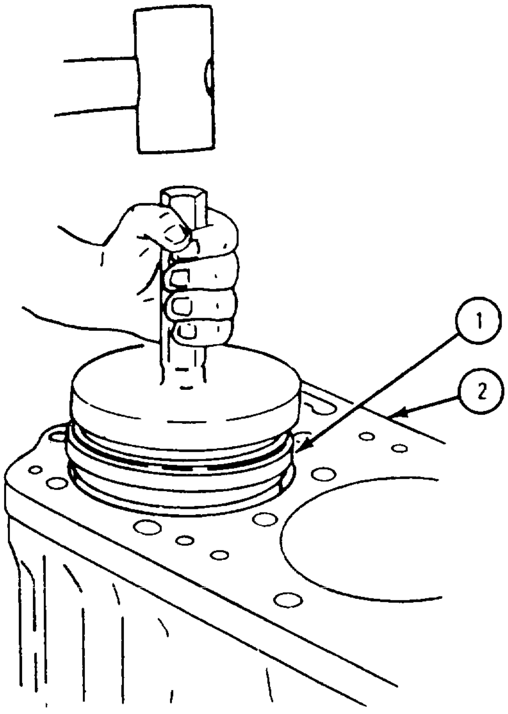


Figure 3-33.—Cylinder liner installation.

PISTONS AND RINGS SERVICING

When service is required on pistons and rings, they must first be removed from the engine. Where removal is to be from the top of the cylinder block, take the cylinder head off and examine the cylinder for wear. If the cylinder is worn, there will be a ridge at the upper limit of the top ring travel. Remove this ridge. If not removed, it will damage the piston and rings as they are forced out of the top of the cylinder.

To remove this ridge, use a reamer of the type shown in figure 3-34. Before placing the ridge reamer in the cylinder, be sure the piston has been placed at BDC. Stuff rags into the cylinder to protect the piston and piston rings from metal shavings during the reaming operation. Be sure to adjust the cutters to the correct depth of cut. After the reaming operation is complete, remove the rags and wipe the cylinder wall clean. Repeat the operation for each cylinder.

Before the connecting rods can be detached from the crankshaft, the oil pan must be removed. With the cylinder head and oil pan off, crank the engine so that the piston of the No. 1 cylinder is near BDC. Examine the piston rod and rod cap for identifying marks, and, if none can be seen, mark them with numbering dies to ensure replacing them in the same cylinders from which they were removed. Remove the rod nuts and cap them with a wrench, and slide the rod and piston assembly up into the cylinder away from the crankshaft and out of the cylinder. Place the assembly on a workbench and repeat this operation until all piston and rod assemblies have been removed.

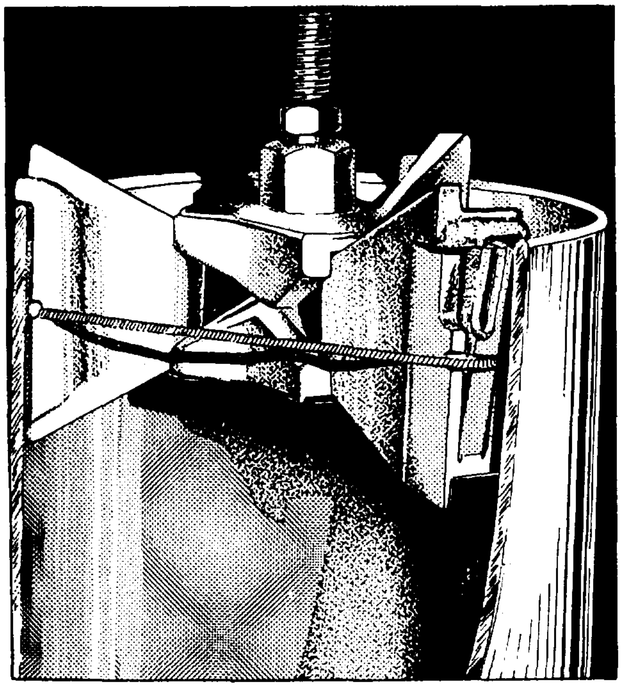


Figure 3-34.—Ridge reamer.

PISTON CLEANING

Before determining whether the pistons may be reused, you should clean them of all accumulations of varnish or carbon inside and out. Examine the old pistons carefully. Cracked skirts, scuffed sides, and broken ring lands are all reasons for piston replacement. It should be obvious that cylinders that are rebored require oversized pistons and rings. In this case, do not waste valuable time cleaning parts that are being discarded. Do not scrape the sides or skirts of the piston, since this may scratch the finish and cause excessive cylinder wall wear. Use a ring groove cleaner to remove built-up carbon from the ring grooves. When pulling this cleaner through the groove, remove only the carbon; do not remove any of the metal.

PISTON FITTING

After a piston has been cleaned, it should be measured with an outside micrometer. The measurements must be taken in various places to determine whether the piston is excessively worn or collapsed. Compare the measurements with those of the cylinder to determine if correct clearance exists. Consult the engine manufacturer's maintenance manual for details of measurements and allowable clearance as well as for maximum allowable piston and cylinder wall taper. Most of the pistons you will encounter will be of the cam-ground type. This type is not round when cold but slightly elliptical in shape. On this type of piston, taper is measured over the largest dimension, which is perpendicular to the piston-pin holes.

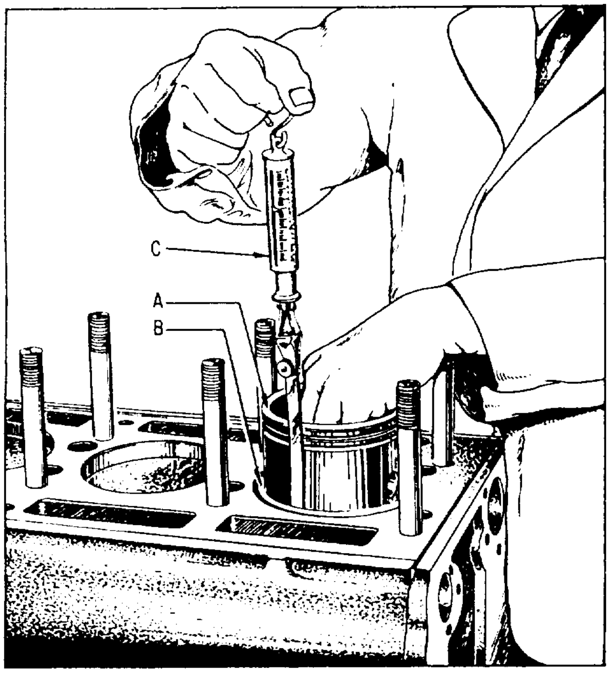
The fit of the piston in the cylinder must be accurately determined. You can measure this fit with a piece of feeler stock of the proper thickness and a spring gauge. Insert the piston into the cylinder upside down with the feeler stock (lightly oiled) placed at right angles to, and 90° from, the piston-pin holes.

(See fig. 3-35.) Measure the fit at the point of greatest piston size. Check the amount of force required to pull out the feeler stock on the spring gauge. If the feeler stock pulls out too easily, the fit is too loose. If it pulls out too hard, the fit is too tight. Check the manufacturer's maintenance manual for the correct amount of clearance.

PISTON PINS FITTING

If the piston-pin bushings are worn, they should be reamed or honed oversize and oversize pins installed. The pins should also be replaced if they are worn, pitted, or otherwise defective.

Where the pin is of the type that floats or turns in the piston-pin bushing, the fit is correct if the pin will pass through with a light thumb pressure when the piston and the pin are at room temperature. Where the pin is of the type that does NOT turn in the piston-pin bushing, the pin is forced in place under pressure. Check the manufacturer's maintenance manual for the correct pressure. If the pressure is too low, the fit is too loose and will result in noise. Excessive pressure indicates that the fit is too tight and may fracture the piston-pin bosses.



A. **Piston**
B. **Cylinder Sleeve**
C. **Thickness Ribbon and Spring Scale**

Figure 3-35.—Checking piston fit in sleeve.

PISTON RINGS FITTING

Piston rings must be fitted to their cylinder and to their grooves on the piston. First, check the gap or space between the ends of each ring. To do so, push a ring down into the cylinder with a piston, and measure the ring gap with a feeler gauge (fig. 3-36). If the ring gap is too small, try a slightly smaller ring, which will have a larger gap. If the cylinder is worn tapered, the diameter at the lower limit of ring travel (in the assembled engine) will be smaller than the diameter at the top. In this type of cylinder, the ring must be fitted to the diameter at the lower limit of ring travel. If the piston ring is fitted to the upper part of the cylinder, the ring gap will NOT be great enough as the ring is moved down to its lower limit of travel. This means that ring ends will come together and the ring will be broken or the cylinder walls scuffed. In tapered cylinders, make sure that the ring fits the cylinder at the point of minimum diameter or at the lower limit of ring travel.

After the ring gap has been corrected, install the ring in the proper ring groove on the piston and roll it around in the ring groove to be sure that the ring has a free fit around the entire circumference of the piston. An excessively tight fit means the ring groove is dirty and should be cleaned. After the rings are installed in the ring groove, test each ring for clearance by inserting

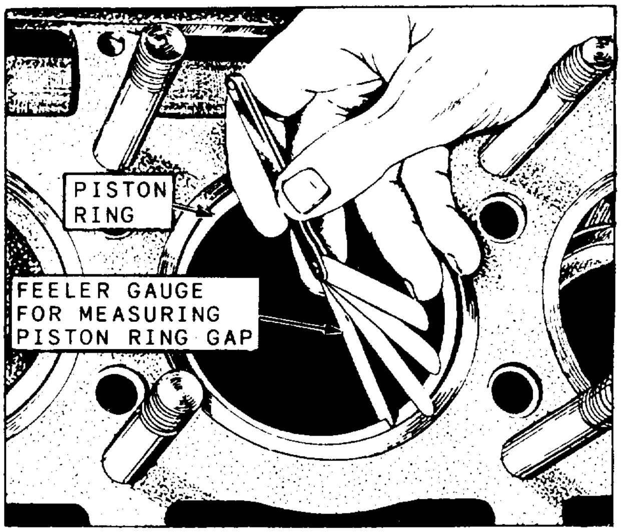


Figure 3-36.—Measuring ring gap clearance in cylinder bore.

a feeler gauge between the ring and the side of the ring groove, as shown in figure 3-37. Check the manufacturer's repair manual for proper clearance. If it is excessive, the piston should be replaced.

OPERATIONAL TESTING

Large engines are expensive items. Repairs, as evidenced by the preceding overhaul procedures, are costly and time consuming. Because of this, to get the most out of the newly overhauled engine, use proper initial start-up and run-in procedures.

PRESTART-UP

Normally, the engine will be set in its own mountings in a piece of CESE. For this reason, more than just engine connections are involved, First, check the level of all of the fluids: coolant, oil, hydraulic, and fuel. Then check things like electrical hookups, mechanical linkage, and cable connections. Recheck all mounting bolts, and be sure that all drive belts are in place and tight. Be sure that there are no loose items lying around that can get caught in the running gear.

WARNING

ENSURE THAT ANY EMERGENCY SHUT-DOWN SYSTEMS ARE OPERATIONAL.

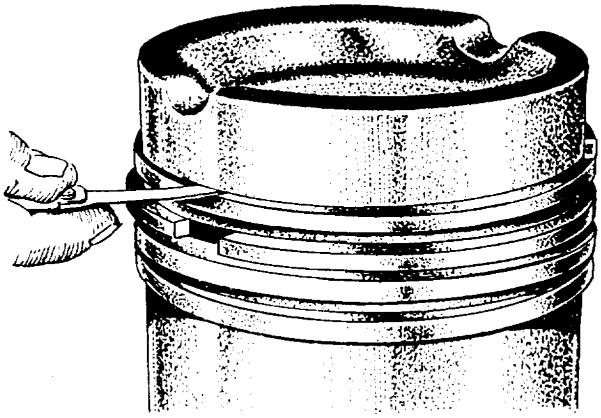


Figure 3-37.—Checking ring groove side clearance.

INITIAL START-UP AND RUN-IN

Upon starting the newly overhauled engine, if no oil pressure is observed in the first 10 to 15 seconds, shut the engine down and find the cause. If oil pressure is observed, allow the engine to warm up at an idle. Do NOT load the engine before it is fully warmed up. During this warm-up period, check for any leaks and listen for any abnormal noises that could indicate trouble. After the warm-up period, shut the engine down and check all fluid levels, repair any leaks, and retorque any bolts, as required.

500-MILE/50-HOUR CHECK

The most probable time for a newly overhauled engine to malfunction is during its initial run-in and break-in period. Therefore, it is absolutely necessary that when these units are returned to service, they are done so with special instructions to the dispatcher and yard boss; for instance, only light loads for the first 500 miles/50 hours, and watch all fluid levels, temperatures, and pressures carefully. Last, ensure that the unit is brought into the shop after the break-in period for an oil and filter change. The unit is now ready for full service.

ASSIGNMENT 3

Textbook Assignment: “Alfa Company Maintenance Shop Supervisor,” and “Engine Troubleshooting and Overhaul,” pages 2-19 through 3–28.

3-1. Making sure an ERO, a copy of the equipment evaluation inspection guide, and a copy of the attachment evaluation inspection guide are prepared for each piece of equipment being BEEPed is the responsibility of which of the following activities?

1. Relieving unit
2. Unit being relieved
3. Both 1 and 2 above
4. COMCBPAC/COMCBLANT

3-2. During a BEEP, at what time, if any, would a piece of CESE in storage be depreserved for testing?

1. When a major discrepancy is suspected
2. When a minor discrepancy is suspected
3. On the last 2 days of the BEEP only
4. Never, stored CESE is not depreserved during a BEEP

3-3. What code is qiven to a piece of deadlined equipment to indicate that its repairs would cost more than 40 percent of its acquisition cost?

1. A6
2. F9
3. S4
4. X1

3-4. In which COMCBPAC/COMCBLANT Instruction would you find guidelines to accomplish the repair parts portion of the BEEP?

1. 1020.1 series
2. 3120.1 series
3. 4400.3 series
4. 5600.1 series

3-5. What company or staff group determines and adjusts load requirements to fit the type of unit doing the transport?

1. The battalion embarkation staff
2. Alfa company
3. The aircraft loadmaster
4. COMCBPAC/COMCBLANT embarkation staff

3-6. Air detachment equipment should receive a low priority durinq a complete embarkation.

1. True
2. False

3-7. When equipment is embarked, you should NOT perform which of the following actions as part of the preparation?

1. Minor repairs
2. Collateral equipment installation
3. Spare tire installation
4. Complete repaint

3-8. Aircraft loading and tie-down is normally under the direction of what person?

1. The embarkation officer
2. The convoy commander
3. The aircraft loadmaster

3-9. Safety instructions for hazardous materials storage may be found in what manual or publication?

1. NAVFAC P–405
2. U.S. ARMY EM-385-l-1
3. NAVFAC P-908

3-10. For the purpose of avoiding congestion, track laying equipment and automotive equipment are usually fueled in the same area.

1. True
2. False

3-11. Compressed gas cylinders should NOT be stored in what way?

1. Segregated
2. Away from the work space
3. Away from any oil and qrease
4. Grouped together

3-12. In a battery shop, you must store electrolyte in what manner?

1. With the container on its side
2. Standing up on the deck
3. Standing up on a stable platform
4. Standing up in an airtight room

3-13. Hosing a fuel spill with water causes what problem?

1. Lowers the volatility
2. Dilutes the fuel
3. Spreads the fuel over a large area

3-14. When field repairs are completed, who is responsible for collecting the waste oil from those operations?

1. The shop supervisor
2. The maintenance supervisor
3. Bravo company personnel for dust control
4. The field repair personnel

3-15. Unless otherwise directed, what action should you take with unneeded materials, excess CESE, and CESE components?

1. Turn them in to DRMO throuqh proper instructions
2. Hold excess items for future use
3. Turn them over to local PWC

3-16. If you are attached to an NMCB, at what time may CESE be placed in DRMO?

1. When disposal instructions have been received
2. When the replacement CESE is at your unit
3. Upon notification that the replacement CESE has been shipped to your unit

3-17. What action should you take with the attachments of a unit of CESE when it is placed in DRMO?

1. Turn in the attachments assigned to that unit to DRMO with parent CESE
2. Turn attachments over to a local public works center
3. Retain the attachments on your site for use

3-18. If doubt arises about turn-in instructions for hazardous materials, you should contact what department or person?

1. Your unit's supply officer
2. The local disposal office
3. The Alfa company commander

3-19. What is the horsepower equivalent of 66,000 foot-pounds of work per minute?

1. 1
2. 2
3. 3
4. 4

3-20. A 6-horsepower engine can produce what maximum amount of work per minute?

1. 50,000 foot-pounds
2. 66,000 foot-pounds
3. 100,000 foot-pounds
4. 198,000 foot-pounds

3-21. What kind of horsepower would an engine deliver if it were possible to eliminate all frictional losses?

1. Friction
2. Indicated
3. Drawbar
4. Brake

IN ANSWERING QUESTIONS 3-22 THROUGH 3-25, REFER TO FIGURES 3-2, 3-3, AND 3-4 OF YOUR TEXTBOOK.

3-22. An increase of engine speed above rated speed affects the torque produced in what way, if any?

1. The torque drops
2. The torque rises
3. The torque matches speed
4. None

3–23. Engine torque increases steadily in which of the following speed ranges?

1. 1,200 to 1,600 rpm
2. 1,600 to 2,000 rpm
3. 2,000 to 2,400 rpm
4. 2,400 to 2,800 rpm

3-24. In which of the following speed ranges does engine torque fall while horsepower rises?

1. 1,000 to 1,700 rpm
2. 1,800 to 2,600 rpm
3. 2,700 to 2,900 rpm
4. 3,000 to 3,200 rpm

3-25. At what speed is engine horsepower at maximum?

1. About 200 rpm less than rated speed
2. At rated speed
3. About 200 rpm greater than rated speed
4. About 500 rpm greater than rated speed

3-26. In the cycle of gasoline operation, which of the following events must be properly timed to ensure correct engine timing?

1. Opening of the intake and exhaust valves
2. Closing of the intake and exhaust valves
3. Spark ignition of the fuel
4. Each of the above

IN ANSWERING QUESTION 3-27, REFER TO FIGURE 5-6 IN YOUR TEXTBOOK.

3-27. To determine all timing events in a four-stroke cycle diesel engine, what number of clockwise revolutions must you trace on the timing diagram?

1. One
2. Two
3. Three
4. Four

IN ANSWERING QUESTIONS 3-28 AND 3-29, REFER TO FIGURE 3-6 IN YOUR TEXTBOOK.

3-28. The intake valve of a four-stroke cycle diesel engine opens during which of the following events?

1. A few degrees before TDC as the piston nears the end of its exhaust stroke
2. A few degrees after TDC as the piston nears the end of its exhaust stroke
3. Just as the piston reaches TDC on its exhaust stroke
4. At 40° before TDC as the piston nears the end of its compression stroke

3-29. What stroke of a four-stroke cycle diesel engine begins slightly before TDC, continues through BDC, and ends during the next upstroke of the piston?

1. Power stroke
2. Exhaust stroke
3. Intake stroke
4. Compression stroke

IN ANSWERING QUESTIONS 3–19 AND 3-20, REFER TO FIGURE 3-7 IN YOUR TEXTBOOK.

3-30. What is the relationship between fuel injection timing and piston position?

1. When the piston is at TDC, fuel is about to be injected
2. When the piston is at TDC, fuel has already been injected
3. When the piston is at TDC, fuel is being injected
4. When the piston is at BDC, fuel is being injected

3-31. A piston in a typical General Motors two-stroke cycle diesel engine delivers power to the crankshaft for a total of how many degrees past TDC?

1. 17.5°
2. 44.5°
3. 92.5°
4. 132.0°

3-32. Which of the following malfunctions can cause an engine to lose power?

1. Incorrect ignition timing
2. Defective valve spark advance
3. Worn distributor cam
4. All of the above

3-33. When a diesel engine has a faulty fuel injector, who should perform repair?

1. Any mechanic who volunteers
2. An experienced mechanic who has been trained to repair injectors
3. A qualified automotive engineer

3-34. The working parts of a diesel or gasoline engine and the capacity of the engine to produce its rated power are directly related to which of the following factors?

1. Pressure and temperature of intake air
2. Ignition, compression, and carburetion
3. Quality of fuel and heat of compression
4. All of the above

3-35. Which of the following factors does NOT relate directly to the working parts of a diesel or gasoline engine but can contribute to loss of engine power?

1. Number of accessories or attachments operated by the engine
2. Pressure of intake air
3. Temperature of intake air
4. Compression ratio

3-36. Locating the source of trouble in a gasoline engine can be accomplished by which of the following means?

1. Examining the engine exhaust gases
2. Operating the engine under load
3. Shorting out spark plugs
4. Each of the above

3-37. Excessive oil consumption of an engine is likely to result in a major engine overhaul due to which of the following problems?

1. A cracked vacuum pump diaphragm
2. Worn valve guides or stems
3. Worn piston rings or cylinder walls
4. Each of the above

3-38. A vehicle operator reports on his trouble card that his vehicle oil pressure gauge shows a continuous low oil pressure reading. The low reading could be caused by which of the following engine problems?

1. Worn oil pump
2. Worn engine bearings
3. Weak relief-valve spring
4. Each of the above

IN ANSWERING QUESTIONS 3-39 THROUGH 3-41, SELECT FROM COLUMN B THE METHOD FOR LOCATING THE ENGINE NOISE GIVEN IN COLUMN A. RESPONSES IN COLUMN B MAY BE USED ONCE, MORE THAN ONCE, OR NOT AT ALL.

	A. ENGINE NOISES		B. METHODS
3-39.	Valve and tappet clicking	1.	Short out spark plugs one at *a* time while engine is floating
3-40.	Piston pin knocking	2.	Short out spark plugs one at a time while engine is idling with advanced spark
3-41.	Connecting rod pounding	3.	Insert feeler gauge while engine is idling
		4.	Squirt 1/2 ounce of oil into each cylinder, reinstall spark plugs and run engine

---

3-42. Suppose you hear a heavy, dull, metallic knock regularly while an engine is operating under load or accelerating. What type of engine noise is indicated?

1. Piston pin knock
2. Crankshaft knock
3. Main bearing knock
4. Piston slap

3-43. To check the uniformity of pressures within the combustion chambers of an engine, a mechanic should use which of the following instruments?

1. Vacuum gauge
2. Compression gauge
3. Cylinder leakage tester
4. Exhaust gas analyzer

3-44. For a gasoline engine in good condition, idling at 550 rpm at a 4,000-foot altitude, the vacuum gauge reading should be within what range?

1. 21 to 26 inches
2. 17 to 22 inches
3. 15 to 20 inches
4. 13 to 18 inches

3-45. When a vacuum gauge indicates an incorrect adjustment of the idle speed screw on a carburetor, the gauge pointer will do which of the following things?

1. Remain steady on 10 inches
2. Remain steady on 18 inches
3. Vary slowly between 13 and 15 inches
4. Vary rapidly between 13 and 19 inches

3-46. A device for introducing compressed air into the cylinder of an engine can be made by removing the insulator from an old spark plug and welding a pneumatic valve stem to the threaded end of the plug.

1. True
2. False

3-47. When using compressed air to test an engine cylinder for leakage, you notice air bubbles in the radiator coolant. The bubbles indicate that air is probably being released by what means?

1. A defective head gasket
2. A leaking intake valve
3. A defective exhaust valve
4. A piston ring

3-48. A commercial compression tester will indicate compression pressure and what else?

1. The percentage of air loss in a cylinder
2. The air temperature in a cylinder
3. The amount of carbon built up on a piston

IN ANSWERING QUESTIONS 3–49 THROUGH 3-52, SELECT FROM COLUMN B THE POSSIBLE CAUSE OF THE TROUBLE IN COLUMN A. RESPONSES IN COLUMN B MAY BE USED ONCE, MORE THAN ONCE, OR NOT AT ALL.

A. TROUBLES	B. POSSIBLE CAUSES
3-49. Broken valve	1. Insufficient valve tappet clearance
3-50. Burnt valve	2. Rich fuel-air mixture
3-51. Sticking valve	3. Cocked valve spring or retainer
3-52. Valve deposits	4. Insufficient oil

3-53. Which of the following conditions may be directly caused by a valve that is adjusted too tightly?

1. Cocked valve spring
2. Damaged piston
3. Loose adjustment locks
4. Loss of compression

3-54. When you adjust the valves, the piston should be in what position and on what stroke?

1. TDC of the compression stroke
2. TDC of the intake stroke
3. BDC of the intake stroke
4. BDC of the compression stroke

3-55. Why do valve lifters of the type shown in figure 3-14 of your textbook provide ideal valve timing?

1. They operate at zero clearance
2. They compensate for engine temperature changes
3. They adapt automatically for minor wear at various points
4. All of the above

3-56. A mechanic should measure the eccentricity of a valve before deciding whether to reuse or replace it.

1. True
2. False

3-57. Valves and their seats are refaced at exactly the same angle to help the valves cut through carbon deposits for improved sealing.

1. True
2. False

3-58. During the process of grinding valve seats, a valve seat grinder is kept concentric with the valve guide by what means?

1. Upper and lower grinding stones
2. Centered grinding stones in the chuck
3. A self-centering pilot in the valve guide
4. Centrifugal force

3-59. One method of checking the valve seating is to coat the valve face lightly with prussian blue and twist the valve one-quarter turn in its seat. How can you tell whether the valve seat is concentric with the valve guide?

1. Prussian blue will transfer evenly to the valve seat
2. There will be no trace of prussian blue on either the valve or its seat
3. The shade of prussian blue will grow brighter
4. Prussian blue will collect in a pile on the valve seat

3-60. When inserting a new valve seat, you should use which of the following techniques?

1. Heat the engine block or cylinder head to expand the valve opening, then drop the insert in place
2. Shrink the insert by chilling, then drive it in place
3. Hold the insert with pliers, then tap it in place with a hammer
4. Squeeze the insert with a special insert tool, then drop it in place

3-61. When the bore of a solid valve lifter becomes worn, you should take what corrective action?

1. Reface the lifter, ream out the bore, then fit with an oversized lifter
2. Ream out the bore, then fit with an undersized lifter
3. Ream out the bore, then fit with an oversized lifter
4. Replace the complete valve lifter assembly

3-62. To indicate the end of a leak down rate test on an hydraulic valve lifter, what action takes place as the valve seats?

1. The feeler gauge loosens
2. The feeler gauge binds
3. The oil leaks fast
4. The oil leaks slowly

3-63. In the installation of new camshaft bearinqs, it is important that you take which of the following steps?

1. Line-ream them before they are installed
2. Line up the oil holes with those in the block
3. Stake them, whether or not the old bearinqs were staked

3-64. How can you tell whether the timing gear keyed on the camshaft and the one keyed on the crankshaft are installed properly?

1. The number of gear teeth between the marks is divisible by three
2. All the marks on the gear teeth fall on the same straight line
3. There is an even number of teeth between gear marks
4. The gears mesh so that the two marked teeth of one gear straddle the one marked tooth of the other gear

3-65. If bearings appear to have worn uniformly, which of the following actions should you take?

1. Regrind the crankshaft .010 and replace the bearings
2. Replace the crankshaft as is in the unit
3. Perform the crankshaft checks and replace the bearings

3-66. Connecting rod or main bearing journals must be reground if they are tapered or out of round in excess of what measurement?

1. .001
2. .002
3. .003
4. .004

3-67. When you are using plastigage, what could uneven flattening indicate?

1. A crankshaft worn tapered
2. Bearings worn tapered
3. Both 1 and 2 above
4. A torque problem when the engine was assembled

3–68. A sharp irregular knocking sound is coming from the inside of the engine you are working on. This knocking sound could be caused by which of the following problems?

1. Worn main bearings
2. Worn connecting rod bearings
3. Either 1 or 2 above
4. Worn thrust surfaces

3-69. To measure engine cylinders for taper, you should use which of the following tools?

1. An inside micrometer
2. A specific dial indicator
3. Both 1 and 2 above
4. A depth micrometer

3-70. The glaze of a cylinder wall is broken by honing for which of the following reasons?

1. To slow initial ring wear
2. To allow the rings to seat quickly
3. To prevent scuffing of the pistons
4. Each of the above

3-71. For what reason, if any, should a cylinder ridge be removed on an engine being disassembled?

1. To prevent damaging the cylinders
2. To prevent damage to the cylinders after the engine is reassembled
3. To prevent damage being done to the pistons as they are removed

3-72. Scraping the sides of a piston during cleaning may leave scratches that can cause excessive cylinder wall wear.

1. True
2. False

3-73. To measure the fit of a piston to the cylinder, which of the following tools would you need?

1. A feeler gauge
2. A spring qauge
3. Both 1 and 2 above
4. A dial indicator set

3-74. What is the proper procedure for fitting a full-floating type piston pin?

1. Drive the piston pin in place using a soft-faced hammer
2. Press the piston pin in place using light thumb pressure
3. Press the piston pin in place using light hydraulic pressure

3-75. The new piston ring is measured for ring-end gap at what point in the cylinder?

1. At the top of the cylinder
2. Midway in the cylinder
3. At the lowest point in the cylinder
4. At the lowest point of ring travel

CHAPTER 4

TROUBLESHOOTING ELECTRICAL SYSTEMS

In the early days of the automobile, only its ignition system depended on electricity for operation. However, in today's automobile and construction equipment, electricity operates the ignition, lighting, and starting systems and many accessories, such as control units on automatic transmissions and overdrives, choke controls, emission controls, and air conditioning.

Storage batteries, generators, regulators, and other units are required to provide an adequate source of electrical current for construction and automotive equipment. The Construction Mechanic is responsible for maintaining the parts and units of the electrically operated systems and accessories on this equipment. Electrical repairs and adjustments, however, are special tasks that require the know-how of an expert-a person trained for this kind of work; in other words, an automotive electrician.

As a CM1, when you supervise mechanics who perform these special tasks in the shop or garage, you will need automotive electrical testing equipment. For example, in troubleshooting batteries and generators you save time and reduce damage to equipment by using ammeters and voltmeters instead of hit-and-miss methods.

All units in an automotive electrical system operate on the basic principles described in this chapter. You can find more on automotive electricity in *Construction Mechanic 3 & 2* and U.S. Army TM-9-8000, *Principles of Automotive Vehicles.* This chapter includes the techniques of troubleshooting the charging, cranking, ignition, and lighting systems, and other electrical accessories.

AC CHARGING SYSTEMS

The output requirements of automotive electrical generators have increased considerable y in recent years because of the growing popularity of current-consuming electrical accessories, such as two-way radios and radiotelephones for communications, heavy-duty heaters, and air-conditioners.

A conventional dc generator built to produce the required amount of electricity at both high- and low-speed ranges requires an increase in size which limits application. An ac generator (ALTERNATOR) has been developed that can be used with a rectifier bridge to produce enough current to fulfill almost any need over a speed range that varies from idle-to-top engine speed.

ALTERNATORS

The small size of the alternator makes it adaptable to almost any application. It is mechanically constructed to withstand extreme heat, vibrations, and top speeds met in normal service.

A review of *Construction Mechanic 3 & 2* will show that the alternator and the conventional dc generator operate on the same basic principles. The rotor assembly in the alternator does the same job as the field coil and pole shoe assembly in the dc generator. The stator assembly in an alternator has the same function as the armature in a dc generator while in a fixed position. The stator maybe either Y or delta connected to fit the application. (See fig. 4-1.) Normally, the delta-connected alternator is found where lower voltage, but

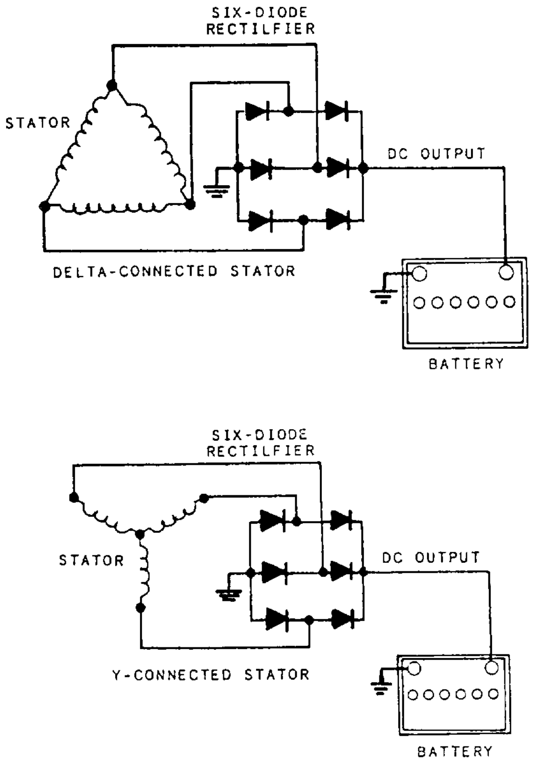


Figure 4-1.-Types of alternator internal windings.

higher current is required. The Y-connected alternator provides higher voltage and moderate current. The device for converting alternating current to direct current is the rectifier bridge. The rectifier bridge may be mounted internally within the alternator casing, or it may be mounted externally.

RECTIFIERS

Rectifiers of various types are manufactured for many uses. The most common type of externally mounted rectifier for automotive use is the magnesium-copper sulfide rectifier.

A rectifier mounted within the generator is the silicon-diode rectifier, as shown in figure 4-2. An advantage of the silicon-diode rectifier is its small size which permits it to be mounted internally within the casing of the alternator. The chemical composition of a diode enables current to flow through the diode in only one direction under normal conditions.

In the automotive type of alternator using silicon-diode rectifiers, six diodes are used: three positives and three negatives of the same construction, making a “full-wave bridge” rectifier.

The markings on silicon diodes vary with the alternator model and manufacturer. Some diodes are plainly marked with a (+) or (-) sign to identify their polarity (fig. 4-2). Others are marked with black or red lettering. When identifying diodes, always refer to the manufacturer’s specifications.

REGULATORS

As with the dc generator, some means must be provided to regulate the electrical output of an alternator. Normally, one of the following types of regulators is used: the electromagnetic, the transistor, or the transistorized.

The electromagnetic regulator is discussed in *Construction Mechanic 3 & 2*. A short description of the transistor and transistorized regulators follows.

The transistor regulator shown in figure 4-3 is a Delco-Remy model. It has two terminals, no moving parts, and limits the alternator voltage through the action of two transistors working together. This model performs the one function of controlling the alternator voltage to a preset value. From the wiring diagram shown in figure 4-4, the charging circuit consists of the alternator, regulator, battery, field relay, junction block, wiring, and either an ammeter or indicator light.

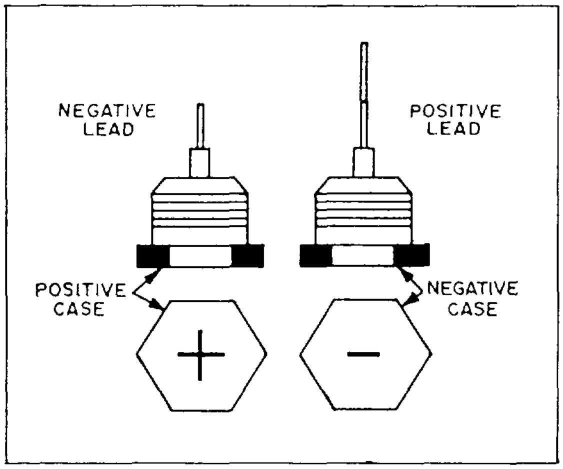


Figure 4-2.-Diodes.

Usually, you may adjust voltage internally by turning a slotted-head screw on the potentiometer which varies the connection, allowing for adjustments less than 1 volt. However, you may adjust voltage settings externally by relocating a screw in the base of the regulator. The screw contacts the series of resistors and makes a connection to ground at the point of contact.

In some transistorized regulators, a single transistor works with a conventional voltage regulator unit containing a vibrating contact point to control the alternator field current and thereby limit the alternator voltage to a preset value.

The complete charging circuit, containing a four-terminal regulator, consists of the alternator, regulator, battery, ignition switch, ammeter, and wiring,

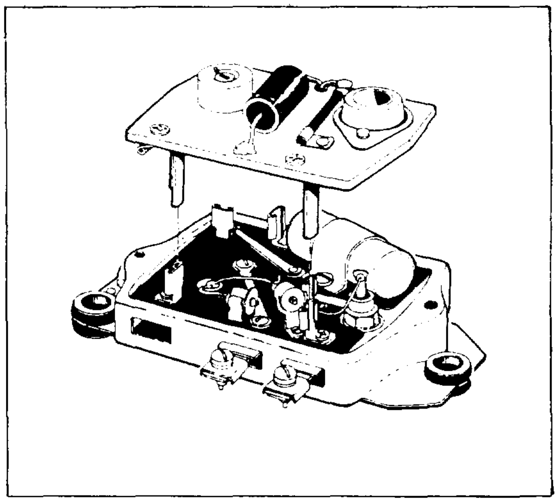


Figure 4-3.-Transistor regulator (Delco Remy).

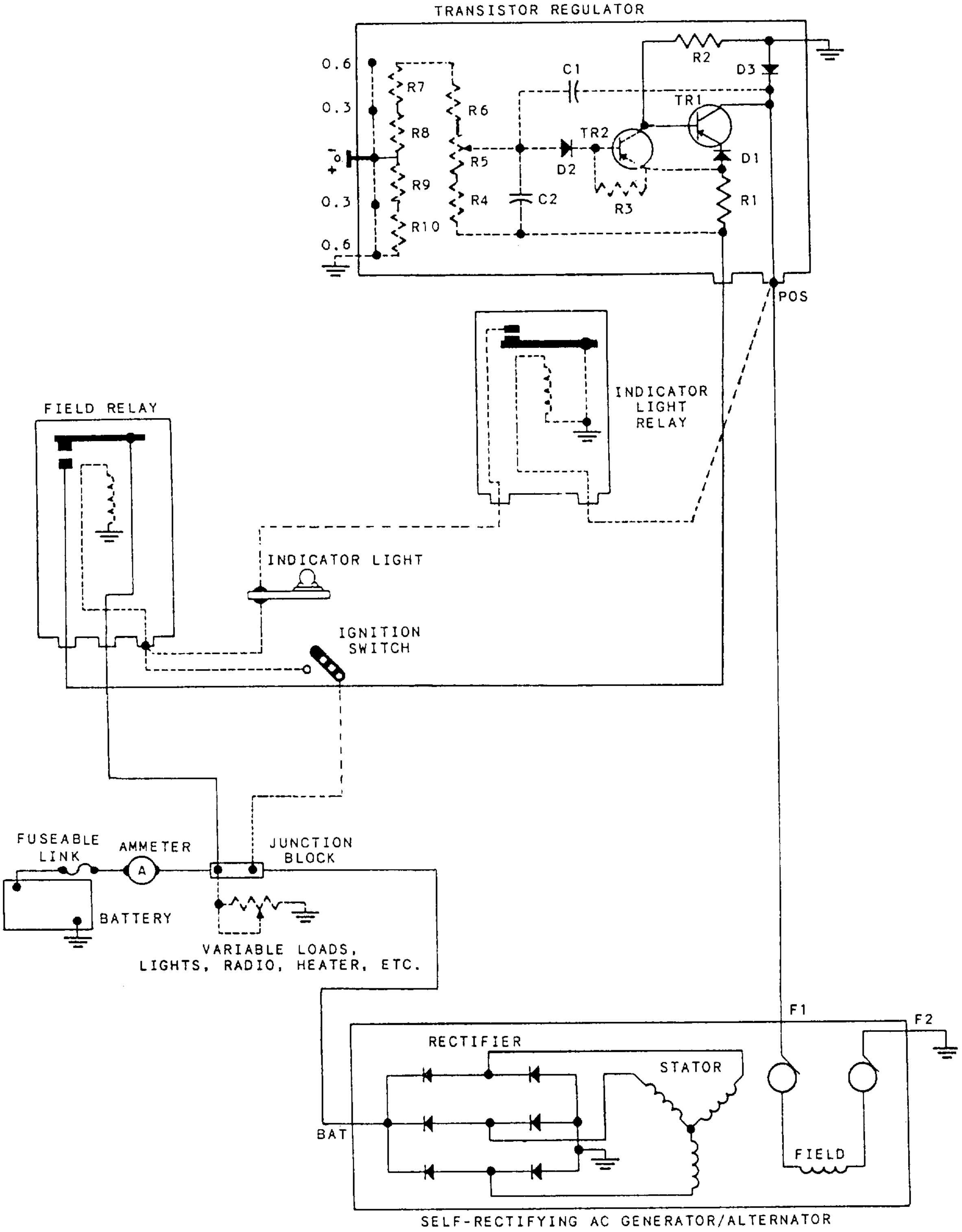


Figure 44.-Typical wiring diagram (transistor regulator).

as shown in figure 4-5. The alternator develops ac voltage in the stator windings and is rectified to a dc voltage that appears across the generator "BAT" terminal and the ground screw in the slip ring end frame.

When you service or repair a regulator, follow the manufacturer's service instructions for that specific make and model of regulator. You are not to guess about how to repair or adjust regulators.

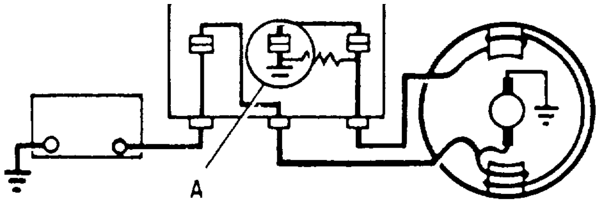


Figure 4-6.-A circuit.

TROUBLESHOOTING THE CHARGING SYSTEM WITH A VOLTAMPERE TESTER

There are two types of vehicle charging systems in use today. One system is equipped with a dc generator, and the other is equipped with an ac generator or alternator. Both systems are tested in much the same manner.

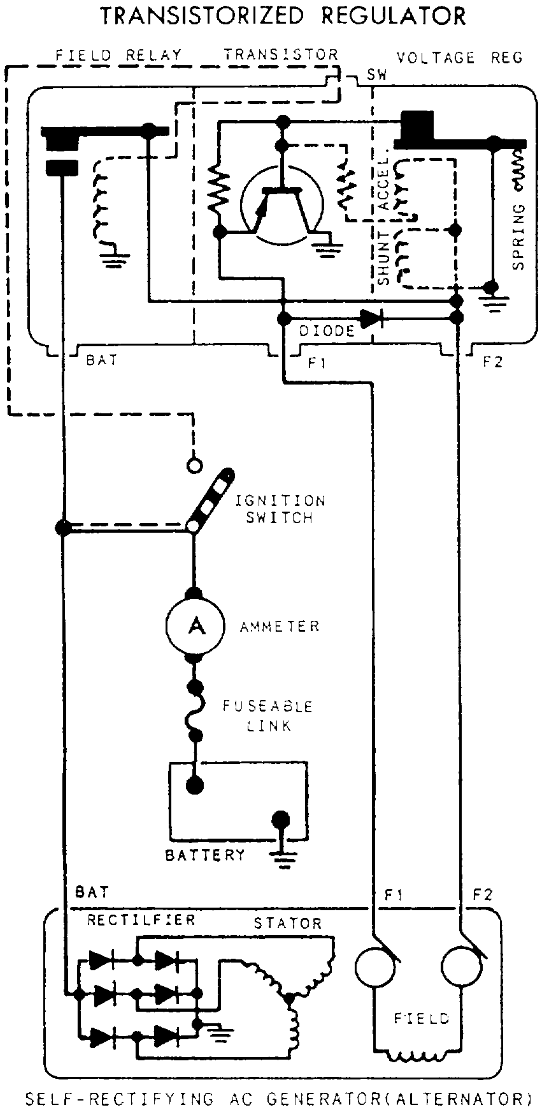


Figure 4-5.-Charging circuit (transistorized regulator).

Field circuits are commonly classified as A and B circuits. The A circuit or externally grounded field, as shown in figure 4-6, is connected to the armature terminal of the generator and is grounded outside the generator by the regulator contacts. In the B circuit shown in figure 4-7, the ground is reached internally, and the supply to the field is obtained via the armature circuit of the regulator. Most alternators and some dc generators are B circuits.

A dc generator depends upon its relatively permanent field pole piece magnetism for initial generator output. The polarity of this magnetic field determines the output polarity of the generator. A mismatched electrical system will cause early component failure. A generator with no magnetic field can produce no output. Therefore, each time a generator is repaired, installed, inoperative for a period of time, or disconnected, it must be polarized. To polarize a generator, you must pass an electric current through the field winding in the proper direction before the system is started.

To polarize an A CIRCUIT GENERATOR at the generator, ground the field and momentarily apply battery voltage to the armature terminal. To polarize at the regulator, momentarily apply a jumper lead from the armature terminal to the battery terminal. To polarize B

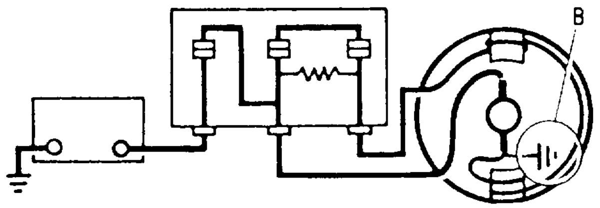


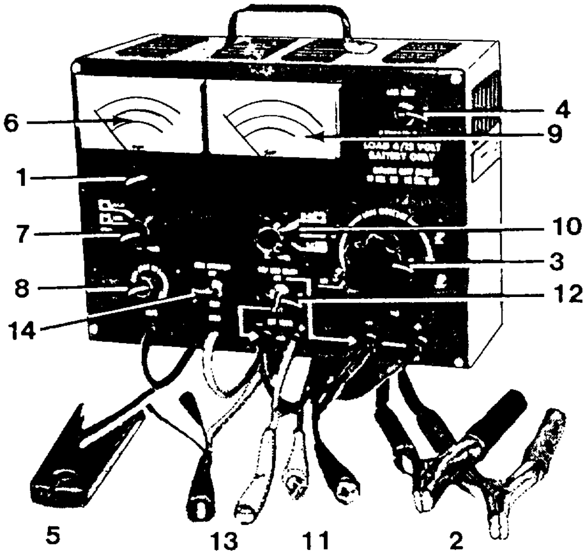
Figure 4-7.-B circuit.

CIRCUIT GENERATORS, you must disconnect the field circuit lead at the regulator and momentarily touch this lead to the regulator BATTERY terminal. Remember, alternators do not require polarization.

Various instruments can be used to locate problems in the charging system. The following sections describe troubleshooting carried out with the voltampere tester (fig. 4-8).

ALTERNATOR TEST

An alternator output test is one of the first tests to be made with the voltampere tester. To conduct this test, perform the following: disconnect the field wire at the alternator, and connect the field lead of the tester (fig. 4-9) to the field terminal of the alternator. Make sure the proper connector for the alternator being tested is used.



1. **Zero adjustment**
2. **Load leads**
3. **Load increase knob**
4. **Load light**
5. **Clamp-on ampere pickup**
6. **Ammeter**
7. **Ampere range knob**
8. **Ampere zero set adjustment**
9. **Voltmeter**
10. **Volt range knob**
11. **External Volt leads**
12. **Volt lead selector**
13. **Field leads**
14. **Field activation switch**

Figure 4-8.-Voltampere tests.

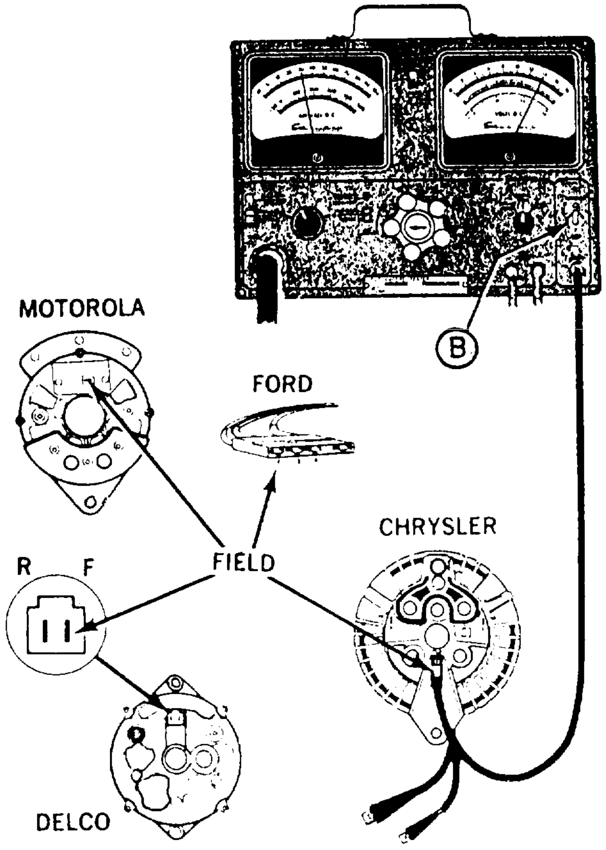


Figure 4-9.-Alternator output test.

CAUTION

Do **NOT** allow the vehicle field wire to contact ground.

Start the engine and bring the rpms up to the manufacturer's specifications. While observing the **AMMETER** scale for the highest current indication, adjust the load increase knob. The field activation switch will be held in the test position during this procedure. If the ammeter indication reads at the normal output (+ or -) 10 percent, the regulator must be replaced. When the ammeter indication reads at low or no output, the alternator must be repaired or replaced.

GENERATOR TEST

When a vehicle is equipped with an A type of field circuit generator, you may conduct a generator test by disconnecting the field at the generator and connecting the field lead of the tester (fig. 4-10) to the generator field terminal. Do NOT allow the vehicle or tester field wires to contact ground. For the B type of field circuit generator, disconnect the field wire at the regulator and connect it to the armature terminal of the regulator. Then start the vehicle engine and slowly increase speed as you observe the **AMMETER** scale for the highest ammeter reading. When the ammeter reads at the normal output, test the field lead of the wiring harness for an open circuit. If the field lead is okay, remove the regulator for testing, repair, or replacement, as required. When the ammeter reads at low output or normal voltage, the generator must be replaced or repaired. When the ammeter reads at no output or high voltage and the circuit is not fused at the regulator, remove the regulator for replacement or repair of its cutout relay. Also check the regulator ground. If the regulator is fused, bypass the fuse with a heavy jumper and observe the ammeter for output. An output at this point in your check indicates a blown fuse.

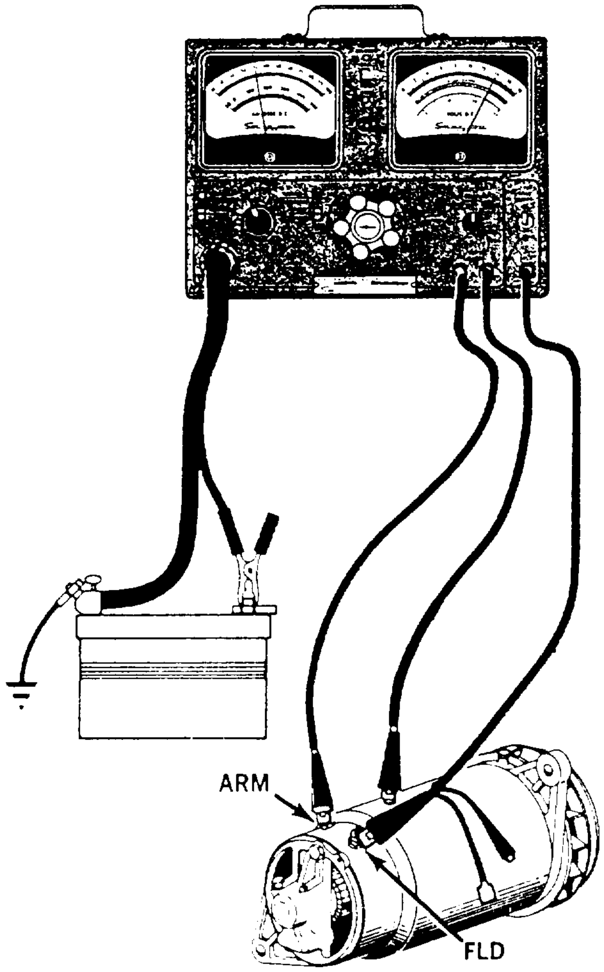


Figure 4-10.-Generator output test.

EXCESSIVE OUTPUT TEST

To conduct an excessive output test, set the volt range knob to the correct voltage range and the volt lead selector to the EXT VOLTS position. Connect the black external volts lead to the generator armature terminal and the red external volts lead to the generator frame or a good ground. While observing the **VOLTMETER** scale for the highest voltmeter reading, start the engine and slowly increase its speed. If the voltmeter reads less than 16 volts (12-volt system) or 8 volts (6-volt system), the current limiter relay of the regulator is the reason for the high output. If the voltmeter reads more than 16 volts (12-volt system) or 8 volts (6-volt system), remove the **FIELD** wire at the regulator and observe the **AMMETER** scale. When the ammeter reading shows no output, you have a defective regulator which should be repaired or replaced. When the ammeter reading indicates a current flow, remove the field wire at the generator and observe the ammeter. If the ammeter reading then shows no output, you have a shorted field wire. Replace the field wire and connect the generator to the regulator. On the other hand, if the ammeter shows that current is flowing, then the generator has a grounded field.

Another component of the vehicle charging system you should test is the **VOLTAGE REGULATOR.** If the results of the test indicate the voltage is too high or too low, a faulty regulator voltage limiter or a high-series resistance in the charging system could be causing the trouble. Erratic or unstable voltage indicates poor circuit electrical connections, faulty regulator contacts (burned or oxidized), or damaged regulator resistors. In any case, you should proceed with a charging system circuit resistance test.

CHARGING SYSTEM CIRCUIT RESISTANCE TEST

The purpose of the charging system circuit resistance test is to determine the voltage loss between the output terminal of the generator or alternator and the insulated battery post, and between the generator or alternator housing and battery ground post, respectively. These tests can be run with any voltmeter having a small scale; that is, 3-5 volts. Any voltage loss caused by high resistance in these circuits reduces the overall charge rate and leads to eventual battery discharge.

The external volts lead is connected to the generator armature terminal, as shown in figure 4-11, when a generator is tested and to the battery terminal when an alternator is tested.

If a voltage loss exceeds the specified amount for the unit being tested, an excessive resistance is present within the charging system; that is, within the wiring harness, connections, regulator, and vehicle ammeter (if used). The excessive resistance might take the form of **LOOSE** or **CORRODED CONNECTIONS** at the output terminal of the generator or alternator, the armature terminal of the regulator, or the back of the ammeter or battery terminal of the starter solenoid battery cable connections. Excessive resistance can also be due to faulty wiring from generator to regulator, regulator to ammeter, or ammeter to starter solenoid; to burned or oxidized cutout relay contacts within the regulator; or to poor electrical connections between the generator or alternator and the engine. To isolate the point of excessive resistance, conduct a charging system insulated circuit resistance test.

CHARGING SYSTEM INSULATED CIRCUIT RESISTANCE TEST

You can conduct a charging system insulated circuit resistance test by setting the volt range selector knob to the -0.3 to 3.0 volt scale position. When you test an alternator, observe the polarity, and connect the external volts lead to the generator armature terminal or to the battery terminal. (See fig. 4-12.) Remember to reverse the external volts lead for positive ground systems. Start the engine and adjust its speed to approximately 2,000 rpm. Then adjust the load increase knob until the **AMMETER** scale indicates a current of 20 amperes for dc systems or 10 amperes for ac systems. Also observe the voltage reading on the (3-volt) **VOLTMETER** scale and compare it with the specifications for proper charging system operation, as required by the vehicle manufacturer. If the reading is within specification, you should proceed with a charging system ground circuit resistance test.

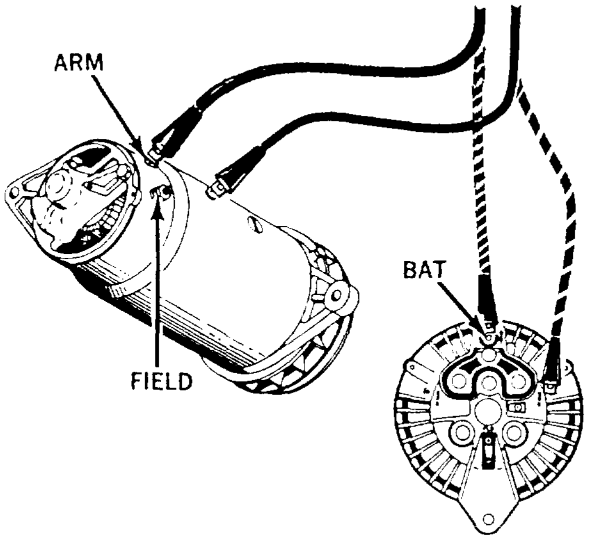


Figure 4-11.-Circuit resistance test.

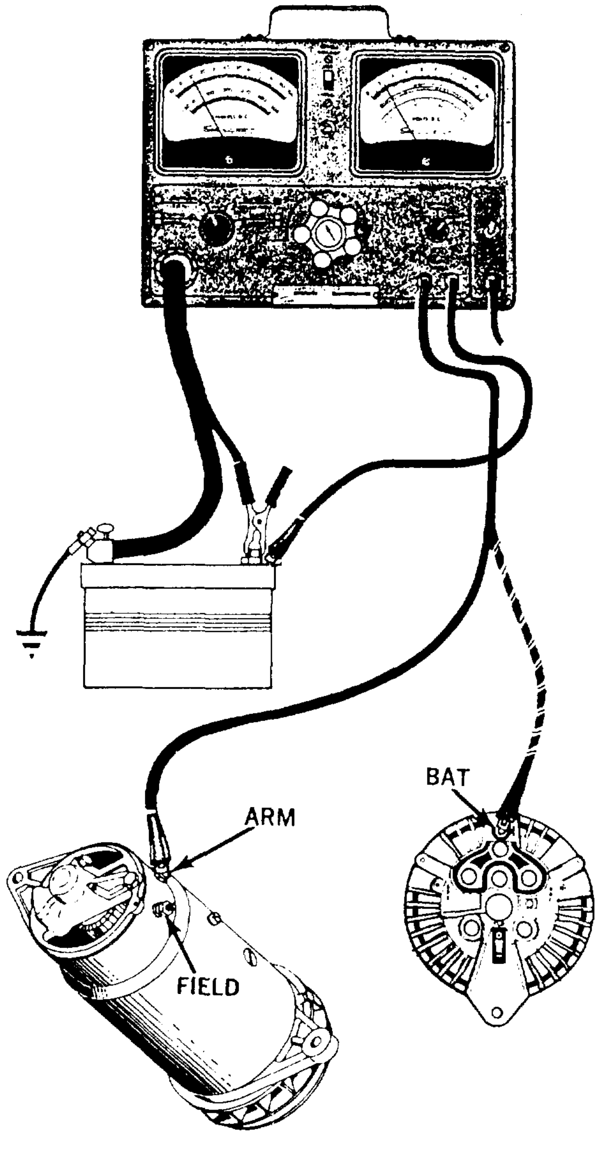


Figure 4-12.-Insulated circuit resistance test.

CHARGING SYSTEM GROUND CIRCUIT RESISTANCE TEST

When you conduct this test, observe polarity and connect the external volts lead to the generator or alternator ground terminal. (See fig. 4-13.) Then adjust the load increase knob until the ammeter scale indicates a current of 20 amperes for dc systems or 10 amperes for ac systems. Also, observe the voltage reading on the (3-volt) **VOLTMETER** scale and compare it with the specifications for proper charging system operation, as required by the vehicle manufacturer. If the reading is within specifications, you should proceed with a regulator ground circuit resistance test.

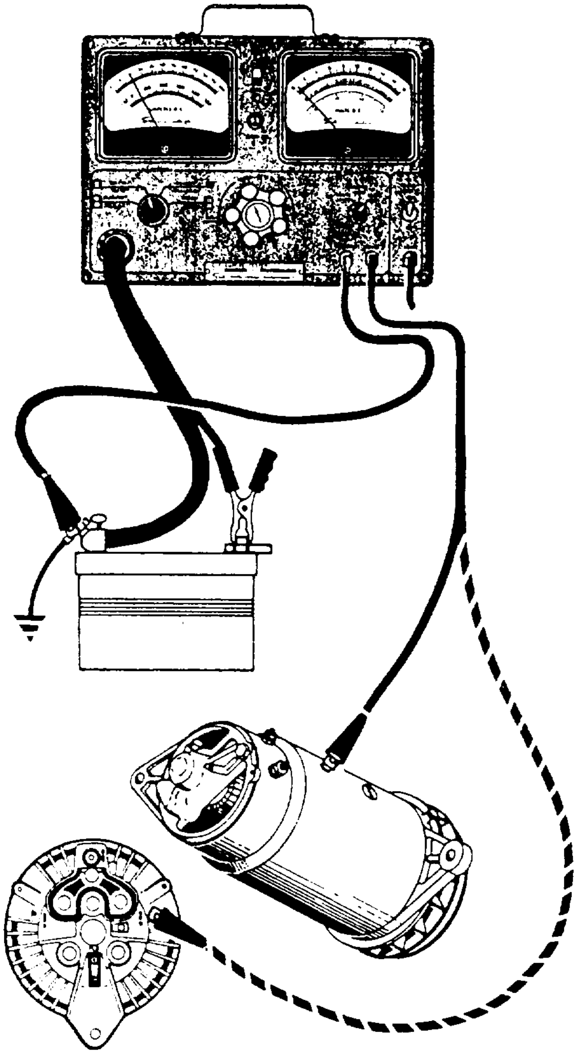


Figure 4-13.-Ground circuit resistance test.

REGULATOR GROUND CIRCUIT RESISTANCE TEST

To conduct this test, set the volt lead selector to the **INT VOLTS** position. Then, observing polarity, connect the external volts lead to the generator or alternator ground terminal and to the regulator ground terminal. (See fig. 4-14.) Adjust the load increase knob until the **AMMETER** scale indicates a current of 10 amperes. Also observe the reading on the (3-volt) **VOLTMETER** scale and compare it with the specifications. If the voltmeter reading exceeds 0.1 volt, excessive resistance is in the ground circuit between the regulator and the generator or alternator. Check the regulator ground system for loose mounting bolts or a damaged ground strap.

BATTERY DRAIN TEST

The purpose of this testis to determine if a discharge current is flowing when all accessories and lights are turned off. Any discharge at this time would indicate the presence of partially shorted or grounded wires,

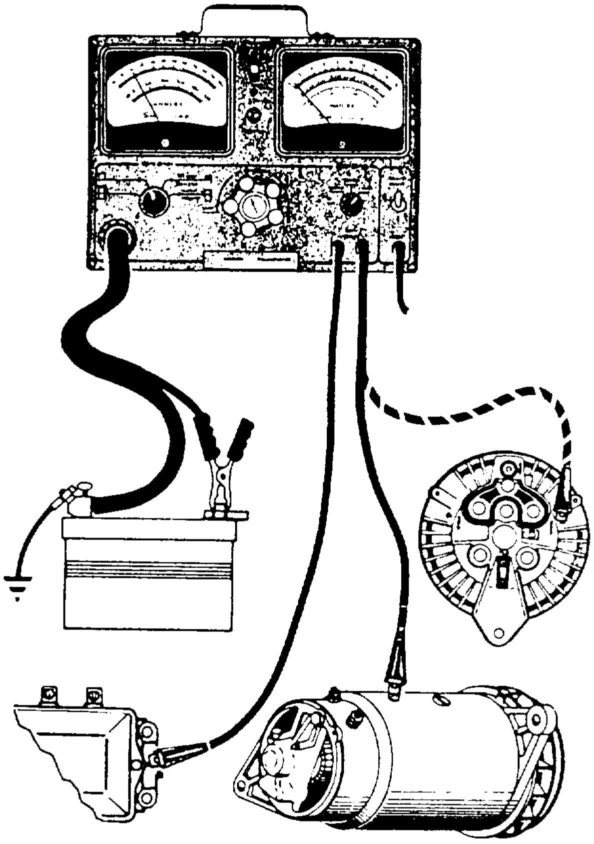


Figure 4-14.-Regulator ground circuit resistance test.

defective switches, or accessories. This condition of discharge leads to a frequently rundown battery and starting failure complaints. Turn the vehicle ignition switch to **OFF.** Lights and accessories must be **OFF** and doors closed. Observe the **AMMETER** scale. If the ammeter scale reads zero, there are no short or grounded circuit paths for current, in which case the electrical system is okay and all tests are completed. If the ammeter scale reads other than zero, an electrical short or grounded circuit exists if all the vehicle circuits are turned **OFF.** The short or grounded circuit may be found by isolating each circuit, one at a time, until the ammeter reads zero. The last circuit isolated, as the ammeter returned to zero, is the defective one. Many circuits can be isolated by removing the circuit& from the fuse panel.

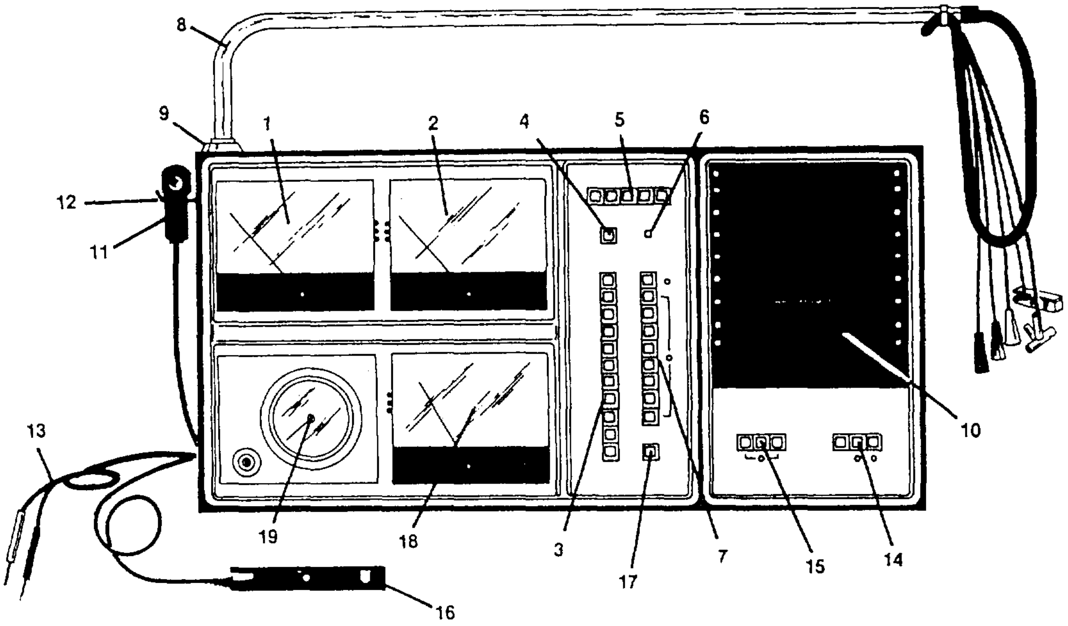
NOTE

When you finish the test, shut the engine down and turn the ignition switch to the **OFF** position before disconnecting any test leads.

Reconnect the ground cable to the ground post of the battery, and make sure all vehicle wires disconnected during the testing are again securely and properly connected.

TROUBLESHOOTING THE ALTERNATOR USING THE ENGINE ANALYZER SCREEN

Normally, when an engine analyzer (fig. 4-15) is available for use, it is in the electrical shop. The following information explains how to use the analyzer to test alternators. In considering this information, remember the following points: (1) the example shown is one of several manufactured, (2) the analyzer will do much more than just test alternators, and (3) **ALWAYS** refer to the manufacturer's manual of the analyzer and the unit being tested before making any connections.



1. Voltmeter-CO
2. Tachometer-ohm
3. Test selector
4. Special ignition
5. Engine selector
6. Primary load "ON" indicator
7. Cylinder selector
8. Boom
9. Boom collar
10. Screen-viewing area
11. Timing light
12. Hanger
13. Ohm leads and special test
14. Sweep selector
15. Pattern selector
16. Current probe
17. On-off
18. Timing-amp-dwell
19. Vacuum gauge

Figure 4-15.-Engine analyzer.

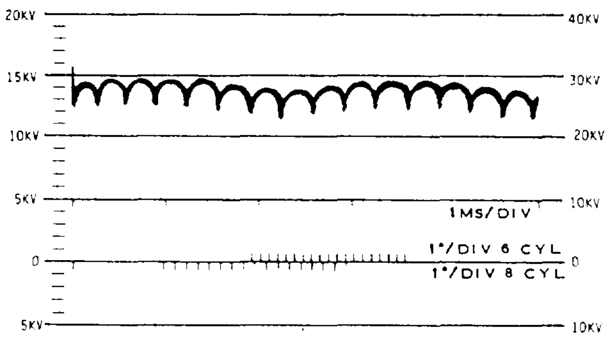


Figure 4-16.-Ripple pattern of alternator output.

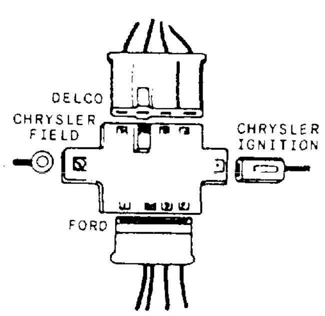


Figure 4-18.–Bypass adapter.

CHARGING CIRCUIT DIODES

When an alternator fully produces, each of its diodes conducts an equal share of the current. This condition is indicated by a ripple pattern that appears on the screen of the engine analyzer. (See fig. 4-16.) But a single nonconducting diode places a strain on the charging circuit which causes a decrease in the output of the alternator. Whereas an ammeter or voltmeter may not detect this strain, the analyzer can do so easily. The strain brought on by an open field condition, for example, will stop the alternator output ripple entirely. See the screen display of figure 4-17.

A likely result of decreased alternator output is an undercharged battery, and without a fully charged battery, there may not be enough current available to start the engine or meet the demands of the electrical circuits. When a good battery cannot be fully charged, the fault is usually in the alternator or voltage regulator. The engine analyzer can help you determine which is at fault. However, the regulator has to be bypassed altogether and battery voltage applied to the field terminal of the alternator. Not all alternators can be full fielded. Refer to the manufacturer's fieldtest procedure.

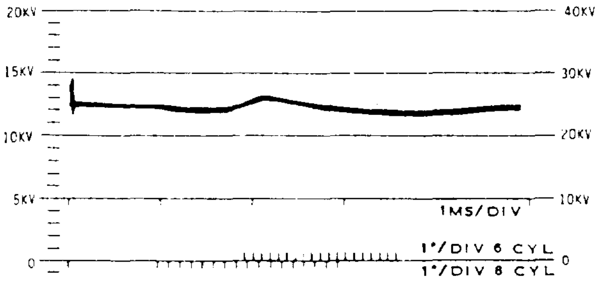


Figure 4-17.-Open file stops the ripple.

BYPASS PROCEDURE

The first step in the procedure for bypassing the voltage regulator is for you to turn **OFF** the engine. Next, disconnect the regulator and place a jumper wire between the positive (+) battery terminal and the field terminal of the alternator. You can also use the bypass adapter hooked up as shown in figure 4-18. Again start the engine and slowly increase its speed until the rated alternator output is reached. **DO NOT RUN THE ENGINE FOR MORE THAN 20 SECONDS.**

If the ripple pattern now appears on the screen of the engine analyzer, the regulator is faulty. No change in the screen pattern means the alternator or output wiring is at fault. Stop the engine, disconnect the jumper wire or bypass adapter, and reconnect the voltage regulator.

OPEN AND SHORTED DIODES

A shorted diode or shorted winding will usually burn itself open. The pattern on the screen will show a shorted diode (fig. 4-19) or open diode (fig. 4-20). Notice the similarity in the patterns. At any rate, the alternator will require service or replacement even

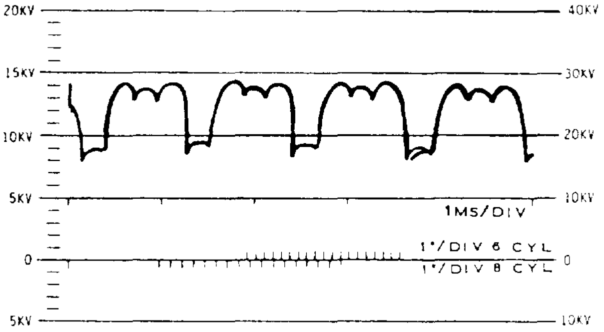


Figure 4-19.-Shorted diode pattern.

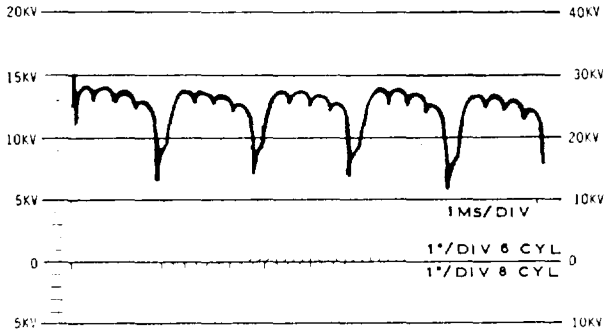


Figure 4-20.-Open diode pattern.

though both output current and voltage regulation appear to be acceptable. As a general rule, a shorted diode affects the output more than an open diode does. It not only reduces the output, but it also opposes the next pulse by allowing the current to flow back through the winding containing the shorted diode.

WEAK DIODES

As you can see from the screen pattern in figure 4-21, there is no interruption in the rectification of the diodes. However, there is a high and low peak every sixth pulse, indicating that the output of one diode is low and that it may be deteriorating (high resistance). This pattern may also occur due to a shorted winding since the number of windings determines the amount of output as well as the condition (resistance) of the diodes.

SHORTED WINDINGS

Depending on the location of the short, shorted windings and shorted diodes produce similar screen patterns because the defect is the same. Compare figures 4-19 and 4-22. The alternator test screen patterns shown arc for diagnosis only; therefore, the alternator must be removed to locate the defective internal component. Now, it is a matter of verifying the problem with simple ohmmeter tests or by replacing defective components.

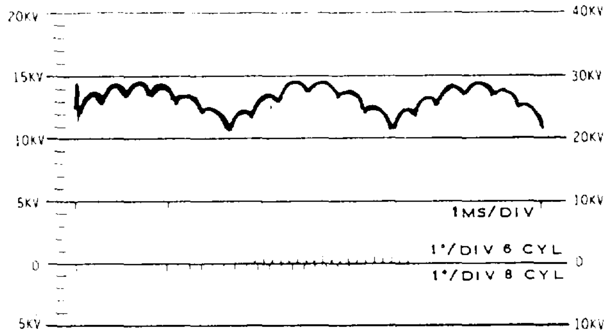


Figure 4-21.-Poor diode pattern.

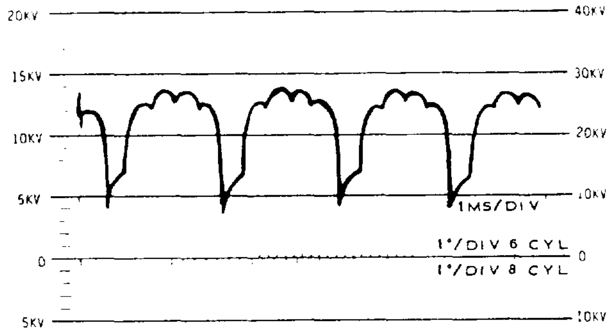


Figure 4-22.-Shorted winding pattern.

TROUBLESHOOTING THE CRANKING SYSTEM USING THE BATTERY STARTER TEST

To determine whether a battery is fit for service, you can perform a cranking system test with a battery starter tester, model **BST,** as shown in figure 4-23. This tester, made by Sun Electric Corporation, is designed to test only batteries and starting systems of vehicles using 6-, 12-, 24-, or 32-volt systems.

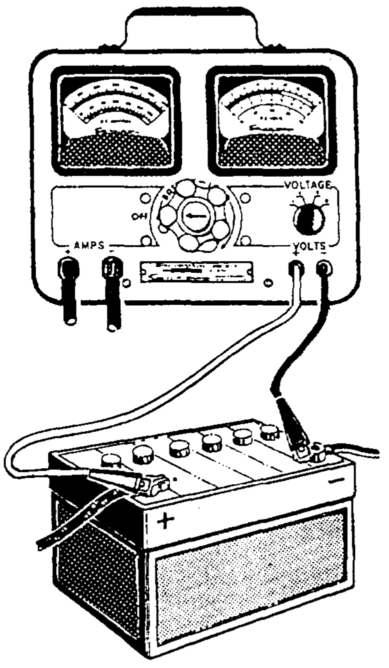


Figure 4-23.-Cranking voltage test.

CRANKING VOLTAGE TEST

When you test the cranking voltage in a 6-, 12-, or 24-volt series system, connect the voltmeter leads of the (ester, as shown in figure 4-23. Observe the polarity as you make the connections. Then turn the voltmeter selector switch to 8 volts for a 6-volt system, 16 volts for a 12-volt system, or 40 volts for a 24-volt system. When a vehicle is equipped with a 24-volt series parallel system, the voltmeter leads arc attached to the two terminals on the starting motor. Before cranking the engine with the ignition switch **ON,** connect a jumper from the secondary terminal of the coil to ground to prevent the engine from starting while testing. While cranking, observe both the voltmeter reading and cranking speed. The starter should crank the engine evenly, and at a good rate of speed, with a voltmeter reading as follows **(UNLESS OTHERWISE SPECIFIED):**

- 4.8 volts or more for a 6-volt system
- 9.6 volts or more for a 12-volt system
- 18 volts or more for a 24-volt system

When the cranking voltage and cranking speed are good, it is reasonably safe for you to assume that the starting motor and starting circuits are in order. If the cranking voltage is lower than specified, test the battery capacity, starter circuits, and starter cranking current. However, if the cranking voltage is high but the starter action is sluggish, check for starting circuit resistance, as outlined in the circuit resistance tests given later in this chapter.

Provided the engine cranking load is normal, excessive starting motor current indicates trouble in the starting circuit. However, increased current is normal on new or newly overhauled engines or where the cranking load is above normal.

To check an excessive starting motor current, you can perform a starting motor current draw test of the 6-, 12-, or 24-volt series system.

STARTING MOTOR CURRENT DRAW TEST

To conduct this test, turn the battery starter tester control knob to the **OFF** position. Then turn the voltmeter selector switch to 8 volts for a 6-volt system or 16 volts for a 12-volt system. When a vehicle is equipped with a 24-volt series system the voltmeter selector switch is turned to 16 volts if 12-volt batteries are used or to 8 volts if 6-volt batteries are used. On a 24-volt series system, connect the voltmeter leads across one 6- or 12-volt battery **ONLY.** Connect the **VOLTMETER** leads of the tester, as shown in figure 4-24.

Before you crank the engine with the ignition switch **ON,** connect a jumper from the secondary terminal of the coil to ground to prevent the engine from starting during testing. While cranking, note the exact reading on the voltmeter. After cranking, turn the control knob of the battery tester clockwise until the voltmeter again reads exactly as it did during cranking. The test **AMMETER** should indicate the starting motor current within the normal range of the vehicle being tested, as determined from the manufacturer's specifications.

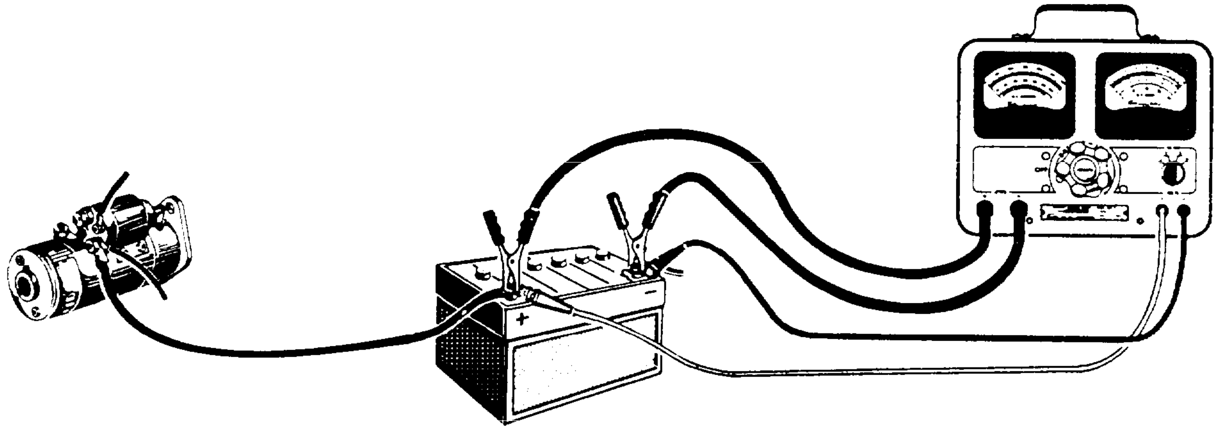


Figure 4-24.-Starting motor current draw test.

However, if the test indicates normal starter current but low cranking speed, check the resistance in the starting circuit. If high starter current is encountered during the test, starting circuit trouble is indicated. In the case of low starter current, accompanied by low cranking speed, or complete failure of the engine to crank, look for resistance within the starting circuit wiring or starting motor.

STARTER INSULATED CIRCUIT RESISTANCE TEST (CABLES AND SWITCHES)

To conduct the starter insulated circuit resistance test on a 6-, 12-, or 24-volt series system, perform the following:

Connect the **VOLTMETER** leads of the tester, as shown in views A, B, and C of figure 4-25, for the type of current being tested, and observe the polarity as you make the connections. The voltmeter will read off-scale

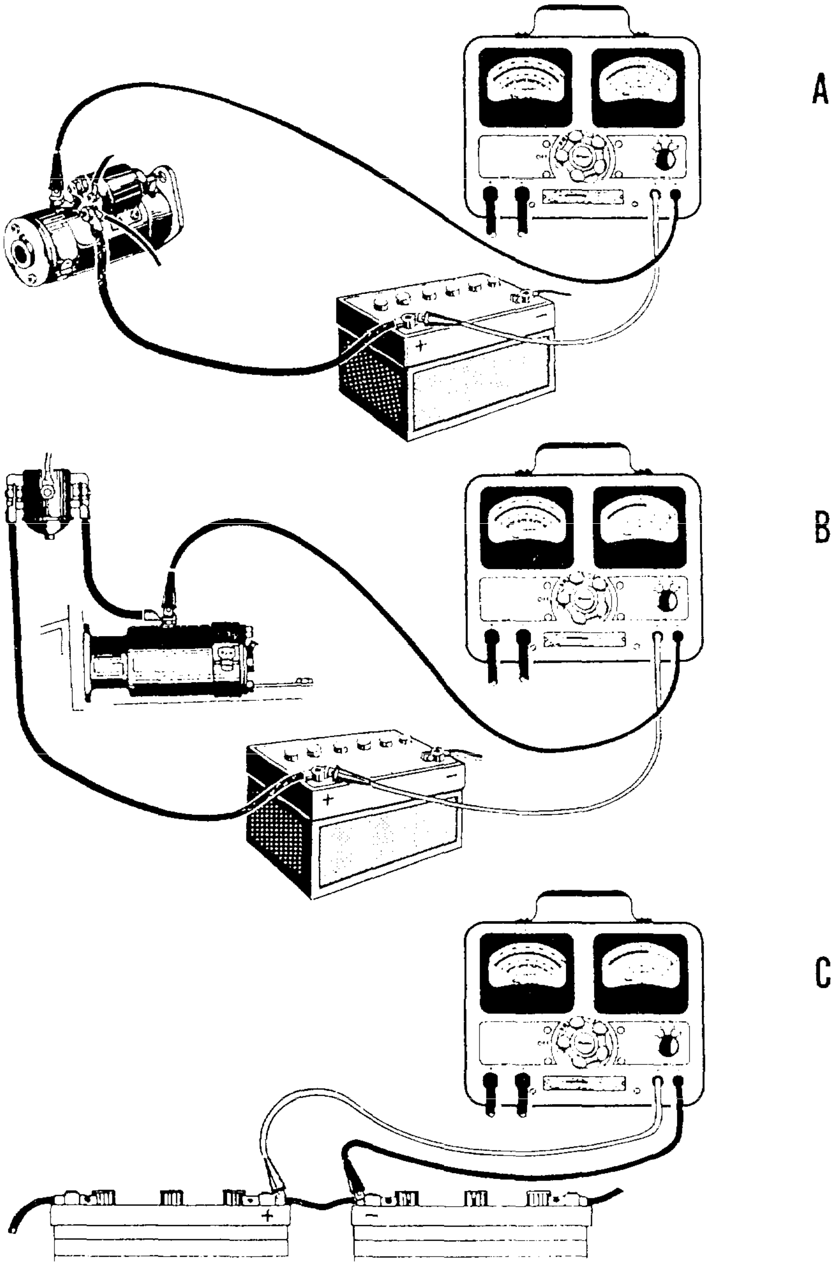


Figure 4-25.-Starter insulated circuit resistance test.

to the right until the engine is cranked. The voltmeter lead clips must be in good contact with the battery posts and the starter terminal. Now, turn the voltmeter selector switch to the No. 4 **VOLT** position. Before cranking the engine with the ignition switch **ON,** connect a jumper from the secondary terminal of the coil to ground to prevent the engine from starting while it is being tested. While cranking the engine, observe the voltmeter reading which should be within the manufacturer's specifications. Unless otherwise specified by the manufacturer, the voltage loss in each of the circuits shown in views A, B, and C should not exceed the value given.

When you test a 6-volt system, the completed circuit shown in view A allows a 0.2 volt loss and that of view B, allows a 0.3 volt loss. When you test a 12-volt system, the completed circuit shown in view A allows a 0.4 volt loss and that of view B, a 0.3 volt loss, and that of view C, a 0.1 volt loss. If testing a 24- or 32-volt system, refer to the manufacturer's specifications. If the voltmeter reading is more than specified for the type of system being tested, high resistance is indicated in the cables, switches, or connections. Repeat the test with the voltmeter connected to each cable, switch, and connector of the circuit. The maximum readings taken across these parts should not exceed the values listed below.

	6-Volt System	12-Volt System
Each cable	0.1 volt	0.2 volt
Each switch	0.1 volt	0.1 volt
Each connector	0.0 volt	0.0 volt

STARTER GROUND CIRCUIT RESISTANCE TEST

Excessive resistance in the ground circuit of the starting system can cause sluggish cranking action or failure to crank. It can also seriously interfere with the operations of the electrical circuits using the same ground.

To conduct the starter ground circuit resistance test on a 6-, 12-, or 24-volt series system, perform the following:

Connect the **VOLTMETER** leads of the tester, as shown in figure 4-26, and observe the polarity as you make the connections. Be sure the voltmeter lead clip at the battery contacts the battery post and not the battery cable clamp. Now, turn the voltmeter selector switch to the No. 4 **VOLT** position. Before cranking the engine with the ignition switch **ON,** connect a jumper lead from the secondary terminal of the coil to ground to prevent the engine from starting while it is being tested. While cranking the engine, observe the voltmeter reading. Unless otherwise specified by the manufacturer's

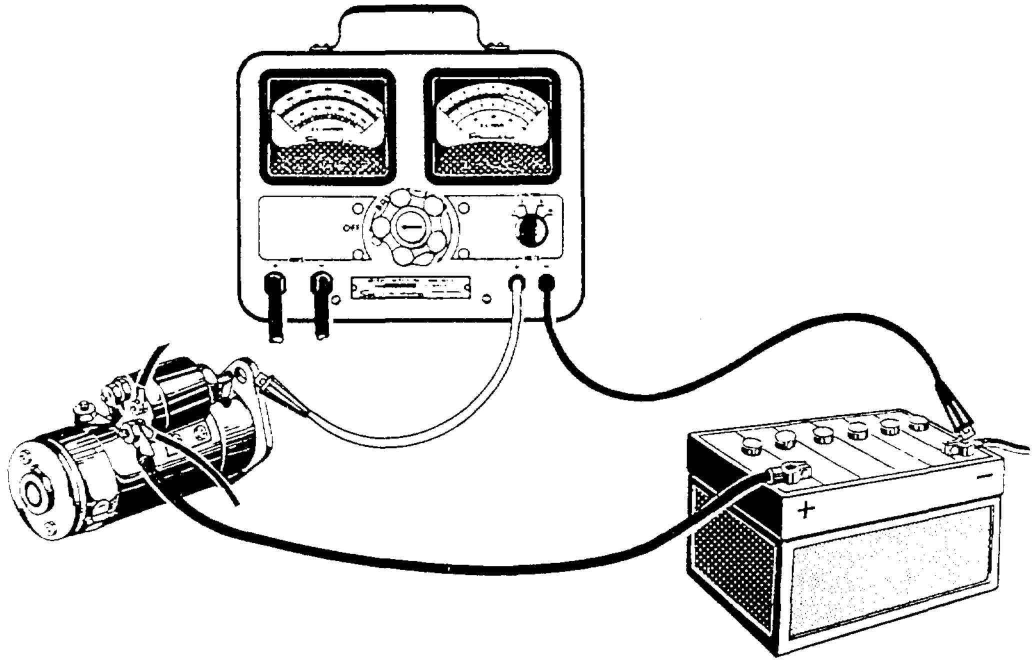


Figure 4-26.-Starter ground circuit resistance test.

specifications, this reading should not exceed a 0.2 volt loss. A reading of more than 0.2 volt loss usually indicates a loose, dirty or corroded connection, or ground cables that are too small to carry the current. To locate the point of excessive resistance, apply the voltmeter leads across each connection and cable, in turn, and take the readings with the starting motor in operation. These readings should not exceed 0.1 volt loss on short ground cables and should be zero across each connection. Long ground cables may have slightly more than 0.2 volt loss.

SOLENOID SWITCH CIRCUIT RESISTANCE TEST

High resistance in the solenoid switch circuit reduces the current flow through the solenoid windings and causes the solenoid to function improperly or not at all. Improper action of the solenoid switch, in most cases, results in burning of the main switch contacts which reduces current flow in the starter motor circuit.

To conduct the solenoid switch circuit resistance test on a 6-, 12- or 24-volt series system, perform the following:

Connect the **VOLTMETER** leads of the tester, as shown in figure 4-27, and observe the polarity as you make the connections. Be sure the voltmeter lead clip at the solenoid contacts the switch terminal–not the solenoid wire end. Now, turn the voltmeter selector switch to the No. 4 **VOLT** position. Before cranking the engine with the ignition switch **ON,** connect a jumper lead from the secondary terminal of the coil to ground to prevent the engine from starting during the test. While cranking the engine, observe the voltmeter reading. This reading, unless otherwise specified by the manufacturer's specifications, should not exceed a 0.5 volt loss. A reading of more than a 0.5 volt loss usually indicates excessive resistance. However, on certain vehicles, experience may show that a slightly higher voltage loss is normal. To isolate the point of high resistance, apply the voltmeter leads across each part of the circuit, in turn, taking readings with the starting motor in operation. A reading of more than 0.1 volt loss across any one wire or switch usually indicates trouble. If high readings are obtained across the neutral safety switch used on automatic transmission equipped vehicles, check the adjustments of the switch as outlined in the manufacturer's manual. Make sure all vehicle wires disconnected during the tests are reconnected securely and properly at the conclusion of the tests.

IGNITION SYSTEMS

The treatment of ignition systems given in *Construction Mechanic 3 & 2,* NAVEDTRA 10644, mainly deals with the operating principles of a conventional automotive ignition system. The treatment

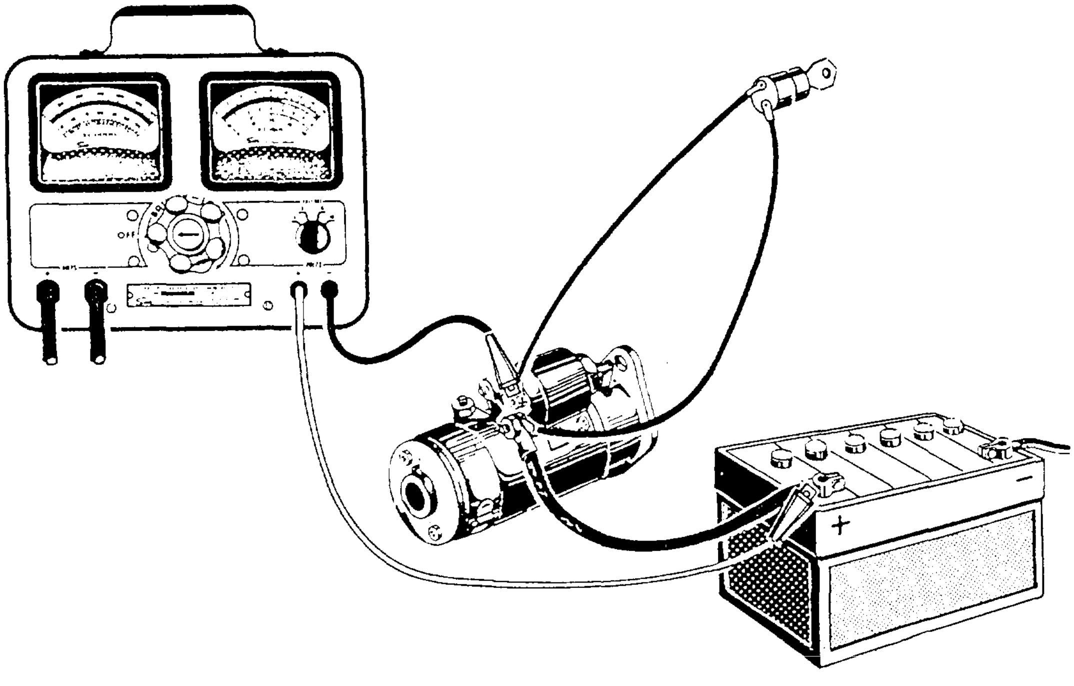


Figure 4-27.-Solenoid switch circuit resistance test.

here continues with the basic types of transistor ignition systems (breaker-point and magnetic-pulse), the capacitor discharge ignition system, the Chrysler electronic ignition system, the Delco-Remy unitized ignition system, and the Ford computerized ignition system.

TRANSISTOR IGNITION SYSTEM (BREAKER-POINT TYPE)

The breaker-point type of transistor ignition system was developed to replace the standard or conventional ignition system. To obtain the maximum power and speed that this engine can produce, you must install an ignition system that outperforms the conventional one. Electronic type of ignition systems provide a hotter, more uniform spark at a more precise interval. This promotes more efficient burning of the air/fuel mixture in the combustion chamber, producing less exhaust emissions, and resulting in better engine performance and increased mileage. The increased reliability of electronic ignition allows less frequent maintenance by increasing parts life. At high speeds, the breaker points of a conventional ignition system cannot handle the increased current flowing across them without pitting too much. Also, the dwell angle of the breaker points is too small for complete saturation of the ignition coil. The transistorized ignition system takes care of both drawbacks.

By comparing figures 4-28 and 4-29, you can see how the transistor ignition system differs from the conventional. When the breaker points are connected to the transistor, as shown in figure 4-29, it nearly eliminates arcing across them since the current flow is small (about one-half ampere). However, the current flow in the primary windings of the coil is about 6 amperes. This amount is enough to saturate the coil completely at high engine speeds, and results in a higher output to the secondary circuit. Therefore, the transistor ignition system is superior to the conventional system at high engine speeds because there is less arcing across the breaker points and higher and steadier voltage in the secondary circuit.

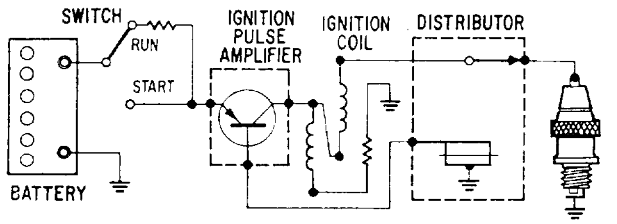


Figure 4-29.-Transistor ignition system (breaker-point type).

TRANSISTOR IGNITION SYSTEM (MAGNETIC-PULSE TYPE)

The drawbacks of a conventional ignition system operating at high engine speeds can also be overcome with the magnetic-pulse type of transistor ignition system (fig. 4-30). Notice that a magnetic pulse distributor, which resembles a conventional distributor, is used instead of a breaker-point type of distributor. An iron timer core in this distributor replaces the standard breaker cam. The timer core has equally spaced projections (one for each cylinder of the engine) and rotates inside a magnetic pickup assembly. This pickup assembly replaces the breaker plate assembly of the conventional distributor. Since there are no breaker points and there is no condenser, there can be no arcing across them. Capacitors in this system are for noise suppression. This overcomes one of the drawbacks already mentioned. The other drawback is overcome by controlling the amount of current that flows through the primary windings of the ignition coil and to ground. Transistors in the ignition pulse amplifier do the controlling. Another feature of this transistor ignition system is its coil, which has fewer and heavier primary windings and a higher turns ratio of primary to secondary windings than the conventional coil. Controlling the current flow and using a special coil

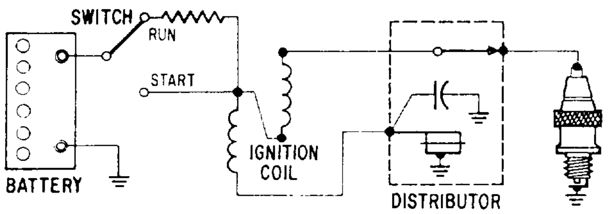


Figure 4-28.-Conventional ignition system.

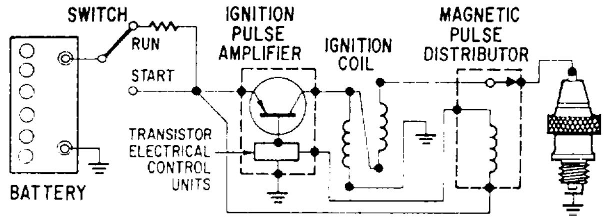


Figure 4-30.-Magnetic-pulse type transistor ignition system.

produce the desired voltage in the secondary circuit at high engine speeds.

CAPACITOR DISCHARGE IGNITION SYSTEM

The capacitor discharge (CD) ignition system is also superior to the conventional ignition system. Like the magnetic- pulse transistor ignition system, the CD system has a special ignition coil, a transistorized pulse amplifier, and a magnetic puke distributor. Unlike the magnetic-pulse transistor ignition system, the CD system has a high-voltage condenser connected across the primary windings of the coil. The input to the coil is constant and assures complete saturation of the coil which results in the desired secondary voltage output at high engine speeds.

ELECTRONIC IGNITION SYSTEM (CHRYSLER)

Like the magnetic-pulse transistor ignition system, Chrysler's electronic ignition system is breakerless; that is, there are no breaker points and there is no condenser. (See fig. 4-31.)

The Chrysler electronic ignition system in figure 4-32 consists of a battery, an ignition switch, a dual ballast resistor, a special ignition coil, an electronic control unit, and a special pulse-sending distributor.

Instead of the cam and rubbing block of the conventional ignition system, the Chrysler electronic system uses a magnetic pickup coil and a rotating reluctor (fig. 4-33). As the teeth of the reluctor pass the magnet of the pickup coil, a voltage pulse is induced in the pickup coil which is a signal for the module to "interrupt" the primary coil current. The magnetic field in the ignition coil collapses and induces a high voltage into The secondary winding which fires the spark plugs.

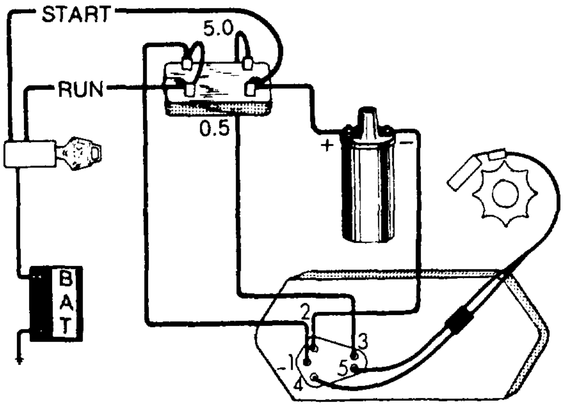


Figure 4-32.-Electronic ignition system.

The electronic module is a solid-state device that interrupts the primary coil current when signaled and self-starts the primary current after a predetermined time lapse. A compensating ballast resistor (0.5 ohms typical) is used in series with the ignition coil and battery circuit. The compensating ballast resistor maintains a constant primary current with changes in engine speed. During starting or cranking, the compensating ballast resistor is bypassed, supplying full-battery voltage to the ignition coil. The auxiliary ballast resistor (5.0 ohms typical) limits the current to the electronic module.

On this system, you adjust the air gap by aligning one reluctor tooth with the pickup coil tooth. After loosening the holding screw, use a nonmagnetic feeler gauge of the correct size to obtain the proper air gap between the reluctor and the pickup coil. Check the setting for proper clearance at the reluctor tooth with a nonmagnetic feeler gauge that is 0.002 inch larger than the manufacturer's specification.

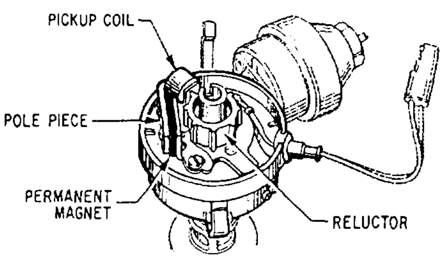


Figure 4-31.-Electronic ignition distributor components.

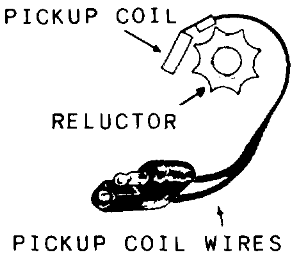


Figure 4-33.-Electronic pickup and reluctor.

CAUTION

Do not force the feeler gauge into the air gap. This should be a go-no-go tolerance.

Unless the distributor sensors depend directly on the electronic module for operation, as they do in the American Motors Breakerless Inductive Discharge System (BID), the engine analyzer may be used to check the magnetic pickup coil. To check the coil, operate the analyzer in the self-sweep mode and disconnect the pickup from the harness.

CAUTION

NEVER connect the analyzer to a distributor without first referring to the operator's manual for the correct procedure.

Connect the red and black test probes across the pickup coil wires and crank the engine as you observe the screen display. The screen trace should oscillate above and below the zero line if the pickup is good.

ELECTRONIC LEAN BURN SYSTEM/ELECTRONIC SPARK CONTROL (CHRYSLER)

Since current model engines burn a leaner fuel air mixture within the cylinders, a special means of igniting this mixture is required; for example, the electronic lean burn system (fig. 4-34). It consists of a solid-state spark control computer, various engine sensors, and a specially calibrated carburetor. Also, the distributor provides centrifugal spark advance only (no vacuum

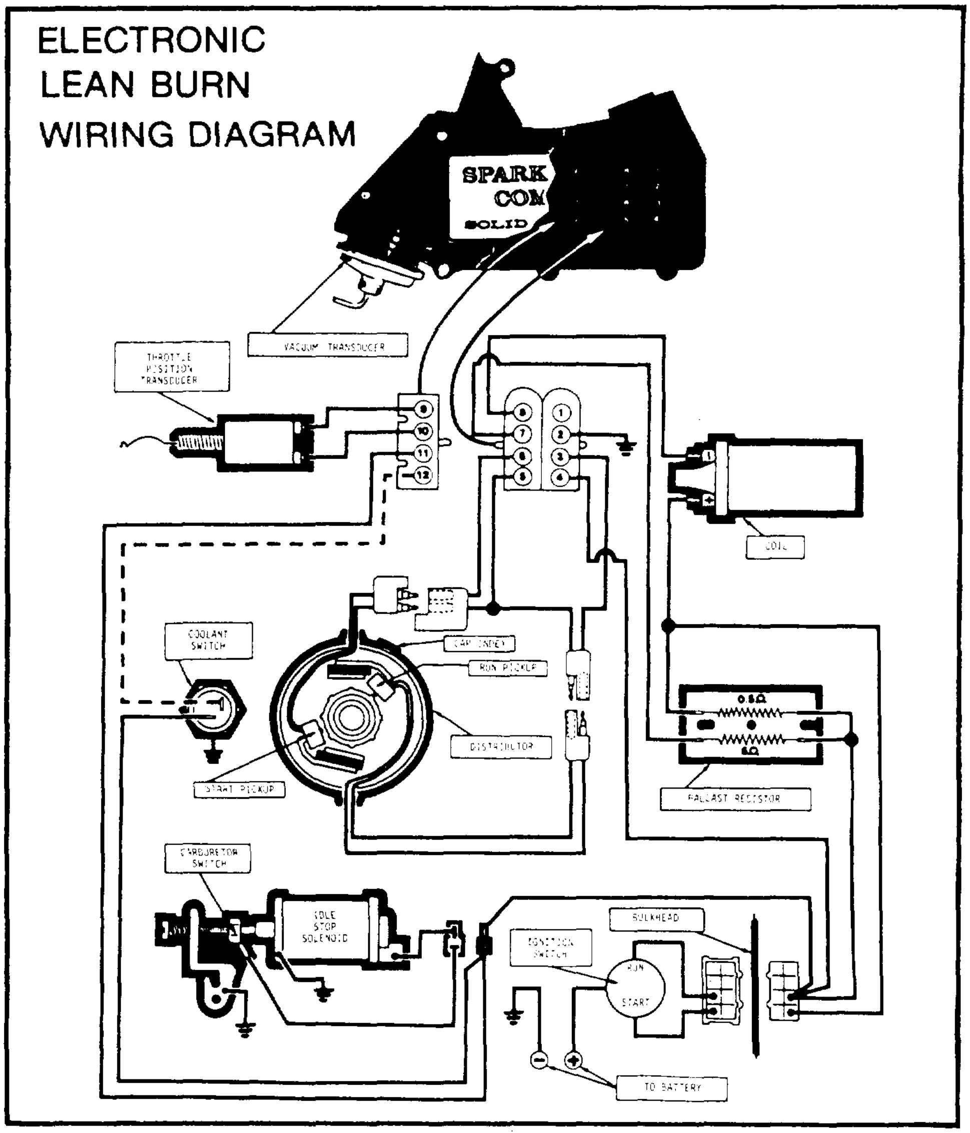


Figure 4-34.-Lean burn ignition system.

advance). Located in the distributor are two pickup coils (fig. 4-35), **NOT** found in 1978-1979 models. One coil operates during starting, whereas the other coil operates when the engine is running. The starting pickup is easily identified; its distributor connection is larger.

The computer selects either the start or run coil, not the ignition switch. The spark advance is controlled primarily by the spark control computer which receives its signals from the following engine sensors:

1. Coolant Temperature Switch (on the water pump housing) signals that the engine temperature is below 150°.

2. Air Temperature Switch (inside the computer, but not used after 1979) senses the temperature of the incoming fresh air which controls the throttle position advance.

3. Carburetor Switch (on the right side of the carburetor) tells the computer whether the engine is at idle or off idle.

4. Vacuum Transducer (on the computer) signals the computer for more spark advance with higher vacuum and less spark advance with lower vacuum. The computer responds over a period of time rather than suddenly, using a timed countdown delay.

5. Throttle Position Transducer (on the carburetor but eliminated in 1980) signals the computer to advance by indicating the new throttle plate position and the rate of change.

UNIT IGNITION SYSTEM (DELCO-REMY)

This unitized ignition system by Delco-Remy is another breakerless ignition system. It is called unitized because the entire system is built into one unit, the distributor. This distributor contains the ignition coil, the secondary wiring harness and cap, shell, rotor, vacuum advance unit, pickup coil, timer core (which replaces the cam), and electronic module. The distributor operates on an electronically amplified pulse. Vacuum spark advance and mechanical spark advance are applied in the usual way. The moving parts of this system induce a voltage that signals the electronic module to interrupt the primary circuit. The desired voltage is then induced in the secondary windings of the ignition coil and directed to the proper sparkplug by the rotor and the secondary wiring harness and cap.

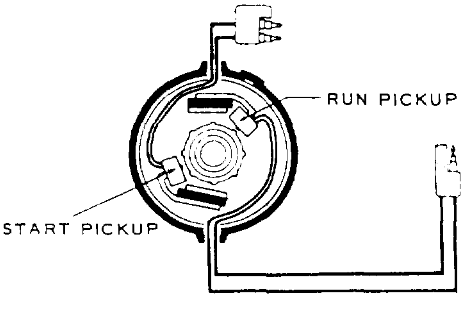


Figure 4-35.-Lean burn pickup coils.

HIGH-ENERGY IGNITION SYSTEM (DELCO-REMY)

The Delco-Remy High-Energy Ignition (HEI) System is a breakerless, pulse-triggered, transistor-controlled, inductive discharge ignition system. The HEI system and the older Unit Ignition System differ in that the HEI system is a full 12-volt system. The Unit Ignition System also incorporates a resistance wire to limit the voltage to the coil, except during starter motor operation.

The cam and point rubbing block of the conventional ignition system are replaced by the timer core, pickup coil, and electronic module in the HEI system (fig. 4-36). A timer core rotates inside the pickup

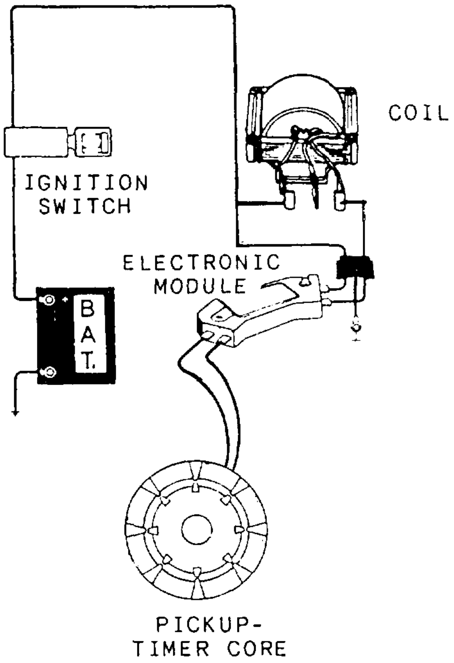


Figure 4-36.-High-energy ignition system.

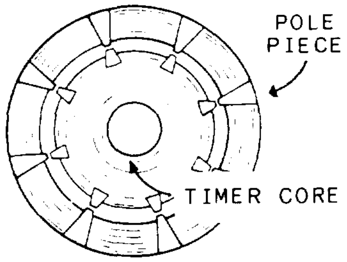


Figure 4-37.-High-energy timer and pole pieces.

coil pole piece (fig. 4-37). When the timer core teeth align with the pole piece, a voltage pulse is induced in the pickup winding. This pulse signals the module to activate the primary coil current, inducting high voltage in the secondary windings and ultimately firing the spark plug. The module automatically y controls the dwell period, stretching it as engine speed increases. Therefore, the primary current reaches its maximum strength at high engine speeds and reduces the chances of high-speed misfire. The secondary coil energy (35,000 volts) is greater than in conventional ignition systems which allows increased spark duration. The longer spark duration of the HEI system is instrumental in firing lean and exhaust gas recirculation (EGR) diluted fuel/air mixtures. The condenser within the HEI distributor is provided for noise suppression only.

COMPUTERIZED IGNITION SYSTEM

Today, minicomputers are being used to control many modern automotive systems. One example is Ford's electronic engine control system (EEC). This system consists of an electronic control assembly (ECA), seven monitoring sensors, a Dura Spark II ignition module and coil, a special distributor assembly, and an EGR system designed to operate on air pressure.

The ECA is a solid-state microcomputer consisting of a processor and a calibration assembly. Refer to figure 4-38 while studying the operation of this system. The processor continuously receives inputs from the seven sensors and converts them into usable information that is received by the calculating section of the computer. The processor assembly also performs ignition timing, does Thermactor and EGR flow calculations, processes this information, and sends out signals to the ignition module and control solenoids to adjust the timing and flow of the systems accordingly. The calibration assembly contains the memory and programming for the processor.

Processor inputs come from sensors that monitor manifold pressure, barometric pressure, engine coolant temperature, inlet air temperature, crankshaft position, throttle position, and EGR valve position.

Manifold Absolute Pressure Sensor

This sensor detects changes in intake manifold pressure that are caused by variances in engine speed, engine load, or atmospheric pressure.

Barometric Pressure Sensor

Barometric pressure is monitored by a sensor mounted on the fire wall. Measurements taken are

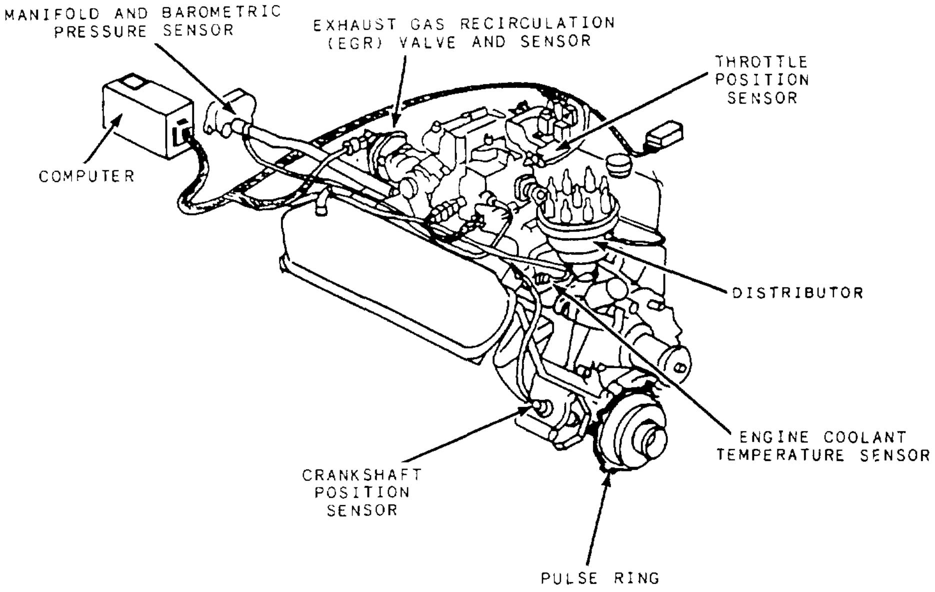


Figure 4-38.-Computer ignition components.

converted into a usable electrical signal. The ECA uses this reference for altitude-dependent EGR flow requirements.

Coolant Temperature Sensor

This sensor is located at the rear of the intake manifold and consists of a brass housing that contains a thermistor. When reference voltage (about 9 volts, supplied by the processor to all sensors) is applied to the sensor, the resistance can be measured by the resulting voltage drop. Resistance is then interpreted as coolant temperature by the ECA. EGR flow is cut off by the ECA when a predetermined temperature is reached. If the coolant temperature becomes too high (due to prolonged idling), the ECA will advance the initial ignition timing to increase the idle speed. The increase in engine rpm will increase coolant and radiator airflow, resulting in a decrease in coolant temperature.

Inlet Air Sensor

Inlet air temperature is measured by a sensor mounted in the air cleaner. It operates in the same manner as the coolant sensor. The ECA uses its signal to control engine timing. At high inlet temperatures (above 90°F), the ECA modifies the engine timing to prevent spark knock.

Crankshaft Position Sensor and Metal Pulse Ring

The crankshaft is fitted with a four-lobe metal pulse ring. Its position is constantly monitored by the crankshaft position sensor. Signals are sent to the ECA representing both the position of the crankshaft and the frequency of the pulses (engine rpm).

Throttle Position Sensor

The throttle sensor is a rheostat connected to the throttle plate shaft. Changes in the throttle plate angle varies the resistance of the reference voltage that is supplied by the processor. Signals arc interpreted by the ECA in one of the following three ways:

1. Closed throttle (idle or decelcration)
2. Part throttle (cruise)
3. Full throttle (maximum acceleration)

EGR Valve and Sensor

A position sensor is built into the EGR valve. The ECA uses the signal from the sensor to determine the position of the valve. The EGR valve and position sensor are replaced as a unit.

Distributor

The distributor is locked in place during engine assembly. Since all timing is controlled by the ECA, there are no rotational adjustments possible for initial ignition timing. There are no mechanical advance adjustments so there is no need to remove the distributor except for replacement.

Because of the complicated nature of this system, special diagnostic tools are necessary for troubleshooting. Any troubleshooting without these special tools is limited to mechanical checks of connectors and wiring.

DISTRIBUTORLESS IGNITION SYSTEM

Some later engines have no distributor as we know it. The distributor and ignition timing are all a part of an electronic control unit or ignition module (fig. 4-39). This system totally eliminates any vacuum or centrifugal advance mechanism and, in most cases, the

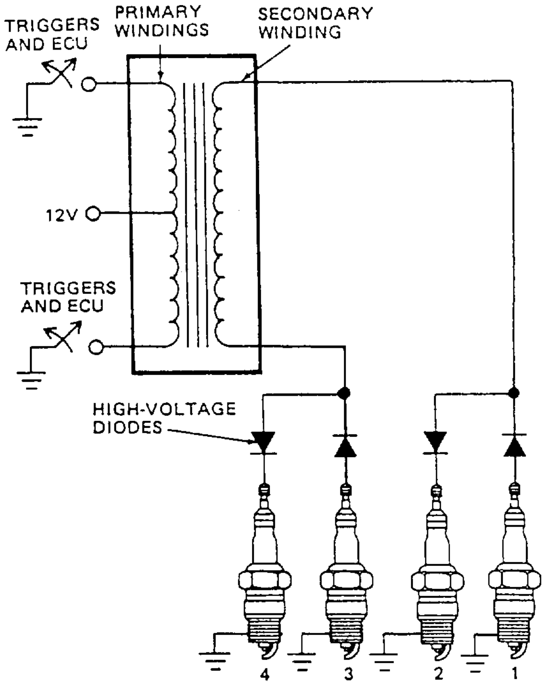


Figure 4-39.–Distributorless ignition system wiring diagram.

distributor itself. A crankshaft or camshaft rotating sensor (fig. 4-40) is used to provide the electronic control unit with piston position and engine speed. This signal is used to trigger the correct coil at the correct time for high-voltage spark. There are several types of this system currently on the market. For testing and repair, consult the manufacturer's maintenance manuals. Use only the correct tools and testing equipment when working on these units.

TROUBLESHOOTING

As an automotive electrician, you will be called on to troubleshoot the conventional, transistor, and electronic ignition systems. The instruments you need to pinpoint problems in a conventional ignition system include the simple voltmeter and ohmmeter. Although an engine analyzer simplifies the troubleshooting of electronic ignition systems, you can do so with a volt-ohmmeter (0 to 20,000-volt/ohm range). Better yet, you may use an ignition scope tester since it can test system components while the engine is running.

CONVENTIONAL/COIL IGNITION SYSTEM

To troubleshoot a conventional ignition system, you must conduct separate tests on the primary circuit (low voltage) and the secondary circuit (high voltage). The primary circuit carries current at battery voltage, whereas the secondary voltage could be as much as 30,000 volts.

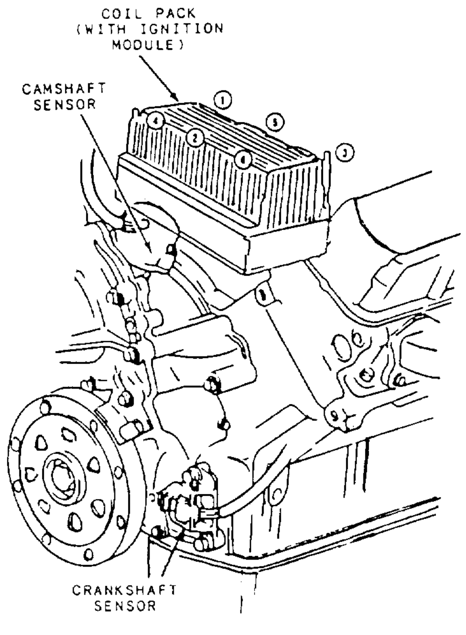


Figure 4-40.-Components of the distributorless ignition system found in some General Motors products.

Primary Circuit Tests

Using a simple voltmeter, you can check a 12-volt primary circuit as follows:

1. Hookup the voltmeter between the switch side of the ignition coil and a good ground. The engine must be at operating temperature, but stopped, and the distributor side of the coil grounded with a jumper wire. (See fig. 4-41.)

2. With the ignition switch on, jiggle it and watch the voltmeter. The switch is defective if the meter needle fluctuates. The voltmeter should read a steady 5.5 to 7 volts with the points open on systems using a ballast resistor.

3. Crank the engine and watch the voltmeter. It should read at least 9.6 volts while the engine is being cranked.

4. Remove the jumper wire from the coil; then start the engine. The meter reading should be 5 to 8 volts on a ballast resistor system while the engine is running.

5. Stop the engine by turning off the ignition switch. Hook up the voltmeter between the distributor side of the coil and ground. Remove the high tension wire from the coil and ground it.

6. Close the ignition switch and slowly open and close the breaker points by bumping the engine. When the points make and break the voltmeter should read between 4 and 6 volts. Normally, with the engine stopped and points opened, the reading will be 12 volts; with points closed, the reading will be near zero volts. If while the engine is cranked, the voltmeter reading

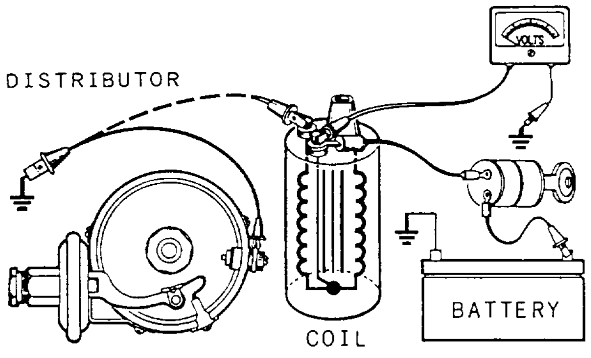


Figure 4-41.–Testing ignition primary circuit.

stays at zero or near zero, conduct the following three checks to locate the source of trouble:

- Check the current flow at the distributor. Disconnect the distributor primary wire from the top of the coil. Take a voltmeter reading from the distributor terminal of the coil. Current should flow through the circuit.

- Check the opening and closing of the breaker points. If not adjusted properly, they may not open and close. Also look for a mechanical failure of the points or cam. Lubricate the rubbing block at this time if necessary.

- Check grounding of the movable breaker point, the stud at the primary distributor wire terminal, or the wire of the condenser (pigtail). None of these should be grounded.

Secondary Circuit Tests

The high voltage in the secondary circuit is produced by the ignition coil. Current flows out of the coil at the secondary terminal through a cable to the distributor cap and rotor. The rotor distributes the current through the cap and cables to the spark plugs, and then to ground. The checkpoints for the secondary circuit are the secondary terminal of the coil, the coil-to-distributor cap cable, the distributor cap, rotor, spark plug cables, and spark plugs.

You should conduct the secondary circuit check as follows:

1. Pull the coil high-voltage cable from the distributor cap and hold the loose end of the cable about one-fourth of an inch from a good grounding point on the engine block.

2. Crank the engine and look for a spark to bridge the gap between the loose end of the cable and the grounding point. If you see a blue spark proceed to the next step since the coil is functioning normally. If you see a yellow spark or no spark at all, the trouble sources are in the primary circuit, the coil, and the coil-to-distributor cable.

3. Remove the sparkplug cables from sparkplugs and lift the distributor cap off. Connect one ohmmeter test lead to a spark plug cable connector and the other test lead to the terminal inside the distributor cap for the spark plug cable. Measure the resistance of the other spark plug cables in turn. Cable resistance should not exceed the manufacturer’s recommendations. Excessive resistance can result from cable damage, defective spark plug connector, corroded distributor cap tower, or unseated cable in the tower.

4. Inspect the distributor cap inside and out for carbon tracking cracks, and inspect it for a worn center contact button or burned spark plug cable contacts.

5. Remove the rotor and inspect it. Look for high-resistance carbon, a burned tip, or a grounded rotor.

NOTE

Because of the difference in materials and quality control used by manufacturers of distributor caps and rotors, you should use both items from the same manufacturer.

6. Remove all spark plugs from the engine and inspect each one. Look for fouled plug tips, gaps that are too wide or bridged, chipped insulators, and other conditions that can cause high resistance at the electrodes.

Coil Resistance Tests

You can use a simple ohmmeter to check the resistance of the ignition coil. Its primary circuit and secondary circuit are tested separately. To check the primary side, connect the ohmmeter leads across the primary terminals of the coil. Use the low ohms scale of the meter. The resistance should be about 1 ohm for coils requiring external ballast resistors and about 4 ohms for coils not requiring the ballast resistors. In checking the secondary side, switch to the high scale of the ohmmeter. Connect one ohmmeter lead to the distributor cap end of the coil secondary wire and the other lead to the distributor terminal of the coil. The condition of the coil is satisfactory if the meter reading is between 4,000 and 8,000 ohms, although the resistance of some special coils may be as high as 13,000 ohms. Should the reading be a lot less than 4,000 ohms, the secondary turns of the coil are probably shortened. A reading of 40,000 ohms or more indicates an open secondary, a bad connection at the coil terminal, or a high resistance in the cable.

TRANSISTOR IGNITION SYSTEM

The preceding techniques for troubleshooting a conventional battery/coil ignition system also apply, for the most part, to troubleshooting the basic types of transistorized ignition systems: breaker-point type and breakerless. Special techniques, however, are used in checking the electronic components of a transistorized ignition system. Before testing any electronic ignition system, refer to the manufacturer's manual. Not all systems may be checked for spark across a gap to ground without damaging the module. Other systems may only allow specific plug wires to be tested by sparking across the gap. Since these components are easily damaged by heat, shock, or reverse polarity, you must be extra careful in checking them. The following steps form the procedure for troubleshooting breakerless systems:

1. Pull the high-voltage cable from the distributor cap and hold the loose end of the cable about one-half of an inch from a good grounding point on the engine block.

2. With the ignition switch **ON,** crank the engine and look for a spark to bridge the gap between the loose end of the cable and the grounding point. If you see a blue spark, reconnect the high-voltage cable to the distributor and proceed to Step 3. If you do not see a spark or see a weak spark, proceed to Step 4.

3. Pull the cable from a spark plug and hold the loose end of the cable about one-half of an inch from the spark plug terminal. With the ignition switch **ON,** crank the engine and look for a spark to bridge the gap between the loose end of the spark plug cable and spark plug terminal. A blue spark here indicates a normal operating condition.

4. With a weak spark or no spark, test the coil. Since a special coil is used in this ignition system, you cannot test it with a conventional coil tester. Use an ohmmeter to check the continuity of the primary and secondary windings of the coil. With leads disconnected from the coil, connect the ohmmeter across the primary terminals. If the meter reading is infinite, the primary winding is open. The

Table 4-1.-Troubleshooting Chrysler Electronic Ignition

Condition	Possible Cause	Corrrection
ENGINE WILL NOT START (Fuel and carburetion known to be OK)	a) Dual Ballast	Check resistance of each section: Compensating resistance: .50-.60 ohms @ 70°-80°F Auxiliary Ballast: 4.75-5.75 ohms Replace if faulty. Check wire positions.
	b) Faulty Ignition Coil	Check for carbonized tower. Check primary and secondary resistances: Primary: 1.41-1.79 ohms @ 70°-80°F Secondary: 9,200-11,700 ohms @ 70°-80°F Check in coil tester.
	c) Faulty Pickup or Improper Pickup Air Gap	Check pickup coil resistance: 400-600 ohms Check pickup gap: .010 in. feeler gauge should not slip between pickup coil core and an aligned reluctor blade. No evidence of pickup core striking reluctor blades should be visible. To reset gap, tighten pickup adjustment screw with a .008 in. feeler gauge held between pickup core and an aligned reluctor blade. After resetting gap, run distributor on test stand and apply vacuum advance, making sure that the pickup core does not strike the reluctor blades.
	d) Faulty Wiring	Visually inspect wiring for brittle insulation . Inspect connectors. Molded connectors should be inspected for rubber inside female terminals.
	e) Faulty Control Unit	Replace if all of the above checks are negative. Whenever the control unit or dual ballast is replaced, make sure the dual ballast wires are correctly inserted in the keyed molded connector.

secondary winding is checked by connecting the ohmmeter to the coil case and to the high-voltage center tower. Again, an infinite reading indicates an open winding; if any reading is obtained, it indicates a shorted winding. Be sure to use the middle- or high-resistance range of the ohmmeter when you check the continuity of the secondary winding.

5. Check the operation of the ignition pulse amplifier by detaching the positive and negative leads from the coil and connecting them in series to a 12-volt, 2-candlepower bulb.

6. Crank the engine and observe the bulb. If it flickers on and off, the amplifier is operating properly. If the bulb does not flicker on and off, check the distributor.

7. Connect a vacuum source to the distributor and an ohmmeter to the two terminals on the distributor connector. Open the vacuum source to the distributor, and observe the ohmmeter throughout the range of the vacuum source. A reading less than 550 ohms or more than 750 ohms indicates a defective pickup coil in the distribute.

8. Remove one ohmmeter lead from the distributor connector and ground it. Again, open the vacuum source to the distributor as you observe the ohmmeter. A reading less than infinite indicates a defective pickup coil.

ELECTRONIC IGNITION SYSTEM

Provided the engine analyzer is not available, you may troubleshoot the electronic ignition system to prevent unnecessary replacement of its expensive units. (See table 4-1.) You will need a volt/ohmmeter with a 20,000 volt/ohm range. Check the battery in the system being tested; battery voltage must beat least 12 volts.

CAUTION

> Make sure the ignition switch is off when the control unit connector is being removed or replaced.

Disconnect the wiring plug from the control unit, and turn on the ignition switch. Ground the negative voltmeter lead. Connect the positive voltmeter lead to the harness cavities designated in the sequence recommended by the manufacturer. Voltage should be within 1 volt of battery voltage with all accessories off. If not, check that circuit through to the battery. Turn the ignition switch off after completing the voltage test. Connect the ohmmeter to the cavities designated. If resistance is not within the manufacturer's range, disconnect the dual lead connector from the distributor. Recheck resistance at the dual lead connector. With one ohmmeter lead still grounded, connect the other lead to either distributor connector. If the ohmmeter shows a reading, replace the distributor pickup coil. To test for control unit continuity, ground one ohmmeter lead and connect the other lead to the control unit pin designated. If continuity cannot be obtained after removing and remounting the control unit in an attempt to get good ground, replace the control unit. Make sure the ignition switch is **OFF,** and reconnect the control unit connector plug and the distributor plug. Check the air gap adjustment as described previously. After these tests or repairs, test the entire system by removing the center wire from the distributor cap. Using insulated pliers and a heavy rubber glove, hold this wire about one-half of an inch from the engine block and operate the starter. If there is no spark replace the control unit and retest. If no spark is obtained, replace the coil.

TROUBLESHOOTING LIGHTING SYSTEMS AND ELECTRICAL ACCESSORIES

Most modern automotive and construction vehicles (Military Tactical CESE included) have up to 60 or 70 lights and numerous electrical accessories, such as small motors, gauges, solenoids, and switches. Each one of these devices presents a new troubleshooting problem to the CM1. To perform these tests, you need a few simple hand tools, such as screwdrivers, pliers, a 12/24 volt test lamp, and most important, a volt/ohmmeter (fig. 4-42). For routine testing of burned out light bulbs,

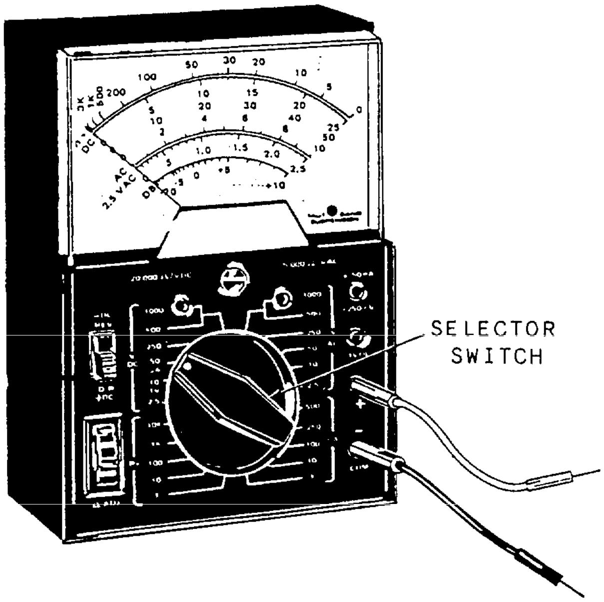


Figure 4-42.-Typical volt/ohmmeter.

burned fuses, or corroded battery terminals, a technical manual may not be required; however, for more complex, electrical systems, it is a necessity. Use EXTREME CAUTION when working around any electrical system on any CESE. Crossing wires or flashing wires to ground-to check for current may all lead to major damage, costly repairs, or personnel injury.

When you troubleshoot any system, have a set plan to approach the problem. Keep it simple; eliminate easy items, such as a dead battery, burned out light bulbs, blown fuses, and so forth. Once the simple fixes are out of the way, use your own set plan to solve the problem. One plan that may be of help to you is the following:

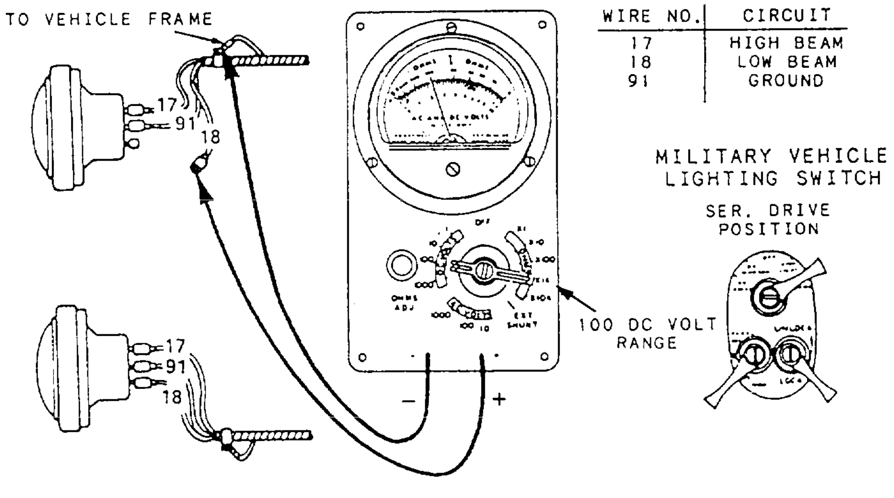
1. Know the machine and find and read the technical manual to understand the problem.
2. List all the possibilities of the fault.
3. When possible, speak to the operator and find out how the unit malfunctioned in a working situation.
4. Operate and inspect the machine yourself.
5. Systematically test individual circuits until the problem is found.
6. Test your findings.
7. Repair CESE and return it to service.

As an afterthought, once a unit of CESE is repaired and returned to dispatch, discuss your findings with other CMs in the shop. Do not play, *I've Got a Secret* with repair information.

Before proceeding with any electrical tests on automotive or construction equipment, check the power source (battery) and its connections first. A dead or poorly grounded battery may not light lights, work solenoids, or run motors. On the other hand, a poorly grounded battery may work many of the vehicle components, but not certain electronic circuits. Remember to check the battery and its connections first; for the remainder of this chapter, before any troubleshooting procedures are explained, it will be assumed that you have done so.

HEADLIGHTS

The most common problem in headlight systems is burned out light bulbs. This may be eliminated simply by replacing the bulbs. If the head lamp still does not work, remove the lamp from the socket and check the leads on the multiwire connector to the lamp with a 12/24 volt test lamp or a volt/ohmmeter (multimeter) (fig. 4-43). Make sure the headlight switch is turned on.



WIRE NO.	CIRCUIT
17	HIGH BEAM
18	LOW BEAM
91	GROUND

Do the following steps to check for voltage to the headlights:

Step 1. Refer to the table above and pick the wire number for each headlight, high or low beam, that is not working. Disconnect that wire from the back of the headlight.

Step 2. Turn lighting switch to "SER. DRIVE" position.

Step 3. Set switch on meter to "100 DC VOLTS" position.

Step 4. Connect red probe to the disconnected wire and black probe to a good ground.

Step 5. If wire 17 and 18 show 24 volts, the problem is in the headlamp. If a zero reading is observed at wire 17 and 18, check the dimmer switch and light switch.

Figure 4-43.-Troubleshooting headlight wiring (typical military system).

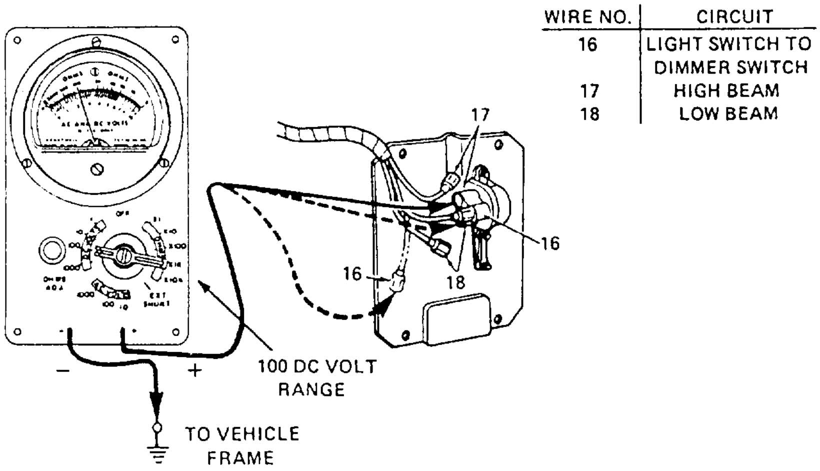


Figure 4-44.-2 1/2-ton military truck foot-operated dimmer switch electrical test.

Obtain a wiring diagram for the particular system you are working with, and trace the circuit back to the next major multi wire connector, then to the light switch itself. Remember, try to avoid unnecessary cutting into wiring looms or harnesses as this type of damage causes moisture to be allowed into the wiring system.

If the headlights do not switch from low beam to high beam, find the dimmer switch (foot operated or steering column mounted), then refer to the wiring diagram (fig. 4-44) and test for voltage.

In the case of all of the headlights being out at the same time, check the fuse; then check for power flow to the light switch. If necessary, remove the light switch from the vehicle and test it on the bench.

The problem of dim headlights could mean the following things:

- Low battery voltage
- Poor connections in the circuit
- Faulty ground wires
- Incorrect voltage head lamps

FUSES AND CIRCUIT BREAKERS

Fuses or circuit breakers are put into electrical circuits to prevent damage from electrical overload. Normally, fuses are mounted in a cluster or fuse block (fig. 4-45). Some may be remotely mounted away from the fuse block, in which case, you will have to get under the dashboard or hood and hunt for them. Still others may be mounted within the circuitry of the accessory (fig. 4-46) that you are testing. Fusible links are usually marked and mounted close to the battery.

Testing fuses is quite simple. You should use a 12/24 test lamp. Attach one end to a good ground, energize the circuit, and use the probe to test both ends of the fuse. If a burned fuse is found, keep in mind there is a reason for it. Trace the circuit and find the fault before replacing the fuse.

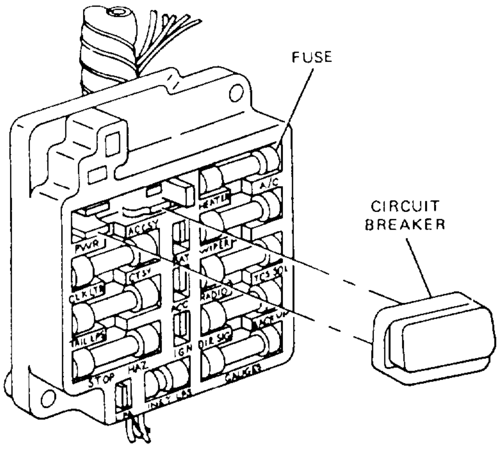


Figure 4-45.-Fuse block with fuses and circuit breaker.

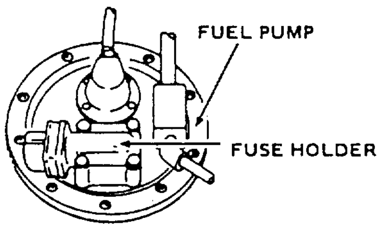


Figure 4-46.-Example of an accessory mounted fuse.

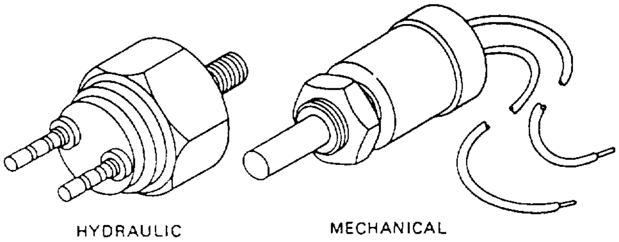


Figure 4-47.-Typical stoplight switches.

CAUTION

Never bypass a fuse or circuit breaker by using tinfoil or direct wire method. Always use the correct amperage rating when replacing any fuse or circuit breaker.

DIRECTIONAL SIGNALS

Troubleshooting directional signals may be somewhat complicated due to the fact that most of the turn signal switches, flashing units, and much of the wiring is located under the dashboard or in the steering column. In addition, the most common design for a turn signal system is to use the same rear lamps for both the stoplights and the turn signals. This somewhat complicates the design as the brake light circuit must pass through the turn signal switch. As the left or right turn signal is energized, the stoplight circuit for that circuit is opened and the turn signal circuit for that circuit is closed.

NOTE

When this type of circuit is used, the front indicator lamps and front signal lights must be on a separate signal switch circuit.

To troubleshoot this type of switch, first find the multiwire connector joining the main wiring harness to the signal switch harness. Use a 12/24 volt test lamp and the manufacturer's maintenance manual as a guide. Test the input and output of the switch. If the switch is at fault and must be replaced, usually the steering wheel has to be removed before the switch maybe removed.

Failure of the signal lights to flash is usually caused by the flasher unit. A flasher unit is a nonrepairable item mounted under the dashboard or on the fire wall.

BRAKE LIGHTS

The two types of brake light switches are hydraulic and mechanical (fig. 4-47). These may be mounted under the dashboard, on the master cylinder, or on the vehicle main frame. To test the switch, first check for power to the switch. Then using a 12/24 volt test lamp, touch the probe to the output terminal of the brake light switch and apply the brakes. If the test lamp lights, the switch is good. If the test lamp does not light, the switch is defective and must be replaced.

HORNS

The current draw of a horn is very high; therefore, it is usually operated by a relay (fig. 4-48). The control switch (horn button) is almost always mounted in the

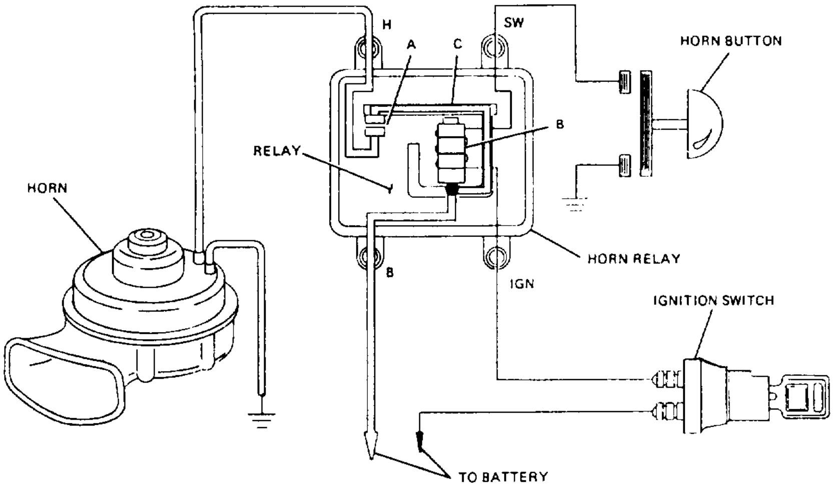


Figure 4-48.-Typical horn circuit using a relay.

center of the steering wheel. Refer to figure 4-4 for troubleshooting. In testing the horn circuit, first find the horn relay. Normally, it is mounted under the hood in the engine compartment. Next, check for voltage at terminals B, ING, and SW. If voltage is present at the relay, switch the probe to terminal H and depress the horn button. If the test lamp lights, the relay is good. Check the horn.

SMALL ACCESSORY MOTORS

Small accessory motors are used to drive cooling and heating fans, windshield wipers, fuel pumps, and so forth. Since most of these motors are basically the same, troubleshooting is reasonably simple. The hardest part may be getting to the motor. Normally, troubleshooting procedures are as follows:

1. Check the fuse.
2. Turn the motor by hand when possible. Some obstruction may be causing it to jam, overloading the circuit and blowing the fuse.
3. Check for power at the last multiwire connector going to the motor. Be sure power is arriving at the motor.
4. Look for burned wiring and loose connections. Burned insulation will be discolored and will smell burned.
5. Troubleshooting of small electrical accessory motors is similar to continuity and ground tests performed on starting motors mentioned earlier in this chapter.
6. Repair the motor according to manufacturer's specifications.

ASSIGNMENT 4

Textbook Assignment: “Engine Troubleshooting and Overhaul,” and “Electrical Troubleshooting," pages 3-28 through 4-29.

4-1. Piston ring clearance is measured at what position on the piston?

1. Between the ring and the top of the groove
2. Between the ring and bottom of the groove
3. At the ends of the piston ring

4-2. Before starting a newly overhauled engine, you should make which of the following inspections?

1. Check for proper fluid levels
2. Make sure the linkages and electrical connections are correct
3. Make sure there are no loose items lying about
4. All of the above

4-3. Before initial start–up, you should make sure the emergency shutdown systems are operational.

1. True
2. False

4-4. Upon starting a newly overhauled engine, you must shut the engine down if no oil pressure is observed in what maximum number of seconds?

1. 5
2. 10
3. 15
4. 30

4-5. A newly rebuilt engine should be run with light loading for at least (a) how long, and (b) what number of miles?

1. (a) 10 hours (b) 100 miles
2. (a) 50 hours (b) 500 miles
3. (a) 100 hours (b) 1,000 miles
4. (a) 250 hours (b) 2,500 miles

4-6. For supplying electrical current in present-day automotive equipment, the alternator is preferred over the conventional generator for which of the following reasons?

1. Its usefulness in supplying current is limited only by its size
2. It produces current that is fed to accessories without alternation
3. Its larger size enables it to supply the additional power required
4. It is small and can produce the power required for operating electrical accessories under nearly all conditions

4-7. In an alternator, the rotor does the same job as which of the following parts in a DC generator?

1. The field coil and pole shoe
2. The stator
3. The armature
4. The rectifier bridge

4-8. Alternator system stators connected in a “Y” produce lower voltage and higher current than delta-connected stators.

1. True
2. False

4-9. What device enables an alternator to produce direct current?

1. A commutator
2. A rotor
3. A rectifier bridge
4. A stator

4-10. The chemical composition of a diode rectifier allows current to do what within the diode?

1. To not flow at all
2. To flow in one direction only
3. To flow in both directions

4-11. In the automotive alternator using positive and negative silicon-diode rectifiers, a total of how many rectifiers of each type are required?

1. One positive and one negative
2. Two positive and one negative
3. Two positive and two negative
4. Three positive and three negative

IN ANSWERING QUESTION 4-12, REFER TO FIGURE 4-2 IN YOUR TRAMAN.

4-12. The polarity of silicon-diodes that are not marked with plus or minus signs is marked with what color(s) of lettering?

1. Copper or silver
2. Blue or green
3. Black or red
4. Brown or yellow

4-13. Which of the following types of regulators is used in an alternator?

1. Transistorized
2. Electromagnetic
3. Transistor
4. Each of the above

4-14. You can adjust the transistor regulator internally by using which of the following procedures?

1. Relocating a screw in the base of the regulator
2. Turning a screw on the potentiometer
3. Interchanging diode connections
4. Sliding the contacts of its resistors

4-15. In troubleshooting a charging system, the mechanic observes that the qenerator field coils are grounded externally at the regulator. What type of field circuit will the mechanic be testing?

1. "A" circuit only
2. "B" circuit only
3. “A” or “B” circuit, depending on whether the system is positively or negatively grounded

4-16. The output polarity of a dc generator is determined by the polarity of its

1. “A” circuit
2. “B” circuit
3. permanent field pole piece
4. silicon-diode

IN ANSWERING QUESTIONS 4-17 THROUGH 4-27, WHICH DEAL WITH TROUBLESHOOTING A VEHICLE’S CHARGING SYSTEM WITH A VOLT-AMPERE TESTER, REFER TO FIGURES 4-8 THROUGH 4-14 IN YOUR TRAMAN.

4-17. During an alternator output test, the ammeter scale indication stays at normal while engine speed is increased slowly. Which of the following components needs to be replaced?

1. The alternator
2. The battery
3. The regulator

4-18. The ammeter shows no output at high voltage during a generator test, and the charging circuit is not fused at the regulator. What component should be repaired or replaced?

1. The field lead of the wiring harness
2. The armature lead of the wiring harness
3. The regulator cutout relay
4. The generator field winding

4-19. While testing a 12-volt charging system, the mechanic gets a maximum voltmeter reading of 15 volts. What is the probable cause of this reading?

1. A blown fuse
2. A shorted field wire
3. A grounded field
4. A defective regulator current limiter relay

4-20. You are testing a vehicle's voltage regulator. A voltage output that is either too high or too low can be caused by which of the following troubles?

1. A damaged regulator resistor
2. A faulty regulator voltage limiter
3. Burned regulator contacts
4. Each of the above

4-21. By measuring the resistance of a negative charging system circuit, you can determine how much voltage is lost between which of the following components?

1. The generator output terminal and the negative battery post
2. The generator housing and the positive battery post
3. The generator output terminal and the positive battery post or between the generator housing and the negative battery post

4-22. Which of the following conditions contributes to voltage drop in a circuit?

1. An open circuit
2. Excessive resistance
3. Low resistance

4-23. Excessive resistance in a vehicle's charging system can be caused by which of the following problems?

1. An open circuit
2. Burned or oxidized cutout relay contacts only
3. Loose or corroded connections only
4. Burned or oxidized cutout relay contacts and loose or corroded connections

4-24. Which of the following tests is required to isolate the point of excessive resistance in a charging system?

1. An insulated circuit resistance test
2. A battery drain test
3. A charging circuit diode test
4. An excessive output test

4-25. When you are performing a regulator ground circuit resistance test, a voltmeter reading exceeding how many volts indicates a possible damaged ground strap or loose mountings?

1. 0.1
2. .01
3. 1.0
4. .02

4-26. A mechanic is measuring the resistance of an insulated circuit in an ac charging system. With the engine running at 2,000 rpm, the mechanic should increase the load with the tester until the ammeter reaches what reading?

1. 24 amperes
2. 20 amperes
3. 10 amperes
4. 5 amperes

4-27. In a battery drain test, the ammeter scale reading is other than zero with all the vehicle’s circuits turned off. What does this reading indicate?

1. An electrical short circuit
2. An electrical open circuit
3. A blown fuse
4. A corroded battery ground post

4-28. You can detect a single nonconducting diode in an alternator system by using which of the following devices?

1. A voltmeter
2. An analyzer screen
3. An ammeter
4. A microfarad meter

IN ANSWERING QUESTION 4-29, REFER TO FIGURE 4-18 IN YOUR TRAMAN.

4-29. When using the bypass device to test a charging system, which of the following steps should you take?

1. Operate the engine at idle
2. Race the engine briefly
3. Operate the engine at high speed for 1 minute
4. Bring the alternator to rated output

4-30. A shorted diode normally affects the alternator output more than an open diode for what reason?

1. A shorted diode opposes the following electrical pulse
2. A shorted diode will not conduct electricity
3. An open diode opposes the next pulse by allowing current to flow back through the winding

4-31. A weak diode will produce what type of pattern on an analyzer screen?

1. A hiqh or low peak every sixth pulse
2. A flat signal each sixth pulse
3. A low ripple pattern
4. An abnormally high ripple pattern

4-32. After a defective alternator is removed for repair, how is the problem verified?

1. Using an oscilloscope
2. Using a simple ohmmeter
3. Using a voltmeter
4. By performing a resistance test

IN ANSWERING QUESTIONS 4-33 THROUGH 4-37, WHICH DEAL WITH TROUBLESHOOTING A VEHICLE’S STARTING SYSTEM WITH A BATTERY STARTER TESTER, REFER TO FIGURES 4-23 AND 4-27 IN YOUR TRAMAN.

4-33. When the battery starter tester is used for a quick overall test of a 12-volt starting system, which of the following tests should be performed?

1. Battery starter test
2. Starting motor current draw test
3. Cranking voltage test
4. Battery switch test

4-34. On a vehicle equipped with a 24-volt series-parallel starting system, what minimum voltmeter reading is considered normal for a cranking voltage test?

1. 18 volts
2. 16 volts
3. 12 volts
4. 8 volts

4-35. If the cranking voltage for a 12-volt system is 8 volts, you should take which of the following actions?

1. Test the battery capacity
2. Test the starter cranking current
3. Test the starter circuits
4. Each of the above

4-36. In a starting motor current draw test, the cranking speed of the motor is low and the current draw is normal. You should take which of the following actions?

1. Check the battery capacity
2. Check the starting circuit resistance
3. Check the starting motor cranking current

4-37. In tests where the engine is cranked with the ignition on, you should keep the engine from starting by connecting a jumper lead in what position?

1. Between the battery posts
2. Between the starting motor terminal and negative post of the battery
3. Between the secondary terminal of the coil and ground
4. Between the primary terminal of the coil and ground

IN ANSWERING QUESTION 4-38, REFER TO FIGURE 4-25 IN YOUR TRAMAN.

4-38. A starter insulated circuit resistance test is being performed on a 12-volt starting system. The voltage loss in each of the circuits shown in views A, B, and C should NOT exceed which of the following amounts?

1. 0.2, 0.3, and 0.4 volt, respectively
2. 0.4, 0.3, and 0.1 volt, respectively
3. 0.6, 0.5, and 0.4 volt, respectively
4. 0.2, 0.3, and 0.2 volt, respectively

4-39. During a starter ground circuit resistance test, the measured voltage loss exceeds 0.2 volt or the loss given by the manufacturer’s specifications. This loss can result from which of the following problems?

1. A loose connection
2. A ground cable too small to carry the current
3. A dirty or corroded connection
4. Each of the above

4-40. High resistance in the solenoid switch circuit causes what to happen in the starting current?

1. Increased current flow
2. Reduced current flow
3. A voltage increase
4. A voltage decrease

4-41. While cranking the engine, you should place the leads of a voltmeter on the solenoid as shown in figure 4-27. What voltmeter reading, in volts, indicates excessive resistance?

1. .005
2. .05
3. 0.5
4. 5.0

4-42. At high engine speeds, which of the following drawbacks of the conventional ignition system is overcome by the transistorized ignition system (breaker point type)?

1. Incomplete saturation of the ignition coil only
2. Arcing across breaker points only
3. Incomplete saturation of the ignition coil and arcing across breaker points

4-43. What component of the magnetic-pulse transistor ignition system replaces the breaker plate assembly of the conventional ignition system?

1. An iron timer core
2. A magnetic pickup assembly
3. An ignition pulse amplifier
4. A reluctor

4-44. What does the transistor in the amplifier of the magnetic-pulse transistor ignition system do?

1. It controls the current flowing between the coil primary and ground
2. It desaturates the ignition coil
3. It eliminates arcing across the breaker points

4-45. To help assure secondary voltage output during high engine speeds in a capacitor discharge system, which of the following components is connected across the primary windings of the coil?

1. An ignition pulse amplifier
2. A high-voltage condenser
3. A pickup coil
4. An electronic control unit

4-46. Which of the following ignition system components is in a conventionial system, as well as in an electronic (Chrysler) system?

1. A pickup coil
2. An ignition coil
3. A reluctor
4. A condenser

4-47. The Chrysler electronic ignition uses a magnetic pickup coil and a rotating reluctor to replace which of the following components?

1. The cam and rubbing block
2. The condenser
3. The primary coil
4. The rotor

4-48. On a Chrysler type of electronic ignition system, the compensating ballast resistor is bypassed for what reason?

1. To limit the voltage to the electronic control module
2. To supply full voltage to ignition coil
3. To reduce the primary voltage
4. To raise the primary voltage

4-49. To adjust the air gap on the Chrysler electronic system, you align a reluctor tooth with the pickup coil tooth. You should then use a nonmagnetic gauge 0.002 larger than specified to obtain what tolerance?

1. Go no-go
2. Loose
3. Tight
4. 0.002 inch

4-50. In the lean burn ignition system, the carburetor switch is used for what purpose?

1. To measure incoming fresh air temperature
2. To signal the computer for more vacuum
3. To signal the computer for a new throttle plate position
4. To tell the computer the engine is either at idle or off idle

4-51. In a General Motors unitized ignition system, what part takes the place of the cam?

1. The pickup coil
2. The timer coil
3. The pole piece
4. The rotor

4-52. In an HEI type of ignition system, what action occurs when the timer core teeth align with the pole piece?

1. Voltage is induced in the pickup winding
2. Voltage is induced in the timer core
3. The dwell period is shortened

4-53. In an HEI type of ignition system, what helps the firing of lean mixtures?

1. A shorter spark duration
2. A longer spark duration
3. Lower secondary voltage in the ignition coil
4. Higher primary circuit voltage

4-54. Minicomputers are being used in many modern automotive ignition systems.

1. True
2. False

4-55. In a computerized ignition system, ignition timing is performed by what assembly?

1. The distributor
2. The processor
3. The thermistor
4. The E.G.R.

4-56. Altitude dependent EGR flow requirements are controlled by what sensor?

1. Coolant
2. Barometer pressure
3. Inlet air
4. Manifold absolute pressure

4-57. Approximately what reference voltage is supplied to the coolant temperature?

1. 4 volts
2. 6 volts
3. 8 volts
4. 12 volts

4-58. The ECA modifies engine timing to prevent spark knock at inlet air temperatures above what temperature?

1. 80°F
2. 90°F
3. 100°F
4. 150°F

4-59. The throttle sensor is a rheostat connected to what part?

1. The position sensor
2. The metal pulse ring
3. The throttle plate shaft

4-60. When a distributorless ignition system is used, which of the following parts is/are eliminated?

1. The distributor itself
2. The vacuum advance mechanism
3. The mechanical advance mechanism
4. All of the above

4-61. It would be better to test an ignition system with a scope tester for what reason?

1. It is more accurate
2. It is less complicated
3. You may do so with the engine running
4. You can test the engine while it is hot

4-62. Of the following components, which is/are NOT a part of the secondary circuit of a conventional ignition system?

1. The spark plug wires
2. The distributor cap
3. The points
4. The distributor rotor

4-63. In a conventional ignition system, excessive resistance may be a result of which of the following problems?

1. A defective spark plug
2. A corroded distributor cap
3. An unseated cable in the coil tower
4. Each of the above

4-64. The condition of a standard ignition coil is satisfactory when the ohmmeter reads within what range?

1. 1,000 to 2,000 ohms
2. 2,000 to 6,000 ohms
3. 5,000 to 10,000 ohms
4. 4,000 to 8,000 ohms

4-65. An ohmmeter can be used to indicate which of the following coil conditions?

1. An open secondary
2. A bad connection at the coil terminal
3. High resistance in the cable
4. Each of the above

4-66. When you are testing a transistor ignition system, a reading of how many ohms resistance indicates a defective pickup coil?

1. 300 to 350
2. 400 to 550
3. 550 to 750
4. 750 to 850

4-67. When you are removing a control unit connector of an electronic ignition system, the ignition switch must be in what position?

1. Off
2. On
3. Start
4. ACC

4-68. Before conducting electrical testing on automotive or construction equipment, you should take which of the following actions?

1. Check the battery
2. Check the battery connections
3. Replace the battery
4. Both 1 and 2 above

4-69. The unnecessary cutting of a wiring harness will cause what type of damage to occur?

1. It will allow moisture to enter the wiring harness
2. It will cause loose connections
3. It will make the system more complicated to troubleshoot

4-70. On automotive and construction vehicles, remotely mounted fuses may be found in which of the following locations?

1. Under the dashboard
2. Under the hood
3. Within the circuitry of the accessory
4. All of the above

4-71. Fusible links are usually mounted close to what component on the electrical system?

1. The multiwire connector
2. The battery
3. The fuse block
4. The alternator

4-72. Turn signal electrical wiring is somewhat complicated for which of the following reasons?

1. The brake light wiring must pass through the turn signal switch
2. Turn signals and brake lights use the same bulbs
3. The front signal lights are on a separate switch

4-73. Usually, before the signal switch can be removed from the equipment, you must take which of the following actions?

1. Disconnect the battery
2. Remove the steering wheel
3. Disconnect the multiwire connector
4. Both 2 and 3 above

4-74. On a vehicle, brake light switches may be found in which of the following locations?

1. Under the dashboard
2. on the master cylinder
3. Mounted on the frame of the vehicle
4. Each of the above

4-75. When troubleshooting a small electrical accessory motor, what should you check first?

1. The fuse
2. The mountinqs
3. The ground

CHAPTER 5

FUEL SYSTEM OVERHAUL

As described in the *Construction Mechanic 3 & 2* it is the job of the fuel system to send the correct quantity of fuel or fuel-air mixture to the engine at all times. To do this, the fuel system components must be clean and correctly adjusted or they will not function properly. After troubleshooting, when the problem has been identified and isolated, it will be your job to see that components of the fuel system are overhauled correctly.

CARBURETOR OVERHAUL

The carburetor has been designed and manufactured in literally thousands of makes and models. Therefore, it is not practical to discuss even a few of them in this training manual (TRAMAN). The basic principles of all carburetors are the same and may be found in the *Construction Mechanic 3 & 2,* NAVEDTRA 10644-G1, or U.S. Army publication *Principles of Automotive Vehicles,* TM-9-8000. The purpose of this section of this chapter is not to make you an expert in carburetor overhaul, but, to familiarize you with carburetor overhaul procedures in general.

CLEANING AND IDENTIFICATION

Before starting any carburetor rebuild, first you should know and make absolutely sure the carburetor is the problem. Good troubleshooting can save you a lot of time and work. Why overhaul when you could have done the job with a simple adjustment. Second, find out the make and model of the carburetor you are about to rebuild and make sure the rebuild kit for the unit that you are going to overhaul is on hand. There is nothing more frustrating for a person than to disassemble an automotive part like a carburetor only to find out that the rebuild kit is unavailable. Third, locate the technical manual and have it on hand for the job. Only now will you be ready to start by removing the carburetor from the engine.

The first thing you should do after removing the carburetor from the vehicle is the initial cleaning, which will remove deposits of dirt and grime and allow the identification tags or numbers to be read. These ID numbers are stamped into the base of the largest part of the carburetor, or they may be found on a small metal tag screwed or riveted to the carburetor. (Remember, when you complete the overhaul job, reattach any identification tags to their proper place.) Before you dip the carburetor into the cleaning solution, remove items that may be affected by the cleaning solution. (These items could be electric solenoids, plastic parts, vacuum pulldowns, etc. They should be removed and set aside for individual cleaning and testing.) Dip the carburetor into the solvent and brush away any deposits of dirt or grease. Remove the unit from the cleaning solution, let it drip-dry, or blow-dry it using low pressure air.

CAUTION

> Compressed air used for cleaning purposes should not exceed 30 psi. Wear goggles and other appropriate protective equipment when using compressed air.

MANUFACTURER'S INSTRUCTIONS AND TOOLS

As you know, modern carburetors are complicated assemblies. They cannot just be taken apart, cleaned out, and put back together again. Each overhaul kit has assembly instructions, an exploded view for parts identification purposes, and a specification sheet with it. If this paper work is not in the overhaul kit, find the manufacturer's repair manual which is available in your technical library. Without this information and the proper tools, you may irreversibly damage the carburetor. If you adjust the carburetor improperly, poor engine performance may result.

DISASSEMBLY AND CLEANING

Carburetor disassembly and cleaning is basically a matter of logic and good judgment. Use common sense and work slowly. Some tips to follow are shown below.

- Have the instructions handy. Read them first to find out any special disassembly techniques.
- Make sure your work space is clean and well ventilated.
- Use a small tray or container to put the reusable parts in that must be cleaned. This will help prevent the search for that lost or missing screw,

check valve, jet, and so forth, a search which is usually held on the floor.

- Have a sufficient quantity of carburetor cleaner on hand.

CAUTION

Wear rubber gloves and eye protection when you use this highly caustic cleaning solution.

Use a small wire basket for dipping the smaller parts into the cleaner.

When you dip larger parts, use a short piece of wire, such as an old coat hanger, to hang the parts into the cleaning solution. Submerge the parts for at least 30 minutes.

During any disassembly operation, be careful not to lose or damage any parts. Keep unauthorized people away from your work area so your parts do not get lost, misplaced, or walk away. Thoroughly rinse the carburetor parts with clean water or solvent and blow-dry them with low-pressure air. Before reassembly, inspect all parts for wear or damage.

CAUTION

Disassemble the carburetor only as far as you have to. Normally, it is not necessary to remove the throttle shaft and its plates or the choke shaft and its plate.

REPAIR AND REPLACEMENT

Very little actual repair work is performed on modern carburetors because it is less expensive to replace the unit than repair it. Most repairs you do on carburetors will be in the form of parts replacement.

REASSEMBLY AND ADJUSTMENT

When you have finished your final cleaning and made the necessary repairs, you are ready to reassemble the carburetor. You do this in reverse sequence; that is, the last item taken out is the first put back. Look at the specification sheet for any special instructions, such as setting the float level and float drop, initial choke setting, initial idle adjustments, and any linkage adjustments.

CAUTION

Use care in the assembly process. Carburetor bodies may be made of aluminum, bronze, iron, or even plastic. Overtorquing may damage or warp the parts and lead to expensive repairs or deadlined equipment.

TESTING

When you reinstall the carburetor on the engine, check all connections for proper attachment. Some manufacturer's mark, with numbers or letters, individual connections; others color-code the vacuum lines. Remember, the incorrect hookup of emissions control vacuum lines will lead to decreased fuel economy, increased exhaust emissions, or both.

WARNING

Unauthorized alteration, disconnection, or any tampering with emission control devices in any way is in direct violation with state and federal law. CESE being shipped to overseas locations may be modified according to the manufacturer's specifications to meet operational requirements as directed by CBC, Port Hueneme, CA, Code 15, COMCBPAC Equipment Office or COMCBLANT Detachment, Gulf Port, MS.

To test and adjust today's carburetor properly, an exhaust gas analyzer is a requirement. Without this machine, it is impossible to know if you are exceeding the allowable ppm (parts per million) emissions of the HC, CO, and CO_2. There are many different makes of this machine. The information listed here is only to give you a basic understanding of the unit.

CAUTION

Follow the directions for the hookup of the unit exactly. These instructions may come from the manufacturer's operating instructions, or even special instructions from the under the hood data plate. Failure to obtain proper hookup may result in testing equipment or vehicle damage.

If the analyzer does not respond, check to see if one of the following conditions exists:

- The vehicle is not at operating temperature. (Warm up the engine by normal running.)

- The probe is not inserted far enough into the tailpipe of the vehicle. (Remove and reinsert the probe.)

- Check the vehicle for an exhaust leak. (Repair the exhaust system.)

- Check the mode switch of the unit you are testing with reset switches.

- The analyzer sampling system leaks. (Check for tight connections at both of the IR hoses. Check the O-rings in the filter bowl of the analyzer. Perform a leak check.)

- Run the analyzer through the test calibration series only after the engine has been brought to operating temperature.

Adjust the cold- and hot-idle speed of the engine. Assuming all other parts of the engine and its controls are working properly, use the specifications provided by the manufacturer's repair manual to adjust the carburetor to meet the minimum ppm of HC, CO, and CO_2 emissions. Return the vehicle to the shop supervisor for final inspection and return it to service.

GASOLINE FUEL INJECTION SYSTEMS

Fuel injection systems are an increasing y popular alternative to the carburetor for providing an air-fuel mixture. They inject, under pressure, a measured amount of fuel into the intake air usually at a point near the intake valve. Fuel injection systems provide the following advantages:

- Fuel delivery can be measured with extreme accuracy, giving the potential for improved fuel economy and performance.

- Because the fuel is injected at the intake port of each cylinder, fuel distribution will be much better and fuel condensing in the manifold will not be a problem.

- There is no venturi as in a carburetor to restrict the air intake, making it easier to keep volumetric efficiency high.

- The fuel injector, working under pressure, can atomize the fuel much finer than the carburetor, resulting in improved fuel vaporization.

There are three basic configurations of gasoline fuel injection: timed, continuous, and throttle body.

TIMED FUEL INJECTION SYSTEMS

In gasoline engines, the timed fuel injection system injects a measured amount of fuel in timed bursts synchronized to the intake strokes of the engine. Timed injection is the most precise form of fuel injection; it is also the most complex. There are two basic forms of timed fuel injection: mechanical and electronic. The operation of the two are very different and will be covered separately in the following two paragraphs.

Mechanical-Timed Fuel Injection

The mechanical-timed injection system (fig. 5-1) has a high-pressure pump that draws fuel from the gas tank and delivers it to the metering unit. A pressure relief valve is installed between the fuel pump and the metering unit to regulate fuel line pressure by bleeding off excess fuel back to the gas tank. The metering unit is a pump that is driven by the engine camshaft. It is always in the same rotational relationship with the camshaft so that it can be timed to feed the fuel at just the right moment to the injectors. There is one injector for each cylinder. Each injector contains a spring-loaded valve that is opened by fuel pressure injecting fuel into the intake at a point just before the intake valve. The throttle valve regulates engine speed and power output by regulating manifold vacuum, which, in turn, regulates the amount of fuel supplied to the injectors by the metering unit.

Electronic-Timed Fuel Injection

In an electronic system (fig. 5-2), all of the fuel injectors are connected in parallel to a common fuel line that is fed by a high-pressure pump from the gas tank. A fuel pressure regulator is installed in line with the injectors to keep fuel pressure constant by diverting excess fuel back to the gas tank, Each injector contains a solenoid valve and is normally in the closed position. With a pressurized supply of fuel behind it, each injector operates individually whenever an electric current is applied to its solenoid valve. By sending electric current impulses to the injectors in a sequence timed to coincide with the needs of the engine, the system will supply gasoline to the engine as it should.

For this function and that of providing the proper amount of fuel to the engine, the system is fitted with an electronic computer to time the impulses. The computer receives a signal from the ignition distributor to

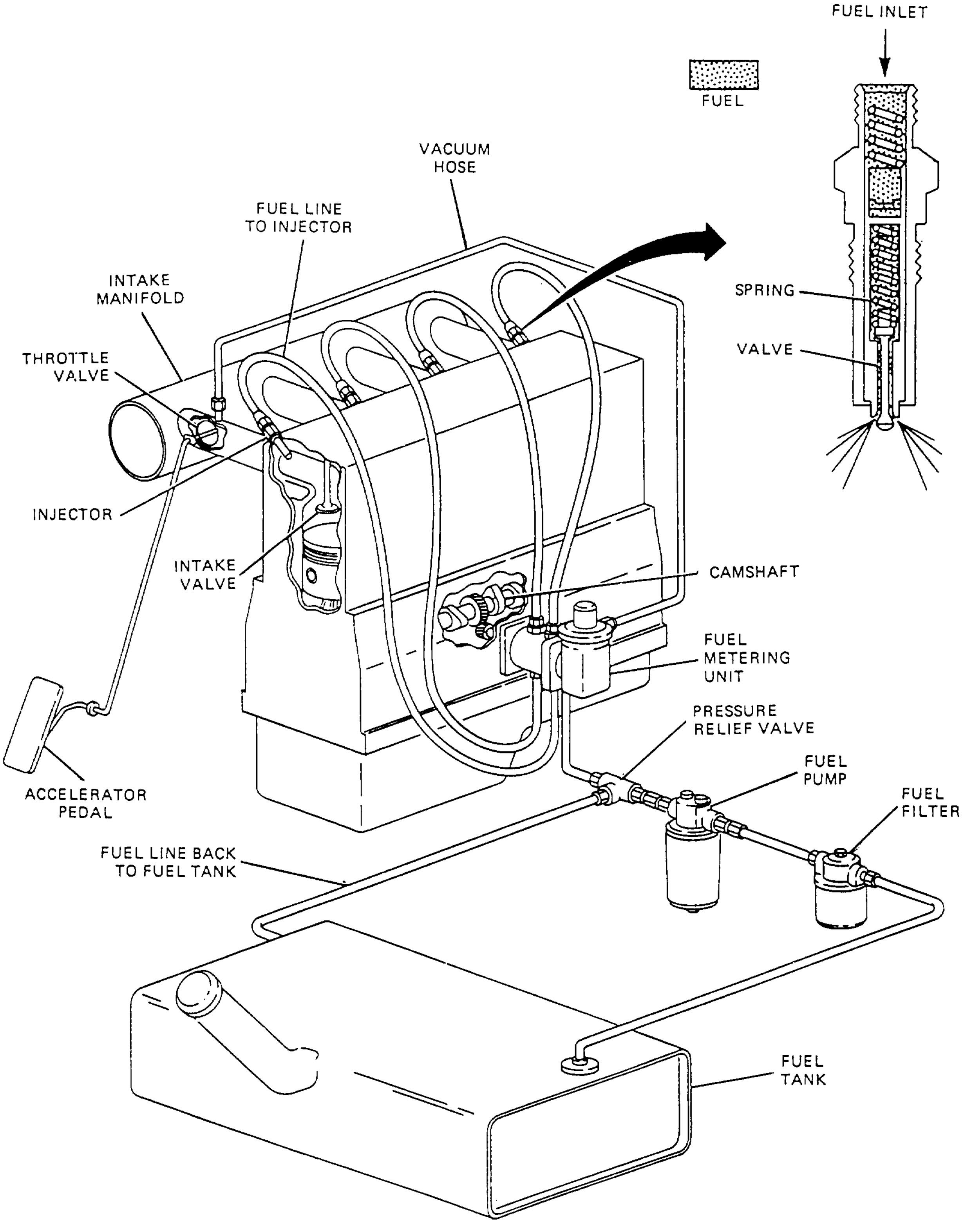


Figure 5-1.-Mechanical-timed injection.

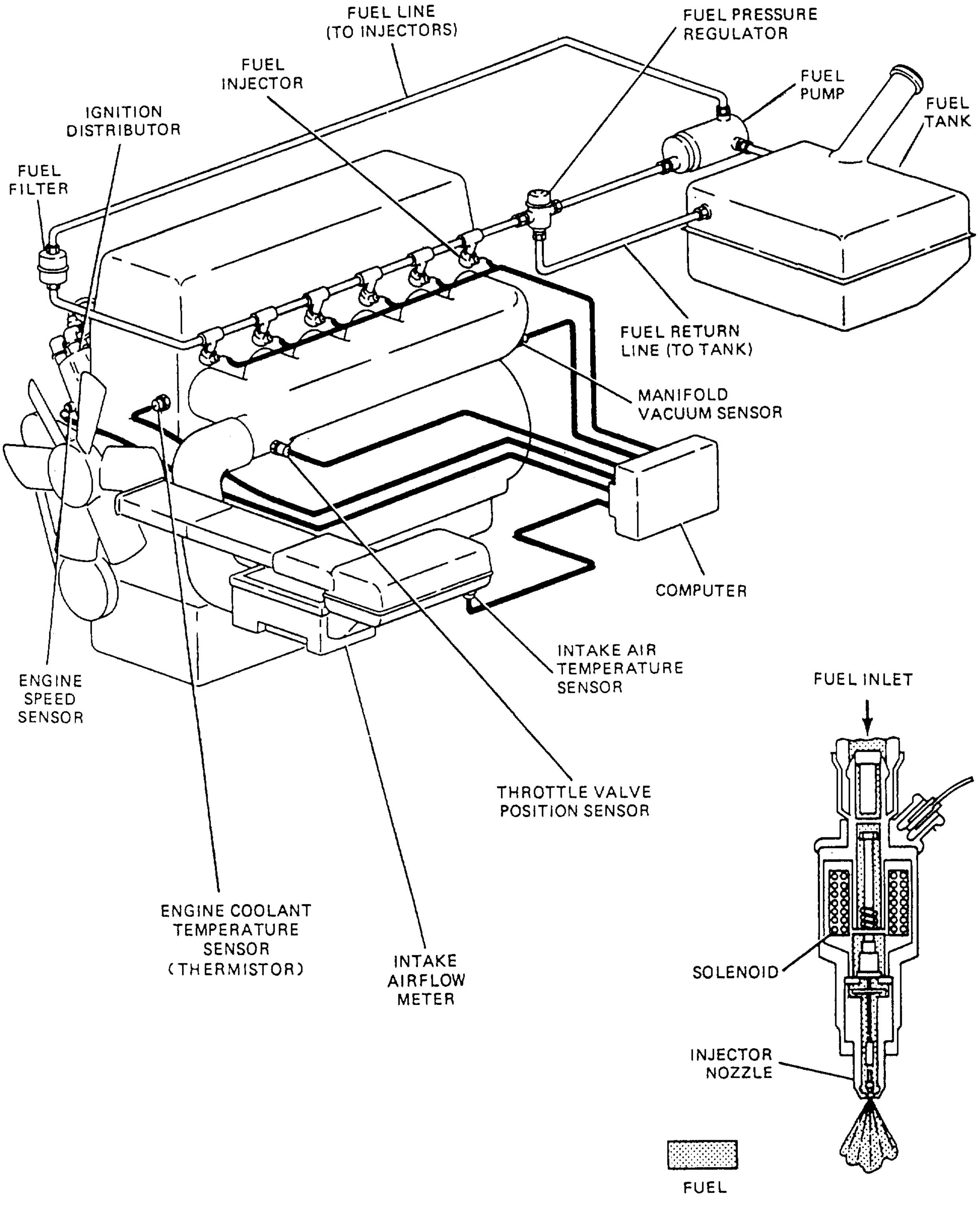


Figure 5-2.-Electronic-timed injection.

establish the timing sequence. The engine is fitted with a variety of sensors and switches to gather the following information:

- Intake air temperature
- Engine speed
- Manifold vacuum
- Engine coolant temperature
- Throttle valve position
- Intake manifold airflow

The computer receives this information and uses it to calculate the amount of fuel delivered at each injection cycle. The computer is capable of changing the rate of fuel delivery to the engine hundreds of times a second, making the system extremely accurate. The computer regulates the amount of fuel delivered by varying the duration of injector operation.

CONTINUOUS FUEL INJECTION SYSTEMS

Continuous fuel injection systems (fig. 5-3) provide a continuous spray of fuel from each injector at a point before the intake valve. Because the entrance of the fuel into the cylinder is controlled by the intake valve, the continuous system will fulfill the requirements of a gasoline engine. Timed injection systems, though a necessity on diesel engines, cost more than continuous systems. They are used on gasoline engines only when more precise fuel metering is desired.

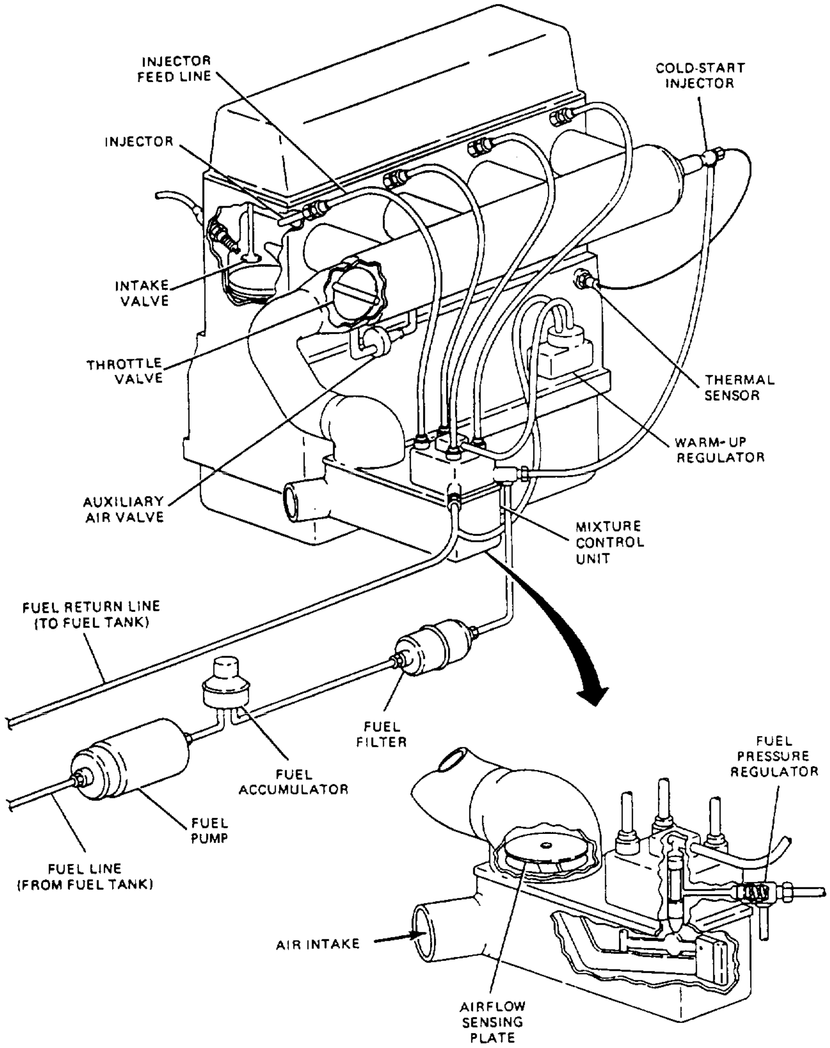


Figure 5-3.-Continuous injection.

In the continuous system, fuel is delivered to the mixture control unit by the fuel pump. The fuel pressure regulator maintains fuel line pressure by sending excess fuel back to the gas tank.

The mixture control unit regulates the amount of fuel that is sent to the injectors, based on the amount of airflow through the intake and the engine temperature. The mixture control unit on mechanical systems is operated by the airflow sensing plate and the warm-up regulator. This information on an electronic system is fed into a computer that regulates the fuel injection rate.

The accelerator pedal regulates the rate of airflow through the intake by opening and closing the throttle valve. A cold-start injector is installed in the intake to provide a richer mixture during engine start-up and warm-up. It is actuated by electric current from the thermal sensor whenever the temperature of the coolant is below a certain level. The cold-start injector works in conjunction with the auxiliary air valve. Its function is to speed up the engine idle during warm-up. It is also actuated by the thermal sensor.

THROTTLE BODY INJECTION SYSTEMS

Throttle body injection (fig. 5-4) is a form of continuous injection-one or two injectors delivering gasoline to the engine from one central point in the intake manifold. Though throttle body injection does not provide the precise fuel distribution of the direct port injection, it is cheaper to produce and to provide a degree of precision fuel metering. The throttle body injection unit is usually an integral one and contains all of the major system components. The unit mounts on the intake manifold in the same manner as a carburetor. Airflow sensors and electronic computers usually are mounted in the air cleaner body.

SERVICING AND PRECAUTIONS

When a vehicle equipped with a gasoline type of fuel injection system has a problem, check all other systems first, such as ignition, air intake, charging, exhaust systems, and so forth-before you work on the fuel injection system. The fuel injection system is usually the last (least problematic) system to cause trouble. There are servicing precautions you should observe before you work on gasoline fuel injection systems.

1. Do not jump the battery to start the vehicle.

2. Do not disconnect the battery cables from the battery with the engine running.

3. When charging a battery in the vehicle, disconnect the negative (grounded) terminal.

4. Do not remove or attach the wiring harness plug to the electronic control unit (computer) with the ignition on.

5. Before performing a compression test, check the manufacturer's repair manual for special instructions.

6. Always make sure all other systems are in good working order before you adjust or troubleshoot the gasoline fuel injection system.

These precautions are general and apply to most systems. Nevertheless, use good judgment, and always

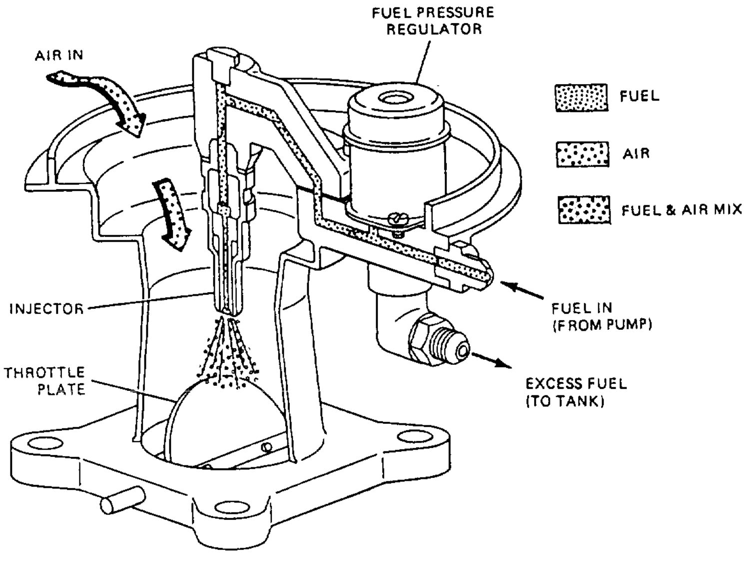


Figure 5-4.-Throttle body injection.

check your manufacturer's repair manual for proper specifications and procedures.

Preventive maintenance is the most frequent type of servicing you will perform on a gasoline fuel injection system. Preventive maintenance consists of periodic visual checks and scheduled fuel filter service. Fuel filters are of the cartridge type, in line type, and disposable type.

All fuel injection system control sensors, such as temperature, oxygen, manifold absolute pressure, and so forth, (these are fully described in chapter 4 of this TRAMAN) are electrically connected to the electric control module (ECM). Some of these sensors, such as the oxygen sensor, have a regular maintenance cycle. Check your manufacturer's repair manual for special instructions pertaining to these sensors.

Be sure the air intake system is sealed properly. Early detection will save fuel and prevent engine damage. Air leaks are a problem to gasoline fuel injection systems. If the air leak is after the air filter, dirt will be ingested into the engine causing internal damage to the engine. Air leaks that bypass temperature sensors can cause false readings to be delivered to the ECM, changing injection quantity. Unmetered air leaks in the intake manifold can cause a lean fuel-air mixture to be delivered to the combustion chambers.

During regular maintenance and always after reassembly, you should check for fuel leaks. Gasoline leaks, however small, are extremely dangerous. They must be dealt with immediately. Clean around all areas to be disassembled. Heavy layers of dirt and grime may make some leaks hard to find. Install new seals on leaking connections and replace cracked or leaking hoses.

CAUTION

Gasoline fuel injection systems operate with fuel pressures up to five times greater than that of standard gasoline fuel systems. Any replacement fuel lines used should be approved for higher pressures. Failure to do so will result in an unsafe fuel system on the vehicle with the danger of possible explosion and fire.

Clean around all areas before reassembly. When you tighten injector line nuts (injector head), use new seals and proper torque specifications. When you tighten fuel lines, use flare nut type of wrenches because regular open-end wrenches may damage these fuel line fittings.

Gasoline fuel injection systems have up to eight different manufacturers and over 21 different models. The 1990 edition of *Electronic Fuel Injection (Domestic) Diagnosis and Testing Manual* by Mitchell is an excellent source for additional study on this subject.

DIESEL FUEL INJECTION SYSTEMS

When you studied the *Construction Mechanic 3 & 2*, you learned about general maintenance, removal, and replacement of diesel fuel; injection pumps, injectors, blowers, and turbochargers, as well as timing, minor adjustments, and repairs to the Caterpillar, International Harvester, General Motors, and Cummins diesel fuel systems. In this section, you will learn about the processes used to overhaul and troubleshoot diesel fuel and air induction systems.

CATERPILLAR FUEL INJECTION SYSTEMS

There are three types of Caterpillar fuel injection systems: the forged body, the compact, and the sleeve metering systems. While these systems serve the same purpose and you use common general troubleshooting procedures, each has an individual design. These systems have a capsule type of injector with a precombustion chamber that conditions the injected fuel for more effective combustion.

Forged Body Fuel System

The two main parts of the Caterpillar fuel injection system are the fuel injection pump (fig. 5-5), which times, meters, and creates the pressure needed for fuel

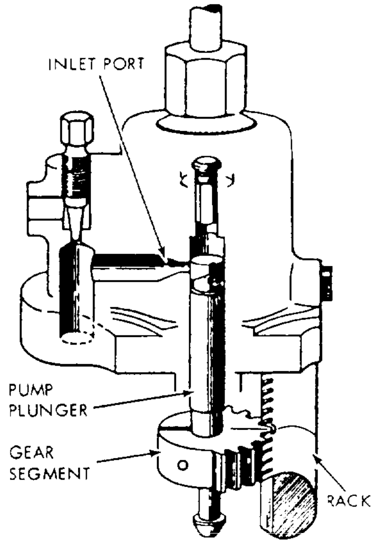


Figure 5-5.-Fuel injection pump.

delivery and the capsule type injector valve (fig, 5-6), which injects and atomizes the fuel.

The most likely causes of faulty fuel injection performance are (1) air in the fuel, (2) low fuel supply, (3) water in the fuel, (4) dirty fuel filters, and (5) low transfer pump pressure. If, after you have checked and corrected these conditions, the engine still does not perform properly, check the fuel injection components. Some of the guidelines for troubleshooting and general test procedures used to test pumps and valves are discussed below.

TROUBLESHOOTING.— Before you remove either the injector pump or injector valve from an erratically running engine, make a simple test. Run the engine at a speed that makes the defect most pronounced. Momentarily, loosen the fuel line nut on the injector pump far enough so that the cylinder misfires or cuts out. Check each cylinder in the same manner. If you find one that has no effect on the irregular operation of the engine or black smoke stops puffing from the exhaust, you have located the misfiring cylinder. You will probably only have to remove the pump and valve for that cylinder for additional testing.

TESTING.— The Caterpillar fuel injection tester provides a means for determining the condition of the fuel injection pumps and valves. Before you perform any test, be sure to study and follow the instructions in the manual for the type of testing equipment you are using.

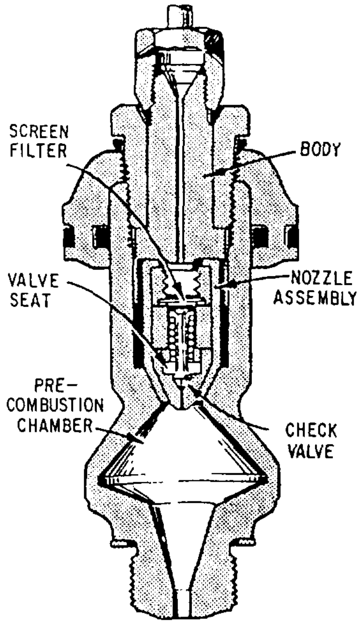


Figure 5-6.-Capsule type of fuel injection valve assembly.

Injection Pump.— Clean the fuel pump thoroughly before installing it on the tester. If any abrasive material enters the pump, it may be carried into the discharge collector of the tester and impair the discharge measurement accuracy. Close the fuel pump openings with the covers provided, holding the plunger in place. Clean the pump thoroughly with cleaning solvent or fuel oil.

Pumps are tested at or near (within .025 inch) the full-load setting of the engine. If the fuel delivery from the pump is within the limits of the full-load setting, the pump will perform properly throughout the full range of rack travel. The governor will compensate for pump wear at any rack setting less than the full-load setting.

Caterpillar fuel injection pumps have no adjustments or replacement parts for rebuilding. If the tester reveals that the pump is no longer serviceable, discard the pump.

To test the injector pump, determine the plunger diameter by inserting the portion of the plunger under the gear into the gauge supplied with the tester. Insert the portion of the pump plunger and gear segment into the gauge setting of the housing of the tester, as shown in figure 5-7. Determine the proper full-load rack setting by referring to the rack setting charts for the engine from which the pump was removed. After you have made the full-rack setting (usually to the nearest .025 inch), you also will be able to determine the number of discharge strokes required from the pump test chart. Now you are ready to attach the collector assembly and jar to the fuel

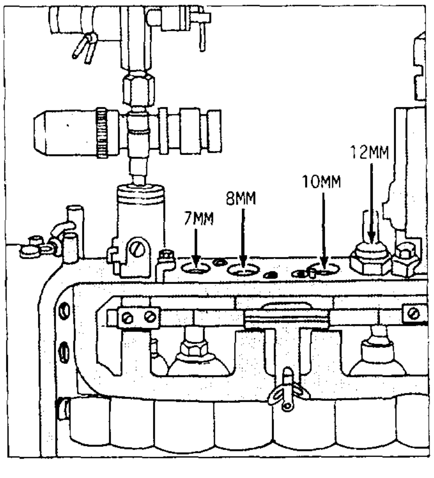


Figure 5-7.-Test location of various size pumps.

pump, as shown in figure 5-8. Remember, bleed the air from the pump and the collector assembly during the priming. After the priming, remove the collector jar and drain. Reset the counter to zero and attach the collector jar to the collector assembly. Operate the pump the prescribed number of discharge strokes. Remove the collector jar and place it on a level surface. The fuel level in the jar is to read from the bottom, as shown in figure 5-9.

The condition of the pump is indicated directly by the calibrations on the collector jar. If the fuel level is within or above the GOOD range, the pump is equivalent to a new one. A fuel level within or below the POOR range shows that the pump plunger and barrel have worn so much that the engine will be hard to start and may have less power. Such pumps should be replaced.

Capsule Type Injector Valve.— Capsule type fuel injection valves can be tested on the fuel injection tester for spray characteristics valve opening pressure, and leakage rate. Before testing the valve, inspect the screen filter. (See fig. 5-2.) If the screen is broken or clogged with the dirt particles, discard the valve.

When cleaning the deposited carbon from the injection valve nozzle (fig. 5-10), use a drill from the cleaning tool group kit, furnished by Caterpillar, that corresponds to the orifice size of the nozzle. The orifice size is usually stamped on the side of the valve.

NOTE

NEVER clean the injection valves with a wire brush. The use of a wire brush to remove carbon from the injection valves might damage the orifice and reduce power output.

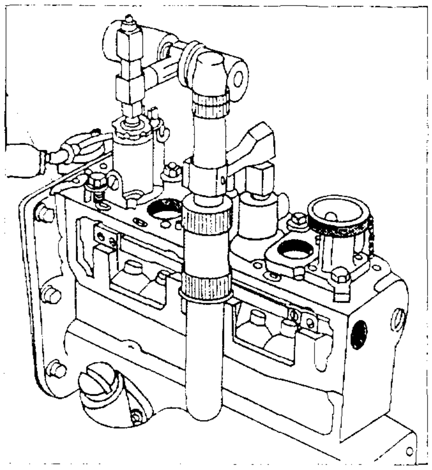


Figure 5-8.-Collector assembly and jar.

Figure 5-9.-Correct level in collector jar.

After inspecting the valve screen filter and cleaning the injector valve nozzle, test the valve for spray characteristics. A solid stream of fuel with little or no atomization is caused either by a gummy carbon accumulation or a particle of foreign material.

If the fuel emitted is properly atomized and the cutoff is sharp with no dribble, the spray characteristics of the valve are satisfactory.

Next, test the valve for opening pressure and leakage. Valve opening pressure ranges from 400 to 800 psi, as registered on the test gauge. If the injection valve fails to reach a minimum of 400 psi, observe the gauge to note any drop in pressure. If the pressure falls more than 100 psi in 30 seconds, discard the injection valve nozzle.

Compact Fuel System

The pressure type of compact fuel system has a separate injection pump and injection valve for each cylinder. Fuel is injected into a precombustion chamber (fig. 5-11). A transfer pump delivers filtered fuel to the manifold from which the injection pumps get their fuel. The transfer pump supplies more fuel than is required

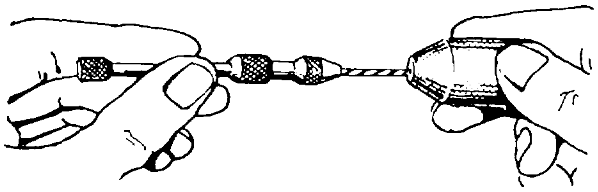


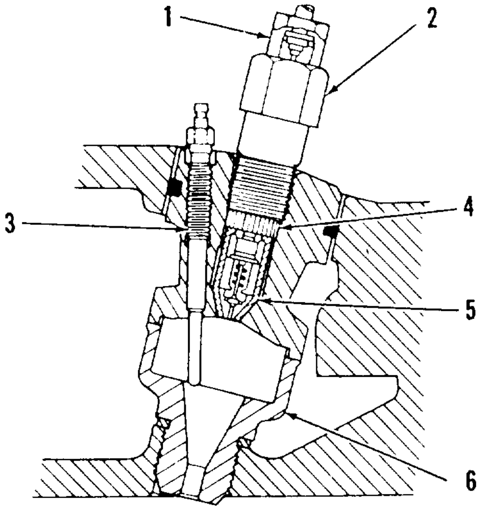
Figure 5-10.-Cleaning capsule type of nozzle.

for injection. A bypass pressure relief valve limits the maximum pressure.

OPERATIONS.— The injection pump (fig. 5-12) forces fuel under high pressure to the injection valves. Injection pump plungers and lifters are actuated by lobes on the pump camshaft and always make a full stroke. The lifters are held against the pump camshaft by spring pressure, applied to the plungers.

GOVERNOR.— The governor on the compact fuel system is hydraulically operated. Governor action controls the amount of fuel injected by turning the plunger (fig. 5-1) in the barrel through a gear segment on the bottom of the plunger. Pressurized lubrication oil enters the passage in the governor cylinder. The oil encircles the sleeve within the cylinder and is directed through a passage to operate the piston.

When the engine is started, the speed limiter plunger restricts the governor control linkage. Operating oil pressure has to react on the speed limiter before the governor control can be moved to the high-idle position. At low idle, a spring-loaded plunger bears against the shoulder of the low-idle adjusting screw. This action forces the plunger past the shoulder on the adjusting screw, and stops the engine.



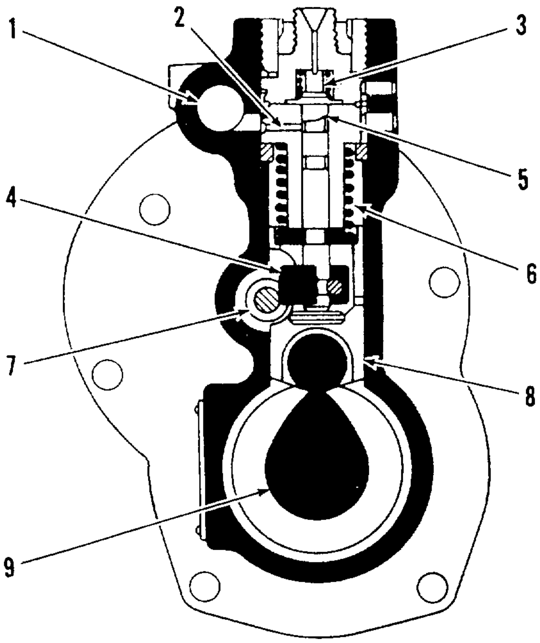
1. Fuel injection line
2. Nut
3. Glow plug
4. Body
5. Nozzle assembly
6. Precombustion chamber

Figure 5-11.-Precombustion chamber and fuel injection valve.

Lubrication oil from the governor drains into the fuel injection pump housing.

TROUBLESHOOTING.— Many times the fuel system is blamed when the fault lies elsewhere, especially when smokey exhaust is the problem. Smokey exhaust can be caused by lack of air for complete combustion, overloading, oil burning, lack of compression, as well as faulty injection valves or pumps.

The two troubles in the compact system are lack of fuel and too much fuel for proper combustion. If the time dimension is too small, injection will begin early; and if too great, injection will be late. When checking plunger wear, check the lifter washer for wear to avoid rapid wear of the plunger. If the plunger length is not within limits, discard the plunger.



1. Fuel manifold
2. Inlet port
3. Check valve
4. Gear segment
5. Pump plunger
6. Spring
7. Fuel rack
8. Lifter
9. Camshaft

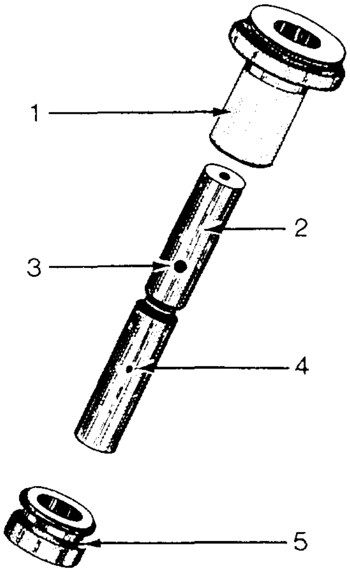
Figure 5-12.-Compact fuel injection pump.

Sleeve Metering Fuel System

The sleeve metering fuel system on some models of the Caterpillar engine gets its name from the method of controlling the amount of fuel injected into the cylinder. This system has an injection pump and an injection valve for each cylinder. Most injection valves are located in the precombustion chamber, while the injection pumps are located in a common housing.

As with other diesel injection systems, proper operation depends on the quality and cleanliness of the fuel. Certain applications of the sleeve metering system have a water separator to remove up to 95 percent of the water in the fuel.

COMPONENTS.— The three main components of the sleeve metering fuel system are designed and operated differently from earlier Caterpillar fuel injection systems. These components are the plunger, barrel, and sleeve, which are mated sets (fig. 5-13) and must be kept together. The plunger moves up and down inside the barrel and sleeve. The barrel is stationary while the sleeve is moved up and down in the plunger. Sleeve position is controlled by the action of the governor through varied loads to regulate the amount of fuel injected. Located in the inlet side of the system is a priming pump. When you open the bleed valve and operate the priming pump, air is removed from the injection pump housing filters and suction lines.



1. Barrel
2. Plunger
3. Fill port
4. Spill port
5. Metering sleeve

Figure 5-13.-Sleeve metering barrel and plunger assembly.

OPERATIONS.— The lifter and plunger are lifted through a full stroke with each revolution of the pump camshaft. Spring force on the plunger, through the retainer, holds the lifter against the camshaft through the full-stroke cycle. The fuel in the housing supplies the injection pumps and lubricates the moving parts in the housing. Before the engine will start, the housing must be charged, as shown in figure 5-14, Position 1. The sleeve must be high enough on the plunger to close the fuel outlet (spill port) during part of the stroke. The chamber fills with fuel through the fuel inlet (fill port), which is below the level of the fuel in the housing.

Injection begins when the rotation of the camshaft lifts the plunger far enough into the barrel to close the fuel inlet (fig. 5-14, Position 2). Both the fuel inlet and outlet are now closed. Continued rotation of the camshaft (fig. 5-14, Position 3) lifts the plunger farther into the chamber of the barrel and increases the pressure on the trapped fuel. This pressure is felt by both the reverse flow check valve in the pump (fig. 5-15, No. 1) and the injector valve located in the nozzle assembly (fig. 5-11, No. 5). When the pressure is high enough to open the capsule, injection occurs.

Injection ends when the camshaft rotation causes the plunger to open the fuel outlet, as shown in figure 5-14, Position 4. The open fuel outlet reduces the

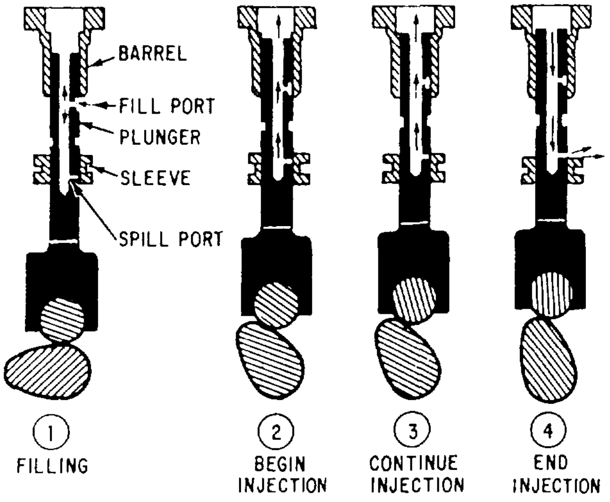
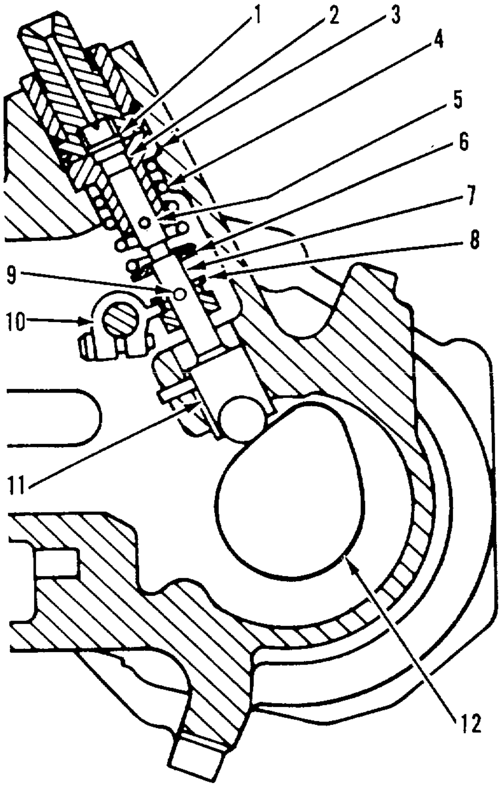


Figure 5-14.-Injection pump operating cycle.

pressure on the fuel within the pumping chamber. Residual pressure in the fuel lines closes the reverse flow check valve in the pump and prevents surges on the fuel lines. No fuel flowing permits the injection valve to close and complete injection.

The camshaft continues to lift the plunger to the top of the stroke. The fuel in the housing fills the space in the pumping chamber through the fuel outlet until the sleeve closes the outlet on the downward stroke. Spring pressure pushes the plunger farther down as the camshaft rotates, allowing the fuel inlet to fill the rest of the chamber and restarting the cycle.



1. Reverse flow check valve
2. Chamber
3. Barrel
4. Spring
5. Fuel inlet
6. Retainer
7. Plunger
8. Sleeve
9. Fuel outlet
10. Sleeve control lever
11. Lifter
12. Camshaft

Figure 5-15.-Sleeve metering fuel pump.

GOVERNOR.— The mechanical type governor shaft of the governor for the sleeve metering fuel system controls the position of the sleeve on the plunger, which regulates the amount of fuel injected. The volume of fuel injected is equal to the displacement of the plunger lift into the barrel between the start and end of injection. The start-up control sets the fuel injection pumps at full stroke to aid in starting, regardless of the throttle position. Normal governor operation takes over at low-idle speed, approximately 500 rpm.

TROUBLESHOOTING AND ADJUSTMENTS.— Most problems in this system can be traced to lack of fuel, low fuel pressure, dirty fuel filters, poor quality fuel, or a broken or damaged fuel line. Air enters the fuel system when there are loose connections of the suction side of the pump.

Individual fuel injection pumps for each cylinder with built-in calibration means little or no balancing or adjustment. Before you calibrate any sleeve metering fuel system, be sure the proper tools and manuals are available.

ROOSA MASTER FUEL INJECTION PUMP

The *Construction Mechanic 3 & 2* covers the general construction and operation of the Roosa Master DB and DC fuel injection pumps.

In this TRAMAN, you will learn about troubleshooting, disassembly, inspection, reassembly, and testing of the basic DC fuel pump of the Roosa Master system. Before you perform any work on an injection pump, refer to the manufacturer's maintenance and service manuals.

The troubleshooting chart (table 5-1) lists some of the problems and their possible causes that you might encounter in the Roosa Master fuel system.

Troubleshooting

A field test (Kiene) on an engine is an efficient way to pinpoint the cause of poor engine performance. This test will eliminate unnecessary fuel injection pump removal. Since this field test permits some analysis of engine condition, as well as the fuel system, you will quickly see the extent of the difficulty and the required remedies.

Table 5-1.-Troubleshooting Chart for Roosa Master Fuel System

CAUSE OF PROBLEM	PROBLEM										CORRECTIVE MEASURES
(Numbers in "Problem" Check Chart indicate order in which to check possible "Causes" of Problem.)	A. Fuel not reaching pump.	B. Fuel delivered from transfer pump but not to nozzles.	C. Fuel reaching nozzles but engine won't start.	D. Engine starts hard.	E. Engine starts and stops.	F. Erratic engine operation–surge, misfiring, poor governor regulation.	G. Engine idles imperfectly.	H. Engine does not develop full power or speed.	I. Engine smokes black.	J. Engine smokes blue or white.	
Hand primer installed backwards.	3										Re-install properly.
One or more connector screws obstructed.		3		2					9		Replace.
Seizure of distributor rotor.	2										Check for cause of seizure. Replace hydraulic head and distributor rotor assembly.
Failure of electrical shutoff.		2			7						Remove, inspect, and adjust parts. Replace parts as necessary.
Fuel supply lines clogged, restricted, wrong size, or poorly located.	6	7	5	3	1	2	8	4			Blow out all fuel lines with filtered air. Replace if damaged. Remove and inspect all flexible lines.
Air leaks on suction side of system.	7			4	6	7	3	5			Troubleshooting the system for air leaks.
Automatic advance faulty or not operating.			8	9		9	8	11	4	2	Remove, inspect, correct, and reassemble.
Water in fuel.			3	6	2	5	1	13			Drain fuel system and pump housing, provide new fuel, prime system.
Return oil line or fittings restricted.				11	4	13	11	8			Remove line, blow clean with filtered air, and reassemble. Replace if damaged.
Air intake restricted.					3			14	1		Check manual.
Pump housing not full of fuel.						6	2				Operate engine for approximately 5 minutes until pump fills with fuel.
Fuel lines incorrect, leaking, or connected to wrong cylinders.			4			1		15			Relocate pipes for correct engine firing sequence.
Shutoff device interfering with governor linkage.			6	8				2			Check and adjust governor linkage dimension.
Governor high-idle adjustment incorrect.								3			Adjust to pump specifications.
Throttle arm travel not sufficient.			2					1			Check installation and adjust throttle linkage.
Transfer pump blades worn or broken.	5			7	9	12	5	12			Replace.
Shutoff device at "stop" position.		1									Move to "run" position.
Metering valve sticking or closed.		4		8	8	10	6	10			Check for governor linkage binding, foreign matter, burrs, etc.
Governor spring worn or broken.		5				11	9				Remove and replace.
Governor linkage broken.		6					10				Remove, replace, and readjust per specifications.
Tank valve closed.	1										Open valve.
Nozzles faulty or sticking.			7	10		8	7		3		Replace or correct nozzles.
Pump timed incorrectly to engine.			1	1		4	4	7	2	1	Correct timing.
Filters or Inlet strainer clogged.	4			5	5	3		6			Remove and replace clogged elements. Clean strainer.

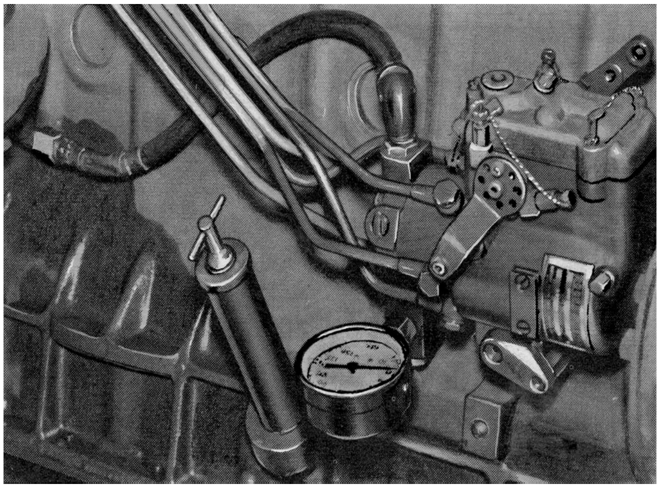


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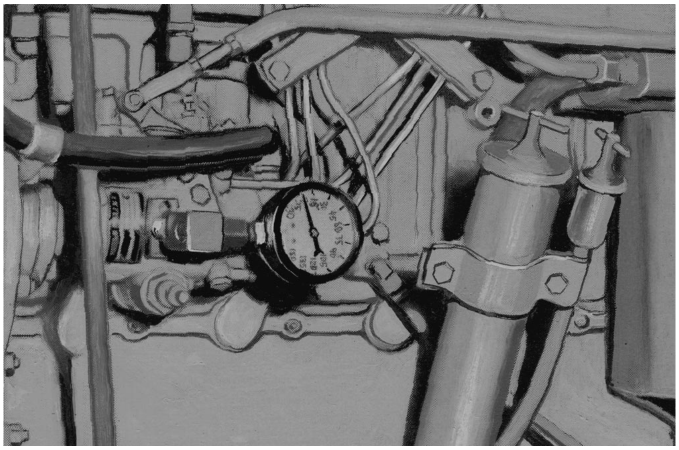
Figure 5-16.-Gauge installed for checking transfer pump pressure.

Since most tests are more conveniently made under no load conditions, all possible readings are determined at high idle. If the supply pressure is lower than normal, an engine can still operate smoothly at approximately the correct high-idle speed. The governor opens the metering valve further to make up for the lower pressure; therefore, you can take successful readings at high idle.

First, disconnect the throttle linkage. Then, with the engine running, hold the throttle lever all the way to the rear. Adjust the high-idle stop screw until the specified high-idle speed is obtained to test the fuel pressure at high idle. Install the gauge assembly in the pressure trap of the transfer pump, as shown in figure 5-16. If this reading does not fall within the prescribed range, the pump will not deliver sufficient fuel to obtain full power under load. The most common causes of low pressure are restricted fuel supply, air leaks on the suction side of the pump, worn transfer pump blades, or a malfunctioning regulator valve.

To test for excessive pressure (fig. 5-17), remove the injection fuel pump timing plate. Be sure you make a small hole in the timing plate gasket as you install the gauge on the pump. This hole allows pump pressure to reach the gauge as you operate the engine at both low



2.493

Figure 5-17.-Testing pump housing pressure.

and high idle. If the pressure is excessive, a restricted fuel return line is the probable cause.

To test for restricted fuel supply on the suction side of the pump, operate the engine at high idle and read the vacuum developed. If the vacuum reading exceeds 10 inches mercury (Hg), check the fuel supply system for dirty filters, pinched or collapsed hoses, or a plugged vent.

Removal

If, after field testing, you find you must remove the injection fuel pump from the engine, be sure to remove all external grease and dirt. Remember, dirt, dust, and other foreign matter are the greatest enemies of the injection fuel pump. As a precaution, keep all openings plugged during removal and disassembly.

Disassembly

The workbench, surrounding area, and tools must be clean. You should have a clean pan available to put parts into as you disassemble the pump, You also need a pan of clean diesel fuel oil in which the parts can be washed and cleaned.

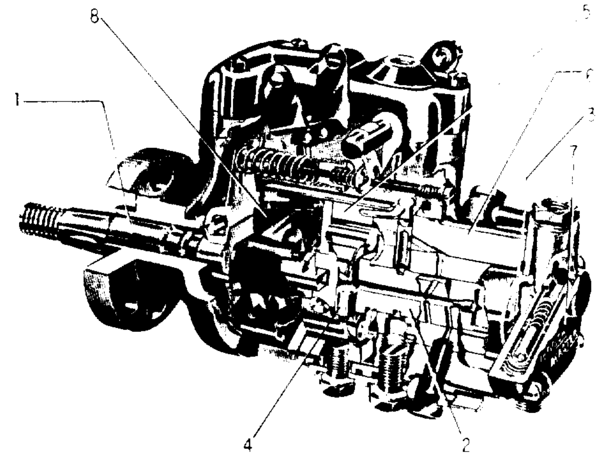
After mounting the pump in a holding fixture, clamp the fixture in a vise. Now you are ready to disassemble the pump. Follow the step-by-step procedure in the manual for the model pump on which you are working. Figure 5-18 shows the main internal working parts of the Roosa Master fuel injection pump.

Cleaning, Inspecting, and Reassembly

Now that you have disassembled the pump, and inspected all the parts carefully, replace all O rings, seals, and gaskets, and inspect all springs for wear, or distortion. Clean and carefully check all bores, grooves, and seal seats for damage of any kind. Replace damaged parts as necessary.

Also, inspect each part of the injection pump for excessive wear, rust, nicks, chipping, scratches, cracks, or distortion. Replace any defective parts.

When you have finished cleaning and inspecting the pump, reassemble it. Follow the steps specified by the manufacture's maintenance and repair manual.



1. **Drive shaft**
2. **Distributor rotor**
3. **Transfer pump**
4. **Pumping plungers**
5. **Internal cam ring**
6. **Hydraulic head**
7. **End plate**
8. **Governor**

Figure 5-18.-Roosa Master fuel injection pump.

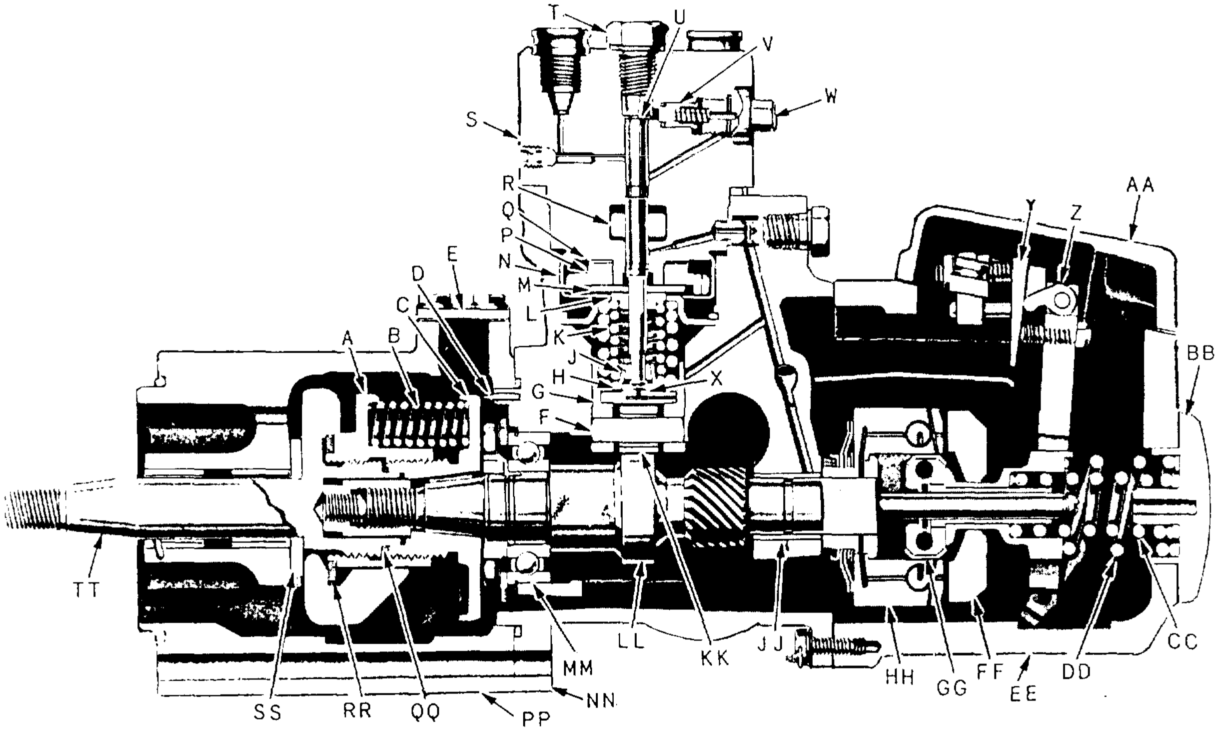
AMERICAN BOSCH FUEL INJECTION PUMP

The American Bosh fuel injection pump is used on multifuel engines. This pump meters and distributes fuel. It is a constant-stroke, distributing-plunger, sleeve-control type of pump. As with other fuel systems, only clean fuel should be used. Good maintenance of the filtering system and reasonable care in fuel handling will give trouble-free operation. Fuels used in the multifuel engine must contain sufficient lubrication to lubricate the fuel pump and injectors. Because of close tolerances, extreme cleanliness and strict adherence to service instructions are required when it is time to service this pump.

In this section, you will learn about the operation and troubleshooting of the American Bosch, Model PSB, pump and the Bosch nozzles that are used with the International Harvester engines.

Operation

The purpose of the fuel pump (fig. 5-19) is to deliver measured quantities of fuel, accurately, under high pressure to the spray nozzle for injection. The positive



A – Sliding gear

B – Advance unit spring

C – Advance unit hub

D – Timing pointer

E – Timing cover

F – Tappet roller pin

G – Tappet guide

H – Spring lower seat

J – Plunger lock

K – Plunger inner spring

L – Spring upper seat

M – Plunger guide

N – Drive gear retainer

P – Plunger drive gear

Q – Gear thrust washer

R – Plunger sleeve

S – Hydraulic head

T – Plunger bore screw

U – Fuel plunger

V – Fuel delivery valve

W – Delivery valve screw

X – Plunger button

Y – Stop plate

Z – Smoke limit cam

AA – Governor cover

BB – Governor end cap

CC – Governor inner spring

DD – Governor outer spring

EE – Governor housing

FF – Governor weight

GG – Sliding sleeve

HH – Friction drive spider

JJ – Camshaft bushing type bearing

KK – Tappet roller

LL – Camshaft

MM – Camshaft ball bearing

NN – Injection pump housing

PP – Advance unit housing

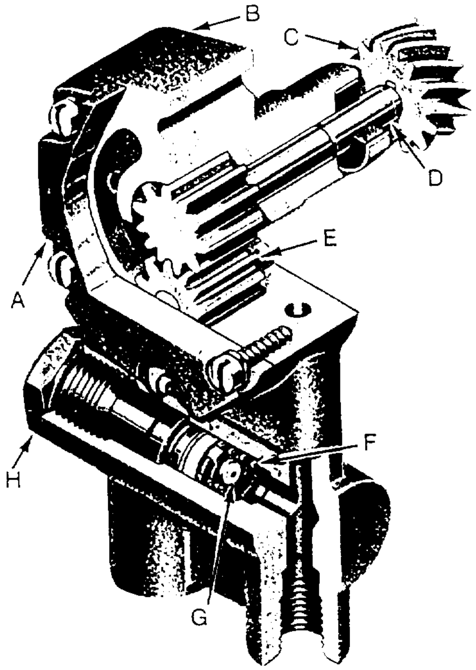
QQ – End play spacer

RR – Sliding gear spacer

SS – Spider thrust plate

TT – Spider assembly

Figure 5-19.-Metering and distributing fuel pump assembly–left sectional view.



A – Housing cover
B – Supply pump housing
C – Camshaft driven gear
D – Drive shaft
E – Idler gear
F – Check valve spring
G – Check valve
H – Valve screw

Figure 5-20.-Fuel supply pump assembly-sectional view.

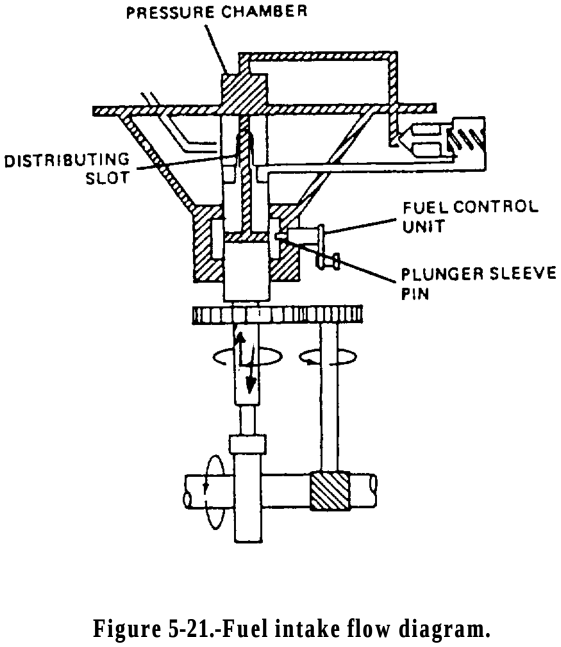


Figure 5-21.-Fuel intake flow diagram.

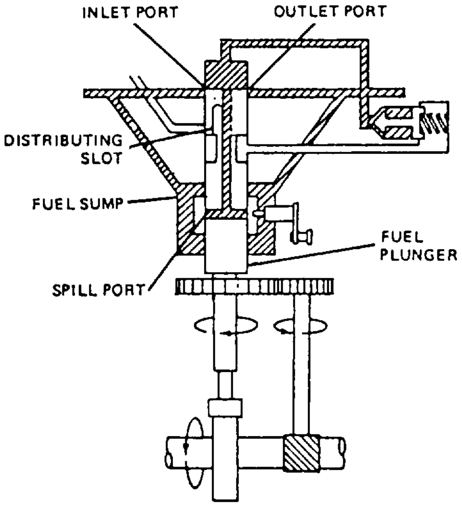


Figure 5-22.–Beginning of fuel delivery flow diagram.

displacement fuel supply pump (fig. 5-20) is gear driven by the pump camshaft through an engine camshaft gear and provides fuel to the hydraulic head for injection and cooling.

Figure 5-21 shows fuel intake at the hydraulic head. Injection (fig. 5-22) begins when fuel flows around the fuel plunger annulus (fig. 5-23) through the open distributing slot to the injection nozzle. A continued upward movement of the fuel plunger causes the spill passage to pass through the plunger sleeve (fig. 5-24). This reduces pressure, allowing the fuel delivery valve to close, ending injection. This is accomplished through a single plunger, multioutlet hydraulic head assembly (fig. 5-19).

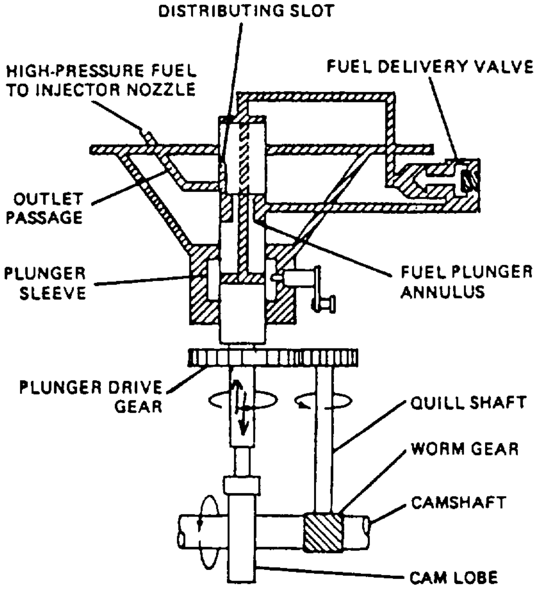


Figure 5-23.-Fuel delivery flow diagram.

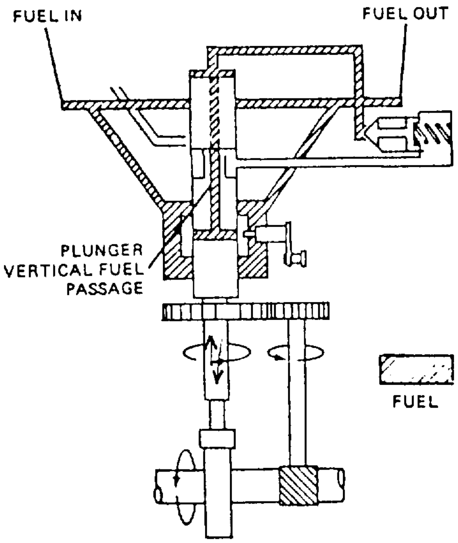


Figure 5-24.-End of fuel delivery flow diagram.

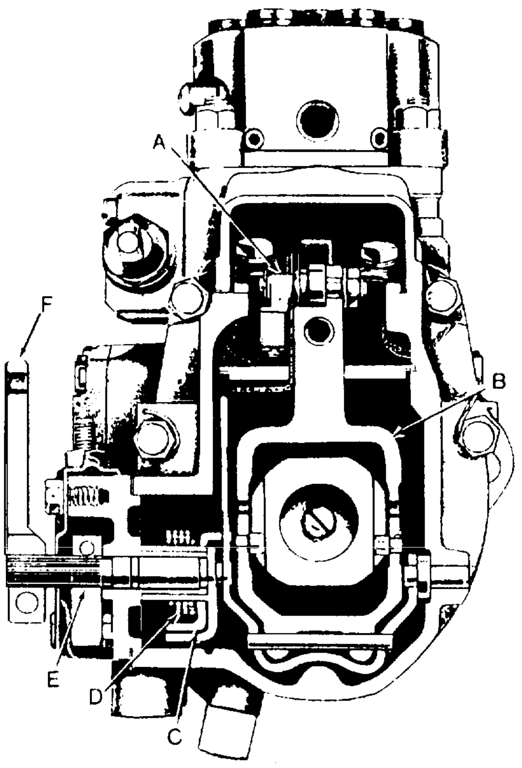
The plunger is designed to operate at crankshaft speed on four-cycle engines. It is actuated by a camshaft and tappet arrangement. The pump camshaft, which also includes the gearing for fuel distribution, is supported on the governor end by a bushing-type bearing and by a ball roller bearing on the driven end. An integral mechanical centrifugal governor (fig. 5-25) driven directly from the pump camshaft without gearing controls fuel delivery in relation to engine speed. This pump has a smoke limit cam within the governor housing to help control the exhaust smoke of various fuels. The mechanical centrifugal advance unit of this pump provides up to 9-degrees advance timing and is driven clockwise at crankshaft speed.

Troubleshooting

Table 5-2 lists the most common malfunctions and the probable causes. Further tests, adjustments, and specifications are available through the manufacturer's manual which you should use for repairs or adjustments.

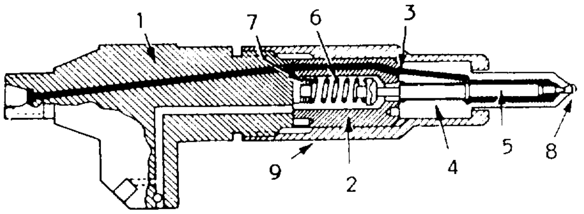
Types of Nozzles

Bosch nozzles are inward opening with a multiple orifice and a hydraulically operated nozzle valve. The two models of this nozzle in use are the American Bosch and the Robert Bosch. They may be easily identified by either the length of the nozzle tip holding nut or the nozzle drilling code on the smaller diameter of the nozzle valve body. The American Bosch nozzle nut is 3 inches long, and the nozzle tip has a hand-printed drilling code. The Robert Bosch nozzle nut is 2 inches long, and the nozzle tip has a machine-etched drilling code. Figure 5-26 shows a view of the nozzle and identifies the various component parts. Component parts, although similar, are not interchangeable between the two nozzles.



A – Fuel control rod
B – Fulcrum lever
C – Shaft spring plate
D – Operating shaft spring
E – Operating shaft
F – Operating lever

Figure 5-25.-Governor–sectional view.



1. **Nozzle body**
2. **Spring retainer**
3. **Annular groove**
4. **Nozzle valve body**
5. **Nozzle valve**
6. **Nozzle spring**
7. **Shims**
8. **Orifice holes**
9. **Nozzle holding nut**

Figure 5-26.-Bosch nozzle nomenclature.

Table 5-2.-Troubleshooting Bosch System

MALFUNCTION	PROBABLE CAUSE
1. No fuel output.	a. Operating shaft frozen in operating shaft bearing. b. Operating shaft spring plate broken or not engaged with fulcrum lever or operating shaft. c. Fuel control rod bent or broken. d. Sheared plunger guide in hydraulic head assembly.
2. Fuel output cannot be controlled.	a. Incorrect idle and full speed adjustments. b. Operating shaft spring not engaged with fulcrum lever or operating shaft. c. Fuel control rod bent or broken.
3. Fuel leakage into oil lubrication system.	a. Hydrualic head lower ring gasket damaged. b. Worn fuel plunger. c. Worn supply pump housing oil seal.
4. Fuel leakage around the fuel control unit.	a. Control unit packing damaged. b. Fuel control unit assembly worn.
5. Fuel leakage around the hydraulic head assembly.	a. Head upper ring gasket damaged.
6. Uneven fuel distribution.	a. Inner plunger spring broken. b. Worn fuel plunger. c. Fuel plunger sticking.
7. Excessive vibration.	a. Excessive camshaft runout. b. Governor weight and spider worn or damaged. c. Camshaft ball bearing worn or damaged. d. Camshaft bushing type of bearings worn or damaged. e. Advance unit housing bushing type of bearings worn or damaged. f. Advance unit weight and spider worn or damaged.

NOZZLE OPERATION.— The pressurized fuel from the injection pump enters the top of the nozzle body and flows through a passage in the body and nozzle spring retainer. An annular groove in the top face of the nozzle valve body tills with fuel, and two passages in the nozzle valve body direct fuel around the nozzle valve. When the fuel in the pressure chamber reaches a predetermined pressure, the spring force (adjusted by shims) is overcome and injection occurs. Atomized fuel sprays from the orifice holes in the nozzle tip as the nozzle valve is opened inward by pressurized fuel. When injection ends, spring pressure snaps the valve in its seat. During each injection, a small quantity of high pressured fuel passes between the nozzle valve stem and the nozzle valve body to lubricate and to cool the nozzle valve. A manifold that connects to all of the nozzles returns this fuel to the tank.

NOZZLE TROUBLESHOOTING.— You can check the condition of a nozzle before it is disassembled by using the field test (Kiene). Remove the nozzle from the engine, and using the test pump shown in figure 5-27, check for nozzle spray angle and pattern. There are four orifices in the nozzle tip, and the spray angle should be uniform from all four. Also, check the spray valve opining pressure. A pressure reading that is more than 50 psi below the specified opening pressure of the valve indicates a need to adjust the pressure by adding shims. Next, test the leakage past the seat and stem. If this leakage is excessive due to wear, install a new nozzle valve.

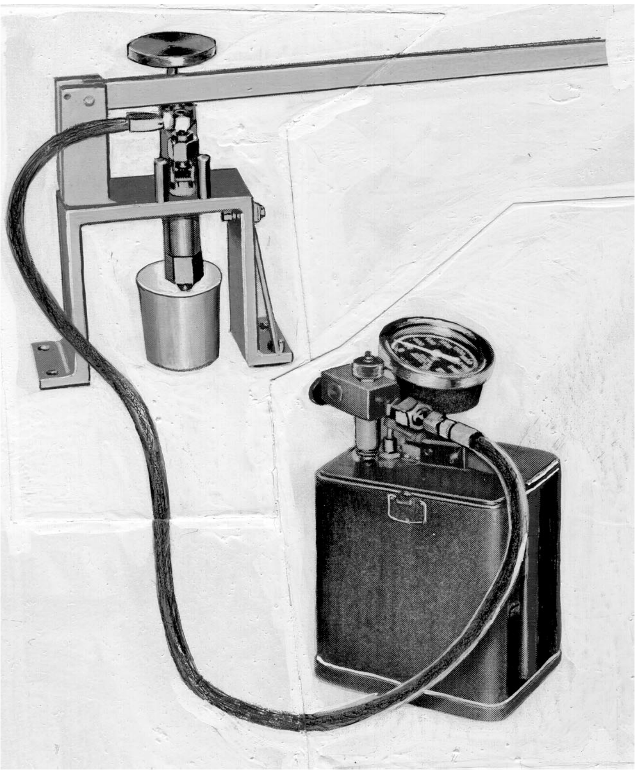


Figure 5-27.-Test pump.

Proceed with nozzle disassembly only after you have performed these and other tests prescribed in the test manual. While testing, record the results of the tests for each nozzle. They can help you determine the nature and extent of necessary repairs.

NOZZLE DISASSEMBLY/REASSEMBLY.-— Before you disassemble the nozzle, clean the external area with cleaning fluid or clean diesel fuel oil, using a brush with long, soft bristles. Keep the disassembled nozzles separated to prevent mixing the various components. During inspection, refer to the test results which are used as a guide to determine the extent of reconditioning necessary.

After you have disassembled the nozzle, make sure each disassembled nozzle has been placed in a separate pan containing a cleaning solvent or clean diesel fuel oil. Soak the tips in a good carbon removal compound for the length of time prescribed by the manufacturer.

NOTE

As a word of caution, remember NOT to mix the tips together. Each tip must be reassembled with its own group parts.

Be careful when you clean the spray holes of the nozzle tip so that you do not enlarge or damage them. Use a magnifying glass during your inspection for signs of scratches, corrosion, or erosion on the spring retainer, the nozzle body holder, and the valve body face. Also, check the stem and the body of the valve, making sure they do not bind.

Reassemble the nozzle in the manner prescribed and specified by the manufacturer’s maintenance and repair manual.

Before you install the nozzle in the engine, retest it for spray angle and pattern, valve opening pressure, and leakage past the seat and stem. When test results are good, install the nozzle in the engine.

GENERAL MOTORS FUEL INJECTION SYSTEM

The General Motors fuel injection system includes fuel injectors, fuel pipes, fuel manifolds, fuel pump, fuel strainer, fuel filter, and fuel lines connecting the fuel tank. The operation of this system depends on the injection of the correct amount of fuel at exactly the right time directly into the combustion chamber.

Efficient engine operation demands that the fuel system be maintained in first-class condition at all times. Use only clean water-free fuel. Good maintenance of the fuel filtering system and reasonable care in handling the fuel are the key to a trouble-free fuel system.

Servicing the fuel system is not a difficult task. However, because of the close tolerances of the various fuel system components, mechanics should practice cleanliness and strictly adhere to service instructions.

In this section, troubleshooting, testing, disassembly, cleaning out, inspection, and reassembly of the fuel pump and fuel injector are discussed. Before you work on these components, refer to the manufacturer's maintenance and service manuals.

Troubleshooting

When a piece of equipment is brought into the shop for maintenance and service, the hard card or Equipment Repair Order (ERO) may show a fuel system problem. You can pinpoint the problem by troubleshooting the fuel system until you find the trouble.

Check the fuel lines for improper or faulty connections. If any leaks occur, tighten the connection only enough to stop the leak. Also, check the filter cover bolt for tightness. If the fuel pump fails to function satisfactorily, first check the level of the fuel tank; then make sure the fuel supply valve is open. Check for a broken pump drive shaft or drive coupling by inserting the end of a wire through one of the pump flange drain holes; then crank the engine and note if the wire vibrates. Vibration will be felt if the pump shaft is turning.

The result of most fuel pump failures is that either no fuel or an insufficient amount of fuel is delivered to the fuel injectors. This lack of fuel will show up if the engine runs unevenly, vibrates too much, stalls at idling speeds, or loses power.

The most common failure of a fuel pump is a sticking relief valve. The relief valve, due to its close fit in the valve bore, may stick in a full-open position because a small amount of grit or foreign material lodges between the relief valve and its bore or seat. The fuel oil circulates within the pump rather than being forced through the fuel system. If the fuel pump is not functioning properly, remove the fuel pump from the engine. hen remove the relief valve plug, spring, and pin, and check the movement of the valve within the valve bore. If the valve sticks, recondition it by using fine emery cloth to remove any scuff marks. Clean the valve bore and the valve components. Then lubricate the valve and check it for free movement throughout the entire length of its travel. If its operation is satisfactory, reassemble the valve in the pump. If not, replace it.

After the relief valve has been checked and the fuel pump reinstalled on the engine, start the engine and check the fuel flow at some point between the restricted fitting in the fuel return manifold and the fuel tank.

If, after making the above checks, there is still a lack of power, uneven running, excessive vibration, or stalling at idle, you should suspect a faulty injector in one or more cylinders. Start the engine and run it at part load until it reaches normal operating temperature. Remove the valve rocker cover(s) and let the engine run at idle speed. Hold the injector follower down with a screwdriver, which prevents operation of the injector. If the cylinder has been misfiring, there will be no noticeable difference in the sound or operation of the engine. If the cylinder has been firing properly, there will be a noticeable difference in the sound and operation when the follower is held down. If that cylinder is firing properly, repeat the procedure on the other cylinders until the faulty one has been located.

At this point you can remove the fuel injector for additional testing, provided that the injector operating mechanism of the faulty cylinder is functioning satisfactorily.

TESTING

The General Motors injector tester gives you a means to determine the condition of the injector to avoid unnecessary overhauling. An injector that passes all of the tests outlined below may be considered to be satisfactory for service without disassembly (except for the visual check of the plunger). If an injector fails to pass one or more of the tests, it is unsatisfactory. Be sure to identify each injector and record the pressure drops and fuel output during the tests. Also remember, all tests must be performed **before** the injector is disassembled.

INJECTOR CONTROL RACK AND PLUNGER MOVEMENT TEST.— To perform this test, lock the injector in a test stand.

CAUTION

Keep your hands away from the tip of the injector while depressing the plunger. High-pressure fuel spray that penetrates the skin will cause blood poisoning.

Depress the plunger to the bottom of its travel while working the control rack back and forth. If the rack sticks, binds, or fails to move at all, it indicates that the internal parts of the injector are either dirty or damaged.

VALVE OPENING/PRESSURE TEST.— The purpose of this testis to determine the pressure at which the valve opens and injection begins. Place the injector in the tester (fig. 5-28). Operate the pump handle until all air is purged from the injector tester and the injector. Then close the outlet clamp. If you are testing an injector that has just been removed from the engine, the flow of fuel through the injector on the tester should be the same as it was on the engine. If required, reverse the fuel connections on the tester to obtain the proper fuel flow.

With the injector rack in the full-fuel position, pump the handle of the injector tester with smooth, even strokes (fig. 5-29), and record the injector valve opening pressure. The specified valve opening pressure for the crown or high valve injector is 450 to 850 psi. For the needle valve injector, the specified opening pressure is 2,000 to 3,200 psi. If the pressure is not within limits, check the manufacturer's maintenance manuals for probable causes and corrections.

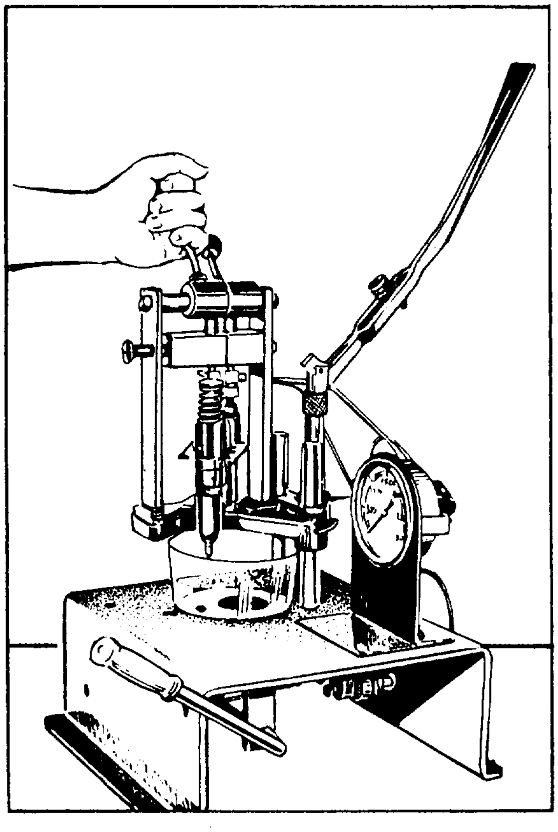


Figure 5-28.-Injector installed in tests.

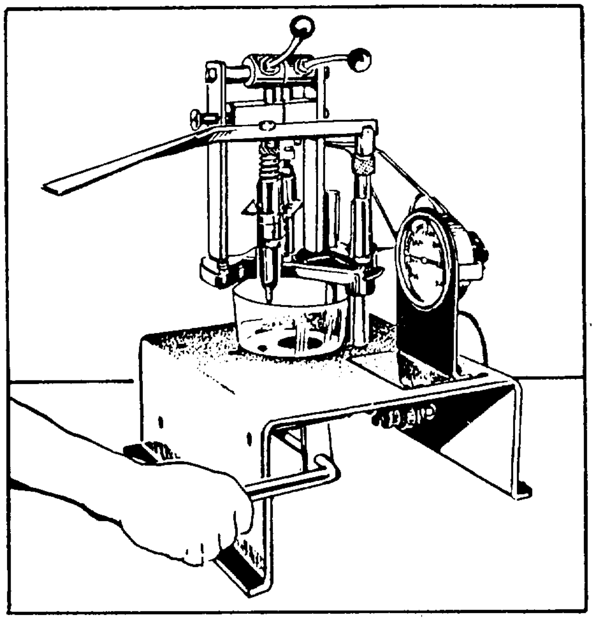


Figure 5-29.-Checking injector valve opening pressure.

HOLDING PRESSURE TEST.— This test is used to determine whether the various lapped surfaces in the injector are sealing properly.

To conduct this test, bring the pressure up to a point just below the valve opening pressure (450 psi for crown, needle, and high valve injectors). Then close off the fuel shutoff valve. These actions cause the pressure to drop. The time for the pressure to drop from 450 psi to 250 psi must **NOT** be less than 40 seconds. If the injector pressure drops from 450 psi to 250 psi in less than 40 seconds, dry the injector thoroughly and make the following checks:

1. Open the injector tester fuel valve and operate the pump to maintain the test pressure.

2. Check for a leak at the injector rack opening. A leak indicates a poor bushing-to-body fit.

3. Check for leaks around the spray tip or seal ring. Leaks in these areas are usually caused by a loose injector nut, a damaged seal ring, or a burned surface on the injector nut or spray tip.

4. Check for leaks at the filter cap, which would indicate a loose filter cap gasket.

5. If you find a dribble at the spray tip orifices, it indicates a leaking valve assembly due to either a damaged surface or dirt. Leakage at the tip will cause preignition in the engine.

NOTE

A drop or two of fuel at the spray tip is only an indication of the fuel trapped in the spray tip at the beginning of the test. It is not detrimental as long as the pressure drop specified is not less than 40 seconds.

HIGH-PRESSURE TEST.— This testis performed to discover arty fuel leaks at the injector filter cap gaskets, body plugs, and nut seal ring which did not appear during the valve holding pressure test. The high-pressure test also indicates whether the injector plunger and bushing clearance are satisfactory. To perform the test, place the injector rack in the **FULL-FUEL** position. Operate the pump handle (fig. 5-30) to build up and maintain a pressure of 1,600 to 2,000 psi. Then inspect the injector filter cap gaskets, body plugs, and injector nut seal ring for leaks.

Next, you should use the adjusting screw in the injector tester handle to depress the injector plunger just far enough to close both ports in the injector bushing. Both ports are closed if the injector spray decreases and the pressure rises. Now, you can determine the condition of the plunger and bushing. If there is excessive clearance between the plunger and bushing, it means that pressure will not rise beyond the normal valve-opening pressure. Next, you should replace the plunger and bushing.

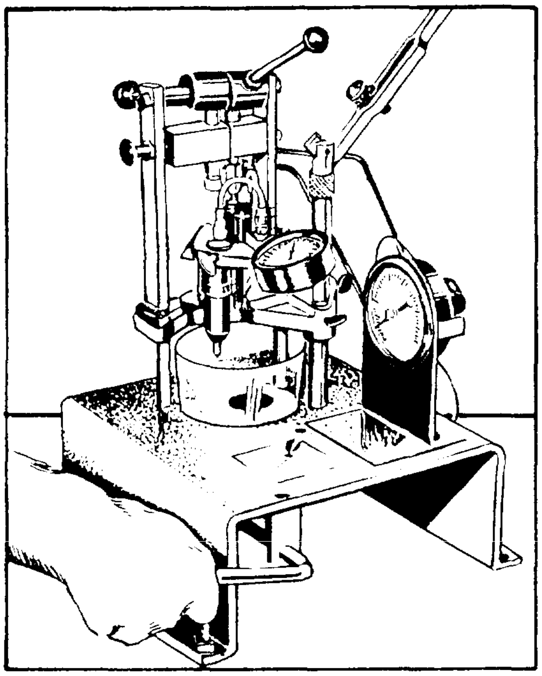


Figure 5-30.-Injector high-pressure test.

SPRAY PATTERN TEST.— This test is performed after you have completed the valve holding pressure test. After placing the injector in the tester, open the fuel shutoff valve; then place the injector rack in the **FULL-FUEL** position. Operate the injector several times in succession by pumping the tester handle (fig. 5-31) at approximately 40 strokes per minute. Observe the spray pattern to see whether all of the spray tip orifices are open and injecting evenly. The beginning and ending of injection should be sharp, and the fuel injected should be finely atomized. If all the spray tip orifices are not open and injecting evenly, clean the orifices in the spray tip during injector overhaul.

CAUTION

To prevent damage to the pressure gauge, do not exceed 250 psi during this test.

You should visually inspect the injector plunger even if the injector passes all of the previous tests. The plunger is visually checked under a magnifying glass for excessive wear or a possible chip on the bottom helix. There is a small area on the bottom helix and the lower portion of the upper helix, that, if chipped, will not be indicated in any of the tests.

FUEL OUTPUT TEST.— This test is performed to check injector fuel output. To test the injector, place it

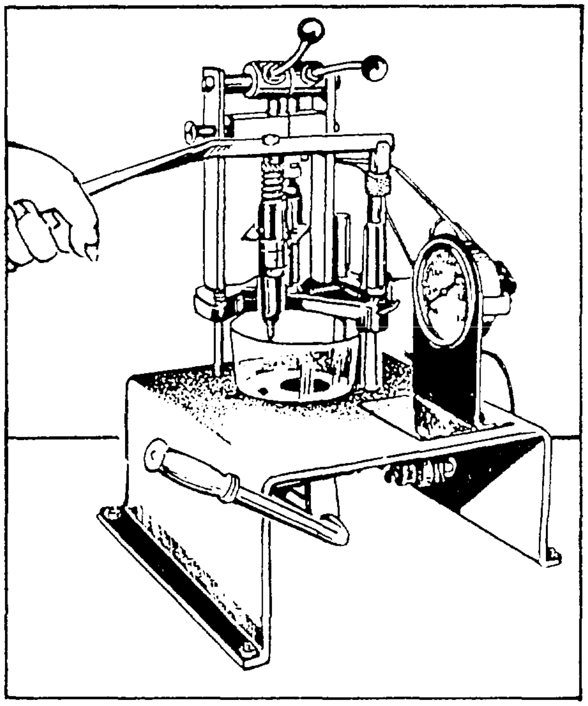


Figure 5-31.-Spray pattern test.

in the comparator (fig. 5-32), and seal the injector firmly by tightening the handwheel. Pull the injector rack out to the **NO-FUEL** position and start the comparator. After the comparator has started, push the injector rack to the **FULL-FUEL** position. Let the injector run for approximate y 30 seconds to purge air in the system. After 30 seconds, press the fuel flow start button to start the flow of fuel into the vial. The comparator will automatically stop the flow of fuel after a thousand strokes. After the fuel has stopped flowing into the vial, pull the injector rack out to the **NO-FUEL** position. Turn the comparator off, reset the counter, and observe the reading on the vial. Refer to the chart on the comparator and see if the injector fuel output falls within its specified limits. If the quantity of fuel in the vial does not fall within the specified limits, refer to the manufacturer's manual for the cause and remedy. Any injector that has been disassembled and rebuilt must be tested again before being placed in service.

Injector Disassembly, Cleaning and Inspecting, and Reassembly

To disassemble an injector, you should place it in an injector assembly fixture. Now, you are ready to remove the falter caps, springs, filter elements, and gaskets. Discard the falter elements and gaskets and replace them with new components during reassembly. Follow the manufacturer's repair and maintenance manual when disassembling injectors.

While you disassemble an injector, put the injector and its parts together in a separate receptacle containing a cleaning solvent or clean diesel fuel oil.

Wash all the parts and dry them. Do not use rags for cleaning. Clean out all passages, drilled holes, and slots in all of the injector parts.

You should soak injector spray tips in a suitable solvent for approximately 15 minutes. This loosens the

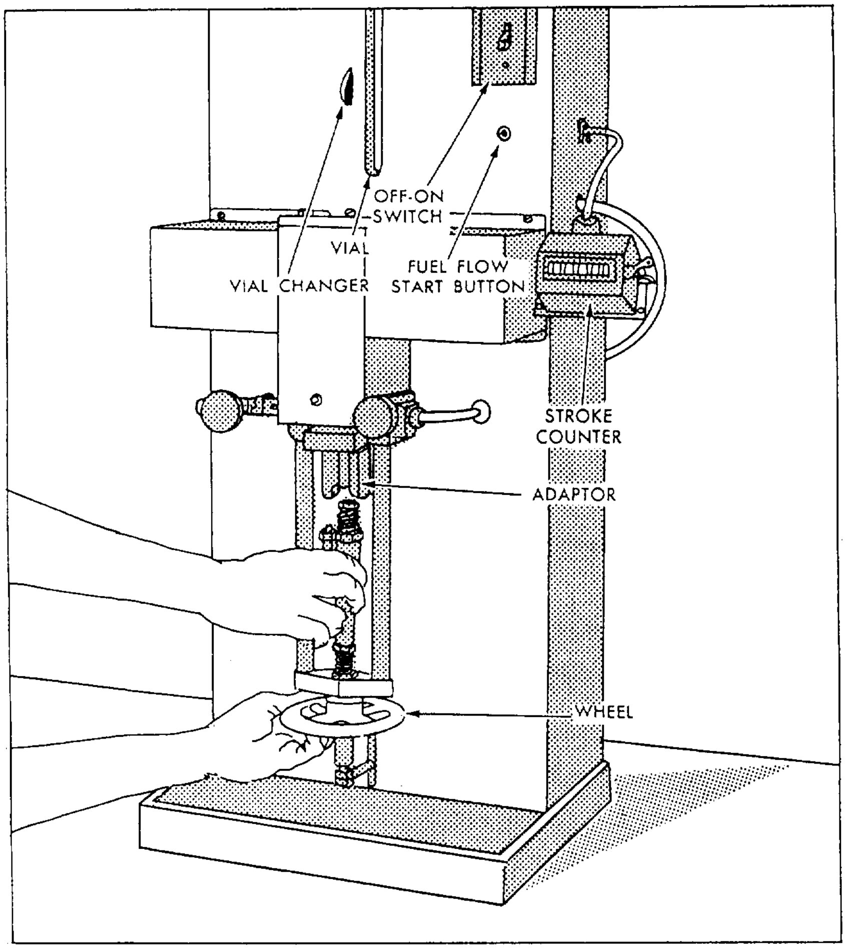


Figure 5-32.-Comparator used to check injector fuel output.

carbon on the inside of the tip. Then they can be cleaned out by using the proper size spray tip cleaning wire.

Inspect injector parts for excessive wear, damage, defects, burrs, scratches, scoring, erosion, or chipping. Replace the damaged or excessively worn parts.

Lap all of the sealing surfaces, such as the bottom of the injector body, the injector bushing, the valve seat, the valve cage, the check valve, and the spray tip, before you reinstall used valve parts in an injector.

Now you are ready to reassemble the injectors. Follow the steps prescribed by the manufacturer's maintenance and repair manuals. The injector is satisfactory if it passes these tests. Failure to pass any one of the tests indicates that defective or dirty parts have been assembled. In this case, disassemble, clean, inspect, reassemble, and test the injector again.

CUMMINS PRESSURE TIME FUEL INJECTION SYSTEM

The Cummins Pressure Time (PT) Fuel Injection System (fig. 5-33) consists of the fuel pump (with governor), the supply lines, drain lines, fuel filters, fuel injectors, and shutdown valve. An aneroid valve is installed on the fuel system of turbocharged engines only.

As in previous sections of this chapter, we will cover troubleshooting, disassembly, inspection, reassembly, and testing of components. Remember, before performing any service on the PT injector or pump, refer to the manufacturer's maintenance and repair manuals.

Troubleshooting

Troubleshooting is an organized study of a problem and a planned method or procedure to investigate and correct the difficulty.

Most troubles are simple and easy to correct; for example, excessive fuel oil consumption is caused by leaking gaskets or connections. A complaint of a sticking injector plunger is usually corrected by repairing or replacing the faulty injector; however, something caused the plunger to stick. The cause maybe improper injector adjustment, or, more often, water in the fuel.

In general, the complaint of low pwer is hard to correct because it can have many causes. There are many variables in environmental operation and installations, and it is difficult to measure power in the field correctly. With the PT fuel system, you can often eliminate the pump as a source of trouble. Simply check to see that the manifold pressure is within specified limits. The fuel rate of the pump must not be increased to compensate

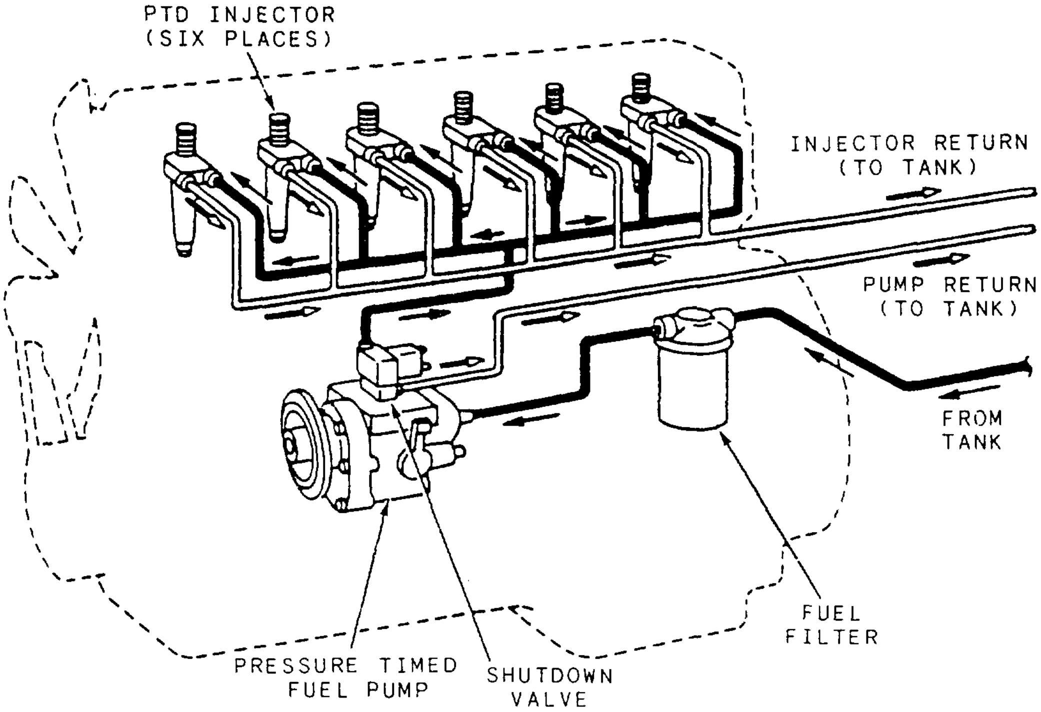


Figure 5-33.-Pressure-timed injection system.

for a fault in other parts of the engine; damage to the engine will result.

When you check the fuel pump on the engine, remove the pipe plug from the pump shutoff valve and connect the pressure gauge. At the governed speed (just before the governor cuts in), maximum manifold pressure should be obtained. If the manifold pressure is **NOT** within specified limits, adjust for maximum manifold pressure by adding or removing shims from under the nylon fuel adjusting plunger in the bypass valve plunger. Be careful you do not lose the small lock washer that fits between the fuel adjusting plunger and the plunger cap.

To check the suction side of the pump, connect the suction gauge to the inlet side of the gear pump. The valve in the pump, if properly adjusted, should read 8 inches on the gauge. When the inlet restrictions reaches 8.5 to 9 inches, change the fuel filter element and remove any other sources of restriction. The engine will lose power when the restriction is greater than 10 to 11 inches.

Always make the above checks on a warm engine. Also, operate the engine for a minimum of 5 minutes between checks to clear the system of air.

If the pump manifold and suction pressures are within specified limits and there is still a loss of power, you should check the injectors.

Carbon in the PT injector metering orifices restricts the fuel flow to the injector cups, which results in engine power loss. Remove the carbon from the metering orifices by reverse flushing; it should be performed on a warm engine. To remove carbon, perform the following steps:

1. Loosen all injector adjusting screws one turn from the bottom or one and one-eighth turns from the set position. Lock with the jam nut after completing the required turns.

2. Start the engine and accelerate with maximum throttle from idling to high-10 to 15 times.

3. Readjust the injectors to their standard setting.

The engine will be difficult to start with the loose injector setting; it will smoke badly and will be sluggish. If the injector adjusting screws are loosened, the meter orifice will not be closed during injection. Extremely high injection pressure will force some of the fuel to backflow through the orifice and should remove carbon deposits. If this method is not effective, remove the injectors for cleaning.

When working on the PT fuel system of a turbocharged Cummins engine, you may find an aneroid control device. This device creates a lag in the fuel system so that its response is equivalent to that of the turbocharger, thus controlling the engine exhaust emissions (smoke level).

WARNING

> The aneroid is an emissions control device. Removing it or tampering with it is in direct violation of state and federal vehicle exhaust emissions laws.

During troubleshooting of the fuel system, you should check the aneroid according to the manufacturer's specifications.

Pump Disassembly

If you determine that the fuel pump (fig. 5-34) must be removed from the engine, take the following precautions:

- Make sure the shop area is clean.
- Use clean tools.

Good cleaning practices are essential to good quality fuel pump repair. Take special care when the PT fuel pump, which is made of a lightweight aluminum alloy, is disassembled. Use proper tools to prevent damage to machined aluminum surfaces, which are more easily damaged than parts made of cast iron.

Before disassembling the unit, try to determine what parts need replacement.

After you place the fuel pump on the holding device, place the device in a vise and disassemble the pump. Follow the procedures given in the manufacturer's maintenance and repair manuals.

Pump Cleaning and Inspection

Now that the pump has been disassembled, you should clean and inspect all parts. Do not discard parts until they are worn beyond reasonable replacement limits. The PT fuel pump parts will continue to function long after they show some wear. Parts that are worn beyond reasonable replacement limits must not be reused. From experience you know reasonable replacement limits. Reuse all those parts that will give another complete period of service without danger of failure.

NOTE

Take special care when you clean aluminum alloy parts. Some cleaning solvents will attack and corrode aluminum. Mineral spirits is a good neutralizer after using cleaning solvents.

Pump Reassembly

After you completely clean and inspect the pump and the parts of it, reassemble the pump as prescribed by the manufacturer's manual. In all assembly operations, be careful to remove burrs and use a good pressure lubricant on the mating surfaces during all pressing operations. A good pressure lubricant aids in pressing and prevents scoring and galling. Use flat steel washers. They go next to the aluminum to prevent goring by the spring steel lock washers.

Pump Testing

The PT fuel pump is mounted on a test stand, as shown in figure 5-35. In the test, the pressure from the PT pump is measured and adjusted before the pump is placed on the engine. To test this pump, let pressure develop across the special orifices in the orifice block assembly. The pressure is measured on the gauges

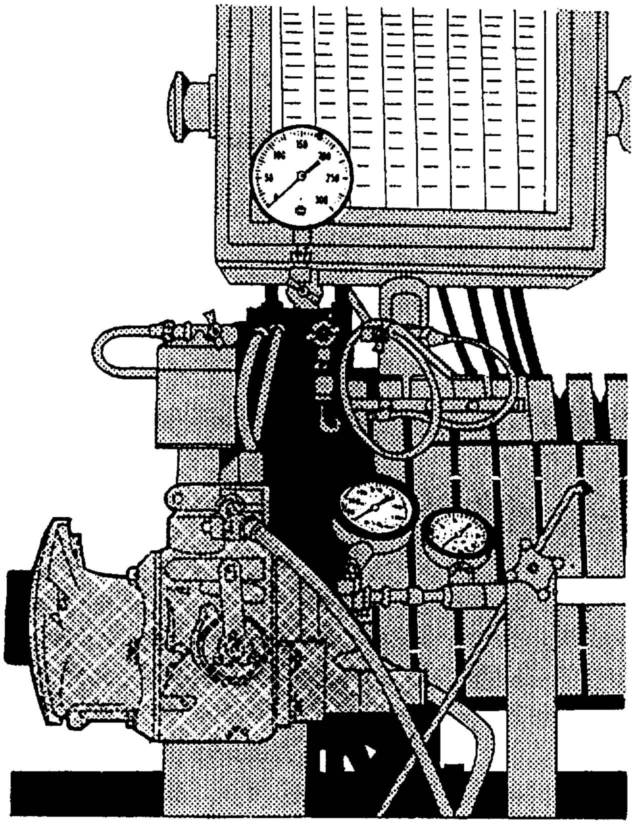


Figure 5-35.-PT pump mounted on test stand.

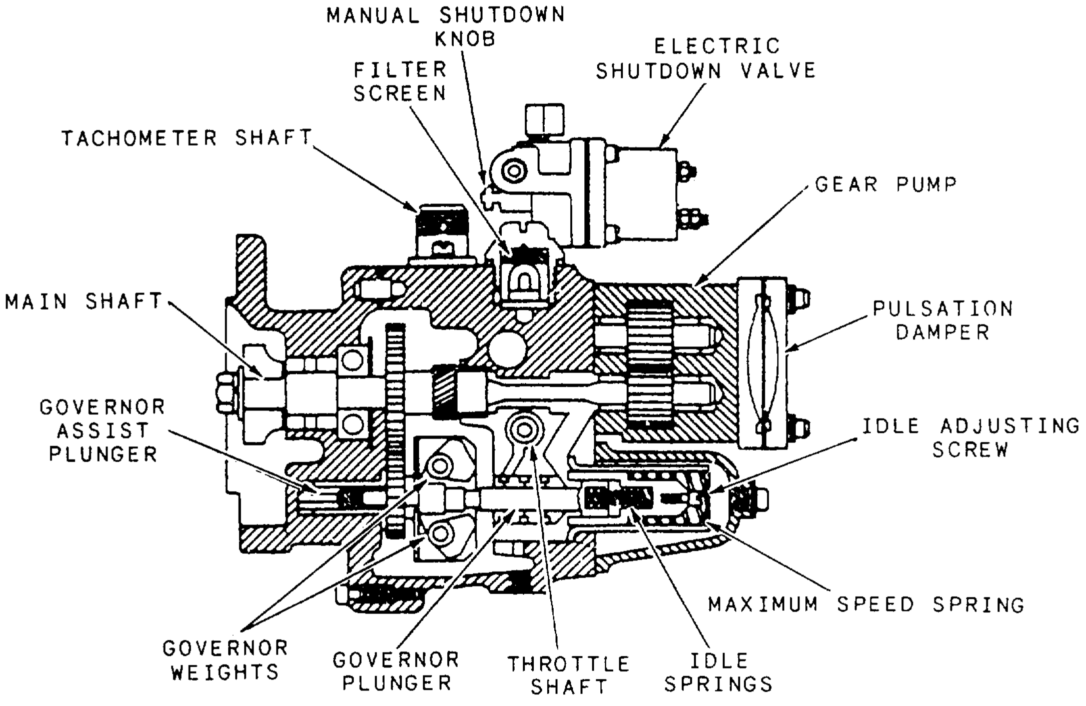


Figure 5-34.-Cummins PT fuel pump.

provided. All pump tests should be made with the testing fuel oil temperature between 90°F and 100°F. Now you are ready to conduct the test.

Open the fuel shutoff valve and manifold orifice valve. Open the stand throttle, start and run the pump at 500 rpm until the manifold pressure gauge shows the recommended pressure. If the pump does not pickup the specified pressure, check for closed valves in the suction line or an air leak.

If the pump is newly re-built, run it at 1500 rpm for 5 minutes to flush the pump and allow the bearings to seat. Continue to run the pump at 1500 rpm and turn the rear throttle stop screw in or out to find the maximum manifold pressure at full throttle.

NOTE

With a standard governed pump, the throttle screws will be readjusted later. If the pump has a variable speed governor, the throttle shaft is locked in full-throttle position; do not readjust. On a dual or torque converter governor pump, the throttle must be locked in the shutoff position and the converter-driven governor idle-adjusting screw turned in until the spring is compressed. The converter-driven governor must be set on the engine.

The pump idle speed is set by closing the bypass and manifold orifice valves and opening the idle orifice valve. Set the pump throttle to idle and run at 500 rpm. To decrease or raise the idle pressure, add or remove shims from under the idle spring. Remember not to set the idle screw until you have adjusted the throttle screws.

Once the tests and adjustments have been completed according to the specifications recommended by the manufacturer, remove the pump from the test stand. Make sure the suction fitting is not removed or disturbed. Next, loosen the spring pack cover and drain the pump body. Cover all openings and bind fittings with tape until you are ready to install the pump.

Injector Maintenance and Testing

In the PT fuel system, fuel is metered by fuel pressure against the metering orifice of the injector. Any change in fuel pressure, metering orifice, or timing will affect the amount of fuel delivered to the combustion chamber. The following two things will interfere with the normal functions of injector orifices:

1. Dirt or carbon in the orifices or in the passages to and from the orifices; and

2. A change in the size or shape of the orifices, particularly caused by improper cleaning of the orifices

After soaking dirty injectors in a cleaning solvent to remove the carbon, be sure to dip the injectors in a neutral rinse, such as mineral spirits, and then dry them.

NOTE

Never use cleaning wires on PT fuel injector orifices.

Be sure to use a magnifying glass to inspect the injector orifices for damage. When the injector orifices are damaged, they cannot be made to function properly and must be replaced.

Check the injector for a worn plunger or injector body. Worn injectors may cause engine oil dilution from excessive plunger to body clearances. Dilution may also result from a cracked injector body or cup or a damaged O ring. To check the injector for leakage, assemble it. Remember to plug off the injector inlet and drain connection holes; then mount the injector on the injector test stand.

Test the injector at a maximum of 1000 psi with the fuel flowing upward through the cup spray holes. If the counterbore at the top of the injector body falls with fuel in less than 15 seconds, the plunger clearance is excessive and may cause engine oil dilution. During this check inspect the injector for leaks around the injector cup, body, and plugs. If the injector does not pass the test and checks, remove the damaged parts and replace them with new parts.

Any time you remove an injector plunger, use the lubricant recommended by the manufacturer when you replace the plunger in the injector body.

If the injector plunger does not seat in the injector cup, change the cup rather than trying to lap the plunger and cup together. Lapping changes the relationship between the plunger groove and metering orifice and disturbs fuel metering. Always use a new injector cup gasket when you assemble the cup to the injector body to avoid distortion of the cup. When the cup is tightened to the injector body, the gasket compresses everywhere, except under the milled slot on the end of the injector body. Then, if the gasket is reused, the uncompressed areas may cause the injector cup to cock and prevent the injector plunger from seating properly.

AIR INDUCTION SYSTEM

The purpose of an air intake system is to supply the air needed for combustion of the fuel. In addition, the air intake system of a diesel engine will have to clean the intake air, silence the intake noise, furnish air for supercharging, and supply scavenged air in two-stroke engines.

The three major components of the air induction systems that increase internal combustion engine efficiency are blowers, superchargers, and turbochargers. They may be of the centrifugal or rotary type, gear driven directly from the engine, or driven by the flow of exhaust gases from the engine.

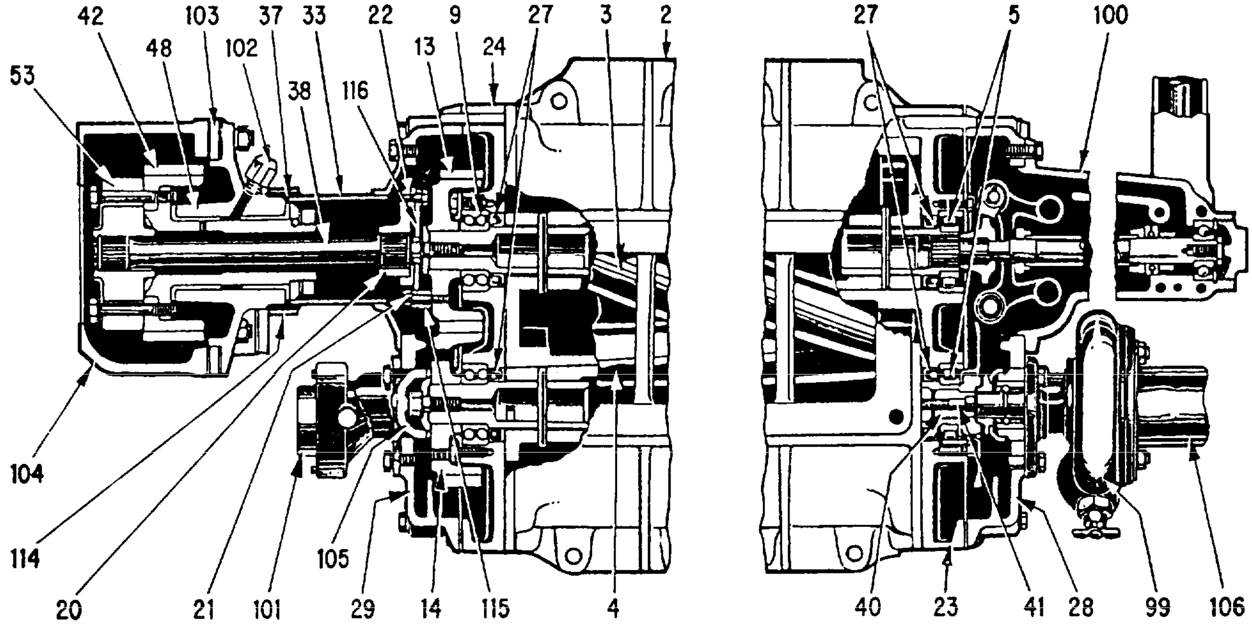
In the following sections, certain abnormal conditions of air induction system components which sometimes interfere with satisfactory engine operation are covered. Also, methods of determining causes of such conditions will be covered. Before performing any work on these components, make sure you follow the recommendations given in the manufacturer's service manual.

BLOWERS

Scavenging blowers are used to clear the cylinders of exhaust gases to introduce a new charge of fresh air. Superchargers and turbochargers increase the power output of specific engines by forcing air into the combustion chambers so that an engine can burn more fuel and develop more horsepower than if it were naturally aspirated.

Blower Inspection

The blower (fig. 5-36) may be inspected for any of the following conditions without being removed from



2. Housing
3. Rotor, blower, upper
4. Rotor, blower, lower
5. Bearing, front
9. Bearing, rear
13. Gear, rotor, upper
14. Gear, lower, rotor
20. Hub, rotor drive
21. Bolt
22. Bolt
23. End plate, front
24. End plate, rear

27. Seal, oil, rear
28. Cover, end plate, front
104. Housing, flywheel
106. Cover, water pump inlet
115. Plate, blower rotor drive hub
29. Cover end plate rear
33. Cover, blower drive shaft
37. Seal, drive shaft cover
38. Shaft, blower drive
40. Shaft coupling
41. Bolt
42. Gear blower drive

48. Support
53. Coupling assembly
99. Pump fresh water
100. Housing, governor weight
101. Pump, fuel
102. Elbow
103. End plate
105. Fork
114. Clamp, drive cover seal
116. Spacer, plate to gear

Figure 5-36.-Blower and drive assembly and accessories.

the engine. However, the air silencer or air inlet housing must be removed.

CAUTION

> When a blower on an engine is being inspected with the engine running, keep your fingers and clothing away from moving parts of the blower. RUN THE ENGINE AT LOW SPEED ONLY.

Dirt or chips, drawn through the blower, will make deep scratches in the rotors and housing and throw up burrs around these abrasions. If the burrs cause interference between rotors or between rotors and blower housing, remove the blower from the engine and dress down the parts to eliminate this interference. Replace the rotors if they are too badly scored.

Oil on the blower rotors or on the inside surfaces of the blower housing indicate rotor shaft oil seal leaks. To confirm your finding, run the engine at a low speed while shining a light into the rotor compartment. A film of oil radiating away from the rotor shafts shows the oil seal leakage.

A worn blower drive results in a rattling noise inside the blower. You can detect this condition by grasping the top rotor firmly and attempting to rotate it. The rotor may move from three-eighths to five-eighths inch, measured at the lobe crown. When released, the rotor should move back at least one-fourth inch. If the rotor cannot be moved this distance or if the rotor moves too freely, the flexible blower drive coupling should be inspected and if necessary, replaced.

If a check shows the drive coupling to be worn, remove the blower drive assembly from the cylinder block end plate. After the blower has been removed from the engine, remove the drive gear hub bearing support-to-cylinder block end plate bolts.

Loose rotor shafts or damaged bearings will cause rubbing and scoring between the following components: the crowns of the rotor lobes and the mating rotor roots, the rotors and the end plates, or the rotors and the blower housing. Generally, a combination of these conditions exists.

Excessive backlash in the blower timing gears usually results in rotor lobes rubbing throughout their length.

To correct any of the above conditions, remove the blower from the engine and either repair it or replace it.

The blower inlet screen should be inspected periodical y for dirt accumulation. After prolonged operation, dirt accumulation affects the airflow. Wash the screen thoroughly in clean fuel oil and clean it with a stiff brush until no dirt remains.

The air box drains should always be open. Check them regularly and make sure the passages are clean. If the liquid collects on the air box floor, a drain tube may be plugged. Remove the cylinder block handhole covers. Wipe the dirt out with rags or blow it out with faltered compressed air. Then remove the drain tubes and connectors from the cylinder block and clean them thoroughly.

Blower Removal and Disassembly

After you inspect the blower and determine what you need to do to recondition it, remove and disassemble the blower. Follow the instructions in the manufacturer's maintenance and repair manual.

After you remove the assembly, disassemble it and be careful not to damage any parts. Use the proper tools and follow the recommended disassembly procedures, particular y when the blower drive, driven gears, and timing gears from the rotor shafts are removed. Pull them from the rotor shaft at the same time or you will damage the rotors.

Cleaning, Inspecting, and Reassembly

After the blower has been disassembled, wash all the parts in cleaning solvent or clean fuel oil. Then blow-dry them, using filtered compressed air. Inspect the parts before reassembly.

Wash the bearings by rotating them by hand in either cleaning solvent or fuel oil until they are free from grease and foreign matter. Clean the balls (or rollers) and races by directing air through the bearings, at the same time, rotating them by hand. Do not spin the bearing with air pressure.

After thoroughly cleaning the bearings, rotate them again by hand and inspect it for rough spots. The bearings should run free. They should not show indications of roughness. The double-row bearings are preloaded and have no end play. A new double-row bearing will seem to have considerable resistance to motion when revolved by hand.

Check oil seals in the end plates. If necessary, replace them, when the blower is being reconditioned which is the recommended time to install new seals.

Inspect blower rotor lobes for smoothness. Inspect rotor shaft serrations and bearing surfaces for wear or burrs.

Check the finished faces of the end plates to see that they are smooth and flat.

Check the finished ends of the blower housing, which receive the end plates, to see that they are flat and free from burrs. The end plates must set flat against the blower housing.

Check blower timing gears for wear or damage. If either timing gear is worn or damaged sufficiently to require replacement both gears must be replaced as a set

Inspect the inside of the housing to see that the surfaces are smooth. The blower drive shaft should be straight and true. Shaft serrations should be clean and straight. You should replace all worn or excessively damaged blower parts.

After you have cleaned and inspected all the blower parts, reassemble the blower as prescribed in the manufacturer's maintenance and service manuals.

SUPERCHARGERS

A diesel engine may be equipped with a supercharger (fig. 5-37). The supercharger is a gear-driven air pump that uses rotors to force air into the engine cylinders when a requirement for more power exists. The supercharger must be maintained periodicaly.

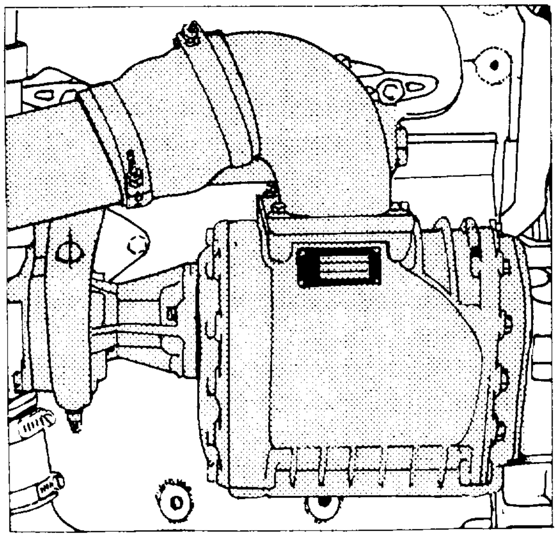


Figure 5-37.-Supercharger.

Remove the outlet connection of the suprcharger and visually check the ends of the rotors and case for evidence of oil leaking from the supercharger seals. Rotors will always show some oil from the vapor tube, which is connected to a rocker housing cover. However, only the appearance of wet oil at tie ends of the rotors would be cause for changing the seals of the supercharger. Be sure to check the lubricating oil lines and connections for any leaks. Correct these conditions if needed.

Removal

When the supercharger has to be removed from the engine, follow the procedures given in the manufacturer's service manual.

Disassembly

If you have to disassemble the supercharger, be careful when you remove the intake and discharge connections. Be sure to cover both openings. To prevent damage to its finished surfaces, usually made from aluminum, wash the outside of the supercharger with mineral spirits. Use the correct service tools and follow recommended disassembly procedures in the manufacturer's maintenance and repair manuals.

Cleaning and Inspecting

As the supercharger parts are disassembled, you should clean and dry them thoroughly with filtered compressed air. Discard all used gaskets, oil seals, recessed washers, roller bearings, and ball bearings. Replace these parts with new ones.

Inspect the rotors, housing, and end plates for cracks, abrasions, wear spots, and buildup of foreign material. With a fine emery cloth, smooth all worn spots found. Discard cracked, broken, or damaged parts. Remember, rotors and shafts we not separable. They must be replaced as a matched set or unit.

Inspect the drive coupling for worn pins, distorted or displaced rubber bushings, and damaged or worn internal splines. Examine the hub surface under the oil seal and replace the coupling if its surface is grooved or worn.

Check the gear fit on the rotor shafts and the gear teeth for evidence of chatter and wear. Replace the rotors and gears if they are not within the required tolerances.

Inspect all dowels, oil plungers, piston ring seals, and gasket surfaces. Replace them as necessary.

Reassembly

After you have inspected, cleaned, and replaced worn or damaged parts, put the supercharger back together as prescribed in the manufacturer's maintenance and service manuals. Upon complete reassembly and after the supercharger is installed on the engine, add the proper quantity of recommended engine lubricating oil to the gear end plate through the pipe plughold.

TURBOCHARGERS

The turbocharger (fig. 5-38) is a unit that is driven by exhaust gas to force (charge) air into the diesel engine cylinders for more complete burning of fuel and to increase engine power. As with any air induction component, the turbocharger is subject to environmental situations that could result in a turbocharger failure.

The real problem lies not in fixing the failure but in determining the cause. Replacing a failed turbocharger without first determining why it failed will often result in a repeated failure.

There are many causes of turbocharger failure, but they can be grouped into the following categories:

- Lack of lubricating oil
- Foreign material or dirt in the lubricating system
- Foreign material in either the exhaust or air induction system
- Material or workmanship

A failure can occur if the lubricating oil being supplied to the turbocharger is not sufficient to lubricate the thrust and journal bearings, stabilize the journal bearings and shaft, and cool the bearing and journal surfaces, even for periods as short as 5 seconds.

Operating the engine with contaminated oil under the assumption that the oil filter will remove the contaminants before they reach the bearings of the turbocharger can be quite costly. Actually, there are certain conditions under which the oil filter is bypassed and, if the oil is contaminated, turbocharger damage can result. Some examples of instances where the filter will be bypassed areas follows:

- The turbocharger lubrication valve is open as it is in starting.

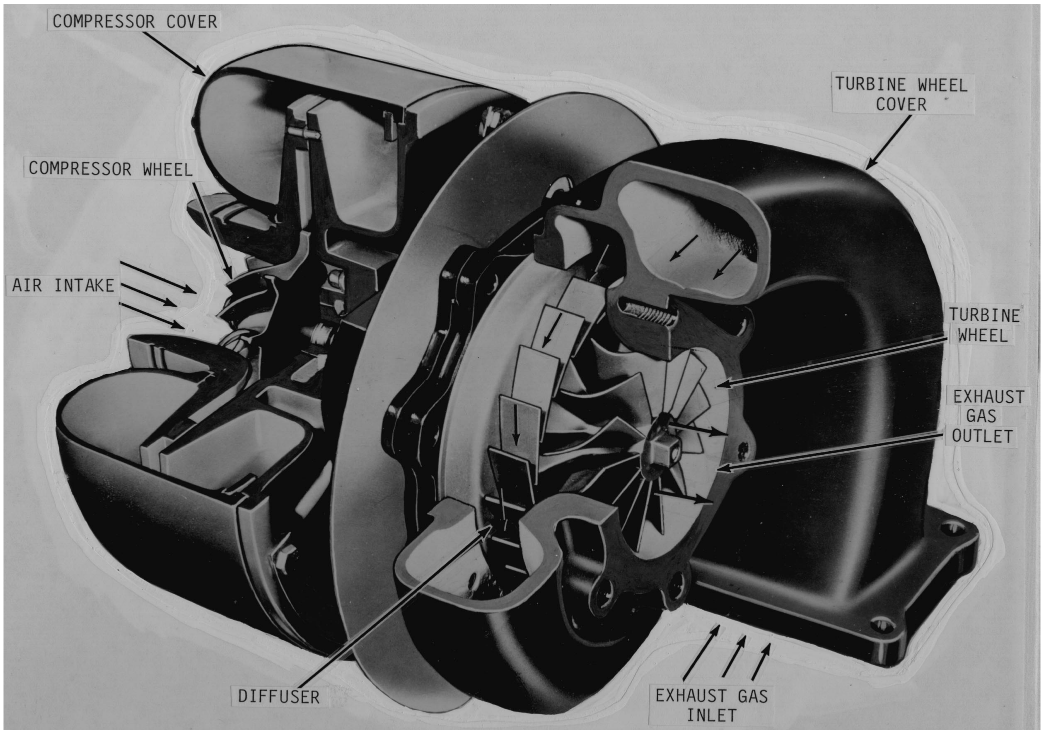


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Figure 5-38.-Turbocharger (cutaway view).

- The oil filter is clogged and the bypass valve is open.
- A lubrication valve or filter bypass valve malfunctions as a result of worn or binding components.

If enough contaminated oil enters the turbocharger bearings, the bearings will wear out or large particles may plug the internal oil passages and starve the turbocharger of oil.

Because of the extremely high top speeds of the turbine and compressor wheels (up to 100 mph), any large particles that enter through the inlet or exhaust systems can mechanical y damage the rotating parts of the turbocharger. Therefore, proper maintenance of the air cleaner is extremely important. Also, thorough cleaning of the inlet and exhaust systems is essential if there has been a previous turbocharger failure, valve failure, or other failure that could leave foreign particles in the engine.

Removal, Disassembly, and Cleaning

The removal of the turbocharger from the engine is not a complicated task when you follow the procedures in the manufacturer's instructions.

After removing the turbocharger from the engine, you should make sure the exterior of the turbocharger is cleaned of all loose dirt before disassembly to prevent unneccessary scoring of the rotor shaft. Disassemble it according to the manufacturer's maintenance and repair manuals.

The turbocharger parts accumulate hard-glazed carbon deposits, which are difficult to remove with ordinary solvents. This is especially true if the turbine wheel and shaft, diffuser plate, and the nozzle ring and inner heat shield are affected. The cleaner must remove these stubborn deposits without attacking the metal. All parts should be cleaned as follows:

1. Place all parts in a divided wire basket so parts will not be damaged through contact with each other. Do not pile them in the basket. Avoid mutilating precision ground surfaces.

2. Immerse the parts in mineral spirits or similar solvents.

CAUTION

Never use a caustic solution or any type solvent that may attack aluminum or nonferrous alloys.

3. Allow the parts to soak as needed to remove the carbon. A soft bristle brush maybe used, if necessary, to remove heavy deposits. Never use wire or other brushes with stiff bristles.

4. With the oil orifice removed, flush out the oil passages in the main casing from the bearing end to remove dirt loosened by the soaking.

5. Remove the parts from the tank. Drain and steam clean thoroughly to remove all carbon and grease. Apply steam liberally to the oil passages in the main casing.

6. Blow off excess water and dry all parts with filtered compressed air.

7. Carefully place parts in a clean basket to avoid damaging them before inspection and reassembly.

Parts Inspection

Inspect all turbocharger parts carefully before you rinse them. All parts within manufacturer's recommended specifications can be used safely for another service period. Damage to the floating bearing may require replacement of the turbocharger main casing with a new part or an exchange main casing.

Inspect the turbine casing. If you find cracks which are too wide for welding, replace the casing.

Do not use the exhaust casing if it is warped or heavily damaged on the inside surface caused by contact with the turbine wheel or a foreign object, or if it is cracked in any way.

Usually, oil seal plates do not wear excessively during service and can be reused if they have not been scored by a seizure of the piston ring.

As you inspect the diffuser plates, look for contact scoring by the rotor assembly on the back of the diffuser plate or broken vanes. This scoring will make the plate unacceptable for reuse.

Inspect the inner heat shield. If it is distorted, replace it.

Dents found on the outer heat shield can usually be removed, allowing its reuse. However, if this shield is cut or split in the bolt circle area, replace it.

Inspect the nozzle rings closely for cracks. If the nozzle rings are cracked or if the vanes are bent, damaged, or burnt thin, replace them.

If you see signs of wear or distortion during the inspection of the piston ring seals, discard and replace them with new ring seals.

Inspect the turbocharger main casing for cracks in the oil passages, cap screw bosses, and so forth. Also, check the casing for bearing bore wear. If it exceeds the limits allowed by the manufacturer, the bearing bore may be reworked to permit oversize, outer diameter bearings.

Check the oil orifices plug for stripped or distorted threads. Install a new plug if necessary.

The rotor assembly, which consists of a turbine wheel, thrust washer, and locknut, is an accurately balanced assembly. Therefore, if any one of the above parts is replaced as a result of your inspection, the assembly must be rebalanced according to the manufacturer's specifications.

When inspecting the semifloating bearing, measure both the outside and inside diameters of the bearing. If either diameter is worn beyond limits allowed by the manufacturer, replace the bearing.

The front covers that are deeply scored from contact with the compressor wheel cannot be reused. Slight scratches or nicks only can be smoothed out with a fine emery cloth and the covers reused. Cracked covers, however, cannot be reused and must be replaced with new ones.

All cap screws, lock washers, and plain washers should be cleaned and reused unless they are damaged.

Reassembly and Installation

After inspection of the turbocharger component parts and replacement of damaged or worn parts, reassemble the turbocharger as prescribed by the manufacturer's maintenance and repair manuals.

Close off all openings in the turbocharger immediately after reassembly to keep out abrasive material before you mount it on the engine.

Turbochargers can be mounted on the engine in many different positions. Always locate the oil outlet at least 45 degrees below the turbocharger horizontal center line when the unit is in the operating position.

COLD STARTING DEVICES

Gasoline and diesel fuel engines are difficult to start in cold weather. They are difficult to start because of the low volatility of the fuel. In this section, the most common cold starting devices for gasoline and diesel fuel injection systems are discussed.

GASOLINE FUEL INJECTION COLD STARTING DEVICES

Gasoline fuel injection systems may have a cold-start injector (fig. 5-39) screwed directly into the air intake manifold. This fuel injector will introduce additional fuel into the intake manifold for cold starts and initial cold engine operation. Other gasoline fuel injection systems have a coolant sensor called a thermistor (fig. 5-2). This sensor changes the electrical resistance with the changes in the coolant temperature. The lower the coolant temperature, the higher the resistance. The electronic control module (ECM) provides a low voltage signal to the thermistor and monitors the return voltage value. A lower value means a warm engine, a higher value means a cold engine. The ECM then knows when the engine is cold and when to provide a richer fuel mixture for cold starts and initial cold operation.

DIESEL ENGINE INJECTION COLD STARTING DEVICES

The most common cold starting system for diesel engines is the glow plug system. This is an electrically operated system used to heat the combustion chamber

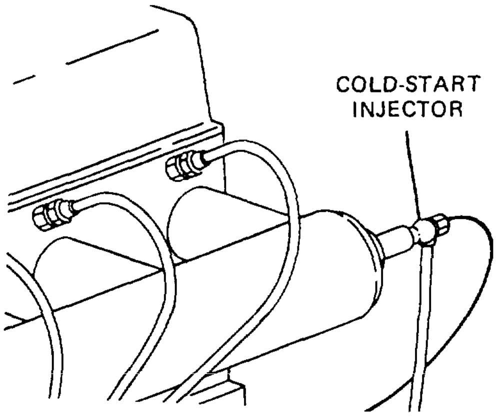


Figure 5-39.-Typical cold-start injector mounted on the intake manifold.

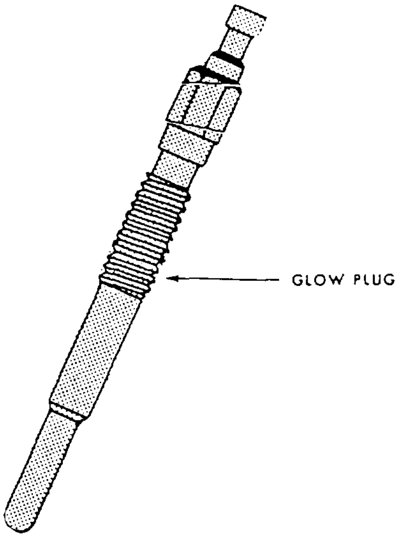


Figure 5-40.-Typical diesel engine glow plug.

before normal initial starting. The glow plug (fig. 5-40) resembles the spark plug of a normal gasoline engine. The system is operated manually by depressing a switch or button; or, it may be turned on with the ignition switch and turned off by a timed relay. During colder weather, the system, with the relay, may have to be run through more than one glow plug cycle to start the engine.

Glow plugs are not complicated and are easy to test. Disconnect the wire going to the glow plug and use a multimeter to read the ohms resistance of the glow plug. Specifications for different glow plugs vary according to the manufacturer. Be sure and check the manufacturer's repair manual for the correct ohms resistance value.

The manifold flame heater system (fig. 5-41) is another type of cold starting system found on diesel

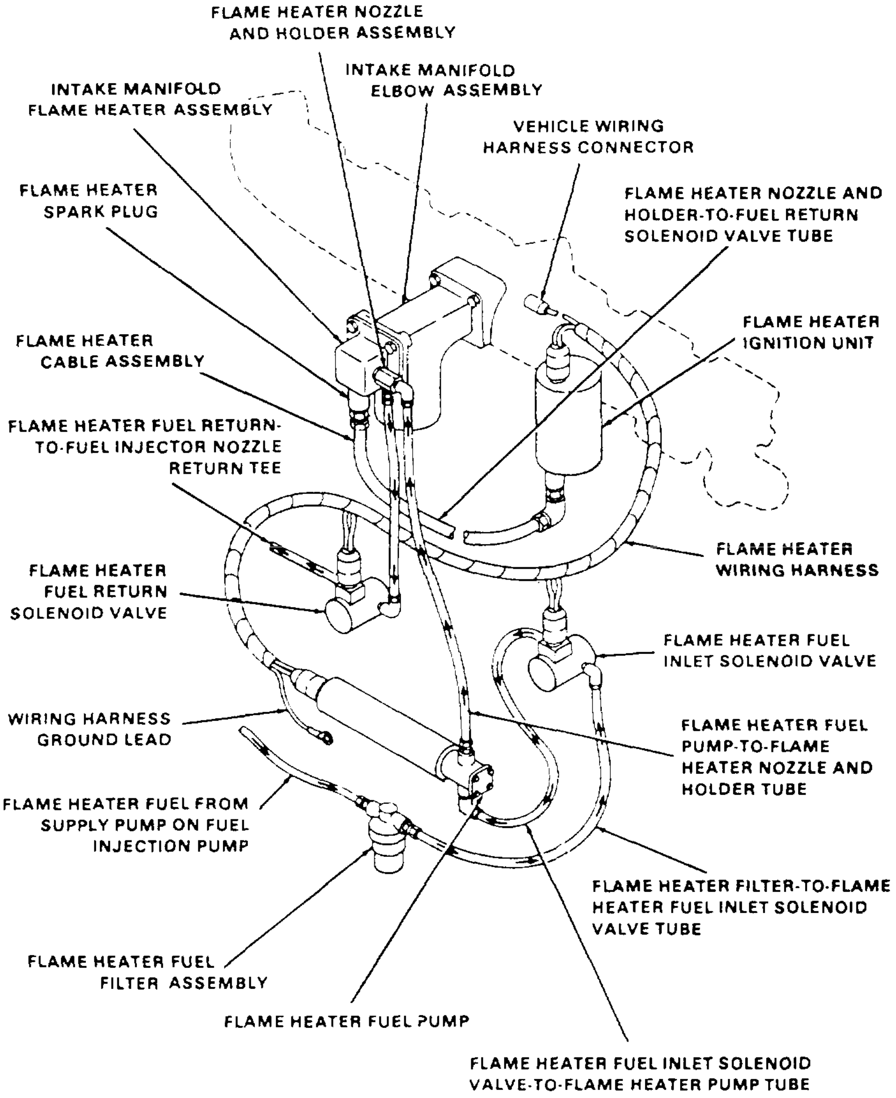


Figure 5-41.-Manifold flame heater system.

engines. This system is composed of a housing, spark plug, flow control nozzle, and two solenoid control valves. This system is operated as follows:

1. The spark plug is energized by the flame heater ignition unit.

2. The nozzle sprays fuel under pressure into the intake manifold assembly.

3. The fuel vapor is ignited by the spark plug and bums in the intake manifold heating the air before it enters the combustion chamber.

The flame fuel pump assembly is a rotary type, driven by an enclosed electric motor. The fuel pump receives fuel from the vehicle fuel tank through the supply pump of the vehicle and delivers it to the spray nozzle. The pump is energized by the on/off switch located on the instrument panel.

The intake manifold flame heater system has a filter to remove impurities from the fuel before it reaches the nozzle.

The two fuel solenoid valves are energized (open) whenever the flame heater system is activated. The valves ensure that fuel is delivered only when the system is operating. These valves stop the flow of fuel the instant that the engine or the heater is shut down.

When troubleshooting or repairing these units, consult the manufacturer's repair manual.

ETHER

Cold starting aids, such as ether, should be used only in extreme emergencies. Too much ether may detonate in the cylinders too far before top dead center on the compression stroke. This could cause serious damage, such as broken rings, ring lands, pistons, or even cracked cylinder heads. If you must use ether, the engine has to be turning over before you spray it into the air intake.

CAUTION

ETHER IS TO BE USED ONLY IN EXTREME EMERGENCIES.

ASSIGNMENT 5

Textbook Assignment: "Fuel System Overhaul," pages 5-1 through 5-27.

5-1. Before rebuilding a carburetor, you should first take which of the following steps?

1. Identify the carburetor
2. Get the repair specifications
3. Make sure the carburetor is the problem
4. Remove the carburetor from the vehicle

5-2. Carburetor identification numbers may be found in which of the following locations?

1. In the operations manual
2. Stamped into the base of the carburetor
3. On a metal tag screwed or riveted to the carburetor
4. Both 2 and 3 above

5-3. Before dipping a carburetor into a cleaning solution, you should take which of the following actions?

1. Plug up all vacuum ports
2. Remove any items that may be affected by the solution
3. Remove all electronic devices
4. Both 2 and 3 above

5-4. Which of the following parts are NOT normally removed during a carburetor overhaul?

1. Throttle shaft and float
2. Throttle shaft and choke shaft
3. Choke shaft and vacuum pull down
4. Any plastic parts

5-5. When, if ever, may emission controls on CESE be modified?

1. When a person wants to increase fuel economy
2. When being shipped overseas
3. During battalion turnover
4. Never

5-6. What organization can authorize an emission control modification?

1. CBC, Port Hueneme, California, Code 15
2. Gulfport, Mississippi, CED
3. NAVFAC, Washington D.C.

5-7. To test and adjust a modern carburetor, which of the following tools do you need?

1. An oscilloscope
2. A Vat 29 or 32
3. An exhaust gas analyzer

5-8. When an exhaust gas analyzer is used to test vehicle emissions, what will be the result if the probe is not set to the correct depth?

1. A low reading
2. The analyzer will not respond
3. A high reading
4. A normal reading

5-9. The fuel injector can atomize fuel more efficiently than a carburetor, resulting in which of the following advantages?

1. Higher volumetric efficiency
2. No-problem with fuel condensation in the manifold
3. Improved fuel vaporization
4. All of the above

5-10. In a gasoline fuel injection system, the fuel pressure regulator diverts the excess fuel to which of the following locations?

1. Back to the fuel tank
2. Back to the fuel filter
3. To a tee fitting in the fuel pickup line

5-11. The computer varies the amount of fuel delivered to the cylinder by which of the following means?

1. Changing the duration of fuel injection
2. Raising the fuel line pressure
3. Lowering the fuel line pressure
4. Both 2 and 3 above

5-12. On a gasoline fuel injection system, the entrance of fuel into the combustion chamber is controlled by what means?

1. The throttle valve
2. Engine vacuum
3. The intake valve
4. The ECU

5-13. Timed fuel injection systems are used only in which of the following situations?

1. When the cost is less
2. When more precise fuel metering is required
3. The timed system maintains a lower fuel line pressure

5-14. What activates the cold start injector?

1. Vacuum
2. Choke lever link
3. Electric current

5-15. What is the most common type of service performed on gasoline fuel injection systems?

1. Preventive
2. Interim
3. Injector

5-16. Air leaks in the air intake system that bypass ECU sensors can cause which of the following problems?

1. False readings to be sent to the injectors
2. A rich fuel-air mixture delivery
3. False readings to be sent to the ECM

5-17. A gasoline fuel injection system operates with fuel pressures up to what number of times greater than a standard gasoline fuel system?

1. Two
2. Four
3. Five
4. Ten

5-18. On the Caterpillar fuel injection system, the capsule type of injector valve serves what function?

1. It times the delivery of fuel
2. It meters the fuel
3. It injects and atomizes the fuel
4. It pressurizes the system

5-19. To check engine performance for faulty fuel injection, you should operate the engine at a speed that accentuates the fault. The next step is for you to try to get the cylinders to misfire by what means?

1. Preventing the spark from reaching each cylinder
2. Loosening the fuel line nut on each injector pump
3. Turning off the ignition switch
4. Enriching the fuel supply to each cylinder

5-20. During operation of a Caterpillar fuel injection system, the governor will compensate for all except which of the following fuel rack settings?

1. 1/4 throttle
2. 1/2 throttle
3. 3/4 throttle
4. Full throttle

5-21. Before proceeding with the final stage in testing a Caterpillar fuel injector pump, the mechanic must remember to perform which of the following procedures?

1. Siphon fuel from the pump into the collector jar
2. Bleed air from the pump and collector assembly
3. Inspect the injector screen filter before attaching the collector assembly

5-22. After testing an injector pump, you see that the fuel level in the collector jar is above the good range. What is the condition of the pump?

1. Its plunger and barrel are worn
2. Its discharge capacity is below normal
3. Its discharge measurement is not accurate
4. It is as good as new

5-23. On the capsule type of fuel injection valves, the fuel injection test apparatus allows the mechanic to make which of the following checks?

1. Leakage rate
2. Spray characteristics
3. Valve opening pressure
4. All of the above

5-24. An injector orifice damaged when carbon deposits are wire brushed from an injector valve could result in which of the following problems?

1. Precombustion
2. Reduced power output
3. Excessive fuel output
4. No valve opening pressure

5-25. To be satisfactory, the injector valve opening pressure (as read on the test gauge) should fall between which of the following pressure ranges?

1. 100 to 200 psi
2. 200 to 300 psi
3. 300 to 400 psi
4. 400 to 800 psi

5-26. The Caterpillar compact fuel system transfer pump delivers fuel to which of the following components?

1. The injection valve
2. The filter
3. The capsule
4. The manifold

5-27. The compact injection pump plungers complete a full stroke at which of the following speeds?

1. Idle only
2. Fast idle only
3. Governed speed only
4. Idle, fast idle, and governed speed

5-28. On a compact fuel injection system, what must react on the speed limiter before the governor control may move to high idle?

1. Oil pressure
2. Fuel pressure
3. The limiter plunger
4. The governor linkage

5-29. Which of the followingl faults does NOT cause a smoky exhaust?

1. Lack of air
2. Lack of fuel
3. Overloading
4. Lack of compression

5-30. The sleeve position in the Caterpillar sleeve metering fuel system is controlled by what component?

1. The plunger
2. The barrel
3. The priming pump
4. The governor

5-31. In a Caterpillar sleeve metering fuel injection system, fuel injection begins at what point?

1. As the fuel inlet closes
2. As the fuel outlet opens
3. As the injector housing is charged
4. As the reverse flow check valve closes

5-32. The reverse flow check valve in the sleeve metering fuel injection pump is closed by what means?

1. Compression pressure
2. Spring pressure
3. Residual pressure
4. Cam action

5-33. After normal start-up, at what rpm does the governor take over in a Caterpillar sleeve metering fuel injector pump?

1. 300
2. 500
3. 750
4. 900

5-34. Most fuel problems may be traced to which of the following causes?

1. Dirty fuel filters only
2. Broken fuel line only
3. Poor quality fuel only
4. Dirty fuel filters, a broken fuel line, and poor quality fuel

5-35. The Caterpillar sleeve metering fuel injection system does not require frequent balancing for which of the following reasons?

1. It is adjusted by fuel pressure
2. It has built-in calibration
3. It is adjusted by normal governor operation
4. Both 2 and 3 above

IN ANSWERING QUESTIONS 5-36 THROUGH 5-43, SELECT FROM COLUMN B THE PROBLEM THAT IS LIKELY TO BE CAUSED BY THE CONDITION GIVEN IN COLUMN A. RESPONSES IN COLUMN B MAY BE USED MORE THAN ONCE.

A. CONDITIONS

5-36. Hand primer installed backwards

5-37. Throttle arm travel not sufficient

5-38. Pump housing not full of fuel

5-39. One or more connector screws obstructed

5-40. Tank valve closed

5-41. Governor linkage broken

5-42. Fuel line leaking or connected to wrong cylinder

5-43. Governor spring worn or broken

B. PROBLEMS

1. Engine idles imperfectly
2. Engine starts hard
3. Fuel not reaching pump
4. Fuel reaching nozzles, but engine will not start

5-44. A Roosamaster fuel injection pump test reading should be taken at (a) what idle, and with (b) what load conditions?

1. (a) Low idle (b) no load
2. (a) High idle (b) no load
3. (a) Low idle (b) high load
4. (a) High idle (b) high load

5-45. When you test the transfer pump, which of the following conditions will NOT cause a low-pressure reading on the test gauge?

1. Air leaks on the suction side of the pump
2. A restricted fuel return line
3. A malfunctioning regulator valve
4. Worn transfer pump blades

5-46. When you are testing a Roosamaster fuel injection pump, a reading of how many inches of vacuum indicates a restricted fuel supply?

1. 5
2. 7
3. 9
4. 10

5-47. Each time a Roosamaster fuel injection pump is overhauled, which of the following parts is/are always replaced?

1. Springs
2. Seal seats
3. O rings and seals
4. Timing plate

5-48. The American Bosch fuel injection pump used on the multifuel engine has which of the following features?

1. Sleeve-control
2. Constant-stroke
3. Distributing-plunger
4. All of the above

5-49. Fuels used in the multifuel engine pump do not require special qualities.

1. True
2. False

5-50. The American Bosch Model PSB fuel supply pump is what type?

1. Centrifugal
2. Positive displacement
3. Diaphragm

5-51. The mechanical centrifugal advance unit provides what maximum amount of advance timing?

1. 22 1/2°
2. 18°
3. 17 1/2°
4. 9°

5-52. When you are adjusting an American Bosch fuel injector, a reading of how many PSI indicates a need to adjust the opening pressure?

1. 30
2. 45
3. 50
4. 65

5-53. Which of the following terms refers to the groove in the top face of the nozzle valve body?

1. Helix
2. Orifice
3. annular

5-54. Assume you are using the test pump shown in figure 5-27 of your TRAMAN to check the spray valve-opening pressure. The opening pressure specified for the check valve is 200 psi. Which of the following readings of the spray valve opening indicates a bad check valve or seat?

1. 195 psi
2. 180 psi
3. 160 psi
4. 140 psi

5-55. Before you install a nozzle in the engine, you should retest it for which of the following defects?

1. Leakage
2. Spray angle and pattern
3. Valve–opening pressure
4. Each of the above

5-56. While troubleshooting the General Motors fuel system, you discover that the fuel pump is not functioning satisfactorily. Before removing the fuel pump, you should make sure of which of the following conditions?

1. There is fuel in the tank
2. The filter cover bolt is tight
3. The fuel supply valve is open
4. Each of the above

5-57. In a General Motors fuel injection system, which of the following is the most common failure of the fuel transfer pump?

1. Leaking seals
2. Worn gears
3. Sticking relief valve
4. Worn bore seat

5-58. An engine lacks power, runs unevenly, or stalls at idle even after its fuel pump is reconditioned. Which of the following faults should you suspect?

1. Restricted fuel flow
2. Faulty injector
3. Excessive vacuum pressure
4. Dirty fuel filter

5-59. If a General Motors injector passes all but one of its pressure tests, the mechanic should allow it to remain in service.

1. True
2. False

IN ANSWERING QUESTIONS 5-60 THROUGH 5-63, SELECT FROM COLUMN B THE INJECTOR TEST THAT CORRESPONDS WITH THE PURPOSE IN COLUMN A. RESPONSES IN COLUMN B MAY BE USED MORE THAN ONCE.

	A. PURPOSES		B. INJECTOR TESTS
5-60.	To measure the pressure at which the valve opens and injection begins	1.	Valve-opening pressure test
5-61.	To determine whether fuel leaks at the injector filter cap gaskets, body plugs, and nut seal ring	2.	Valve-holding pressure
5-62.	To determine whether the injector plunger and bushing clearance is satisfactory	3.	High-pressure test
5-63.	To determine whether lapped surfaces in the injector are sealing properly		

5-64. Which of the following valve-opening pressure readings is within the specified limits for the needle valve injector?

1. 450 psi
2. 800 psi
3. 3,000 psi
4. 4,000 psi

5-65. During the valve-holding pressure test of an injector, the opening pressure drops from 450 psi to 250 psi in 50 seconds. What does the drop rate indicate?

1. A leak due to poor bushing-to-body fit
2. A leaking valve assembly due to a damaged surface or dirt
3. A loose filter cap gasket
4. An injector whose lapped surfaces are sealing properly

5-66. In a General Motors diesel unit type fuel injector, what action should you take if a high-pressure test shows excessive clearance between the plunger and bushing?

1. Replace the plunger
2. Replace the bushing
3. Replace the bushing and plunger as a set
4. Resurface the plunger and reuse the bushing

5-67. The plunger bottom helix and the lower portion of the upper helix should be visually checked during which of the following tests?

1. Spray pattern test
2. Injector control rack and plunger movement test
3. High-pressure test
4. Fuel output test

5-68. To determine whether the fuel output of a General Motors injector falls within the manufacturer's recommended limits, the mechanic should use which of the following devices?

1. A fuel pump and fuel collector assembly
2. A General Motors injector tester
3. A comparator

5-69. The General Motors injector spray tip is normally soaked in solvent for approximately 15 minutes for which of the following reasons?

1. To loosen the dirt on the outside of the tip for easy cleaning
2. To loosen the carbon on the inside of the tip before reaming
3. To loosen the carbon on both the outside and inside of the tip before disassembly

5-70. When working with General Motors unit type of injectors, which, if any, of the following actions must you take before reusing any parts?

1. Lap all sealing surfaces of the internal parts
2. Lap the injector bushing only
3. Lap the check valve and spray tip
4. None of the above

5-71. You can eliminate a PT fuel injection system fuel pump as a potential source of trouble by taking which of the following actions?

1. Checking for internal leakage
2. Checking for external leakage
3. Checking the fuel manifold pressure
4. Each of the above

5-72. On a PT type of fuel injection system. when should maximum fuel manifold pressure be obtained?

1. At idle
2. Just off idle
3. After the governor cuts in
4. Just before the governor cuts in

5-73. To remove carbon from PT fuel injector tips, you should use which of the following methods?

1. A wire brush
2. Reverse flushing
3. A pin vise and the proper size fine wire

5-74. The aneroid controls the exhaust emissions by creating a lag in the fuel system equal to that of the turbo charge.

1. True
2. False

5-75. The body of a PT fuel pump is manufactured of what metal?

1. Plastic
2. Iron
3. Aluminum
4. Bronze

CHAPTER 6

INSPECTING AND TROUBLESHOOTING BRAKE SYSTEMS

Braking systems are usually inspected yearly, or every 12,000 miles to ensure safe operation, to comply with state and local regulations, and to keep personnel and equipment safe. Many accidents caused by defective brakes might have been avoided by frequent and thorough brake inspections. These brake inspections must be done more frequently when vehicles are used in sand, mud, or constant fording.

WARNING

Without a reliable braking system, CESE does not leave the shop. If the problem is discovered in the field, the next stop for that equipment (towed) should be the CM maintenance shop. CESE shall not be operated nor will it be placed in operation with faulty brakes.

Regulations for testing and inspecting brakes are about the same all over. One requirement is that the brakes must stop the vehicle within a prescribed distance, at a given speed, with a minimum of effort, and without deviating the vehicle from a straight line (controlled stop).

The stopping distances for all vehicles depend on the distance the driver can see and think before he or she presses the brake pedal. Figure 6-1 shows some stopping distances from different speeds with good brakes. These stopping distances came from actual tests.

INSPECTING AND TROUBLESHOOTING HYDRAULIC BRAKE SYSTEMS

Hydraulic brakes should be inspected for the external condition of the hoses and tubing, especially for leakage or seepage at the couplings. Hose or tubing worn or weakened by rubbing against other parts of the vehicle must be replaced.

CAUTION

Under no circumstances should steel brake tubing be replaced with copper tubing.

Test for leakage by holding the brake pedal depressed for at least 1 minute. If the pedal does not hold, there is a leak in the system. If you find a leak, repair it, even if you have to pull all the wheels to examine the wheel cylinders. Then fill the master cylinder with fluid and bleed the brakes.

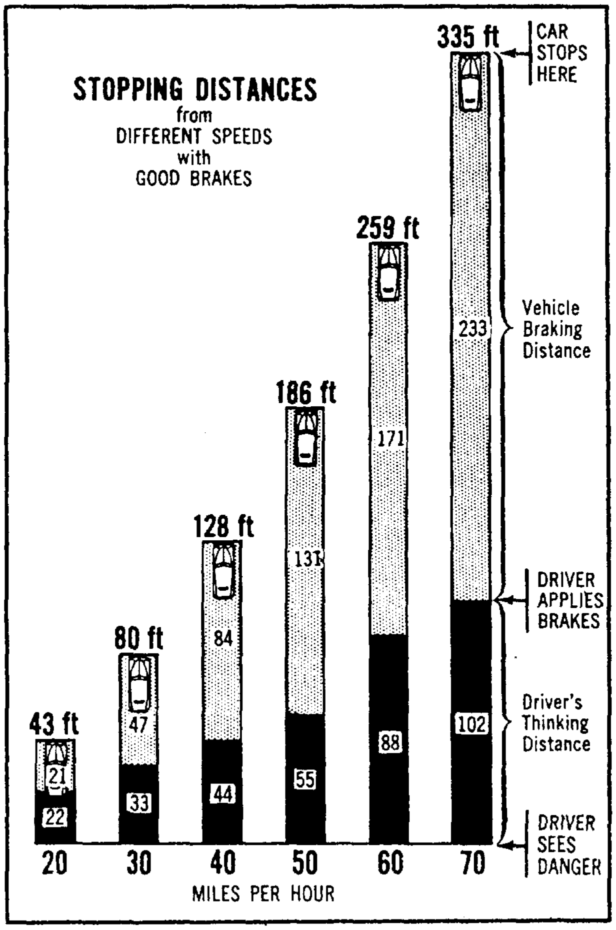


Figure 6-1.-Stopping distances from different speeds with good brakes.

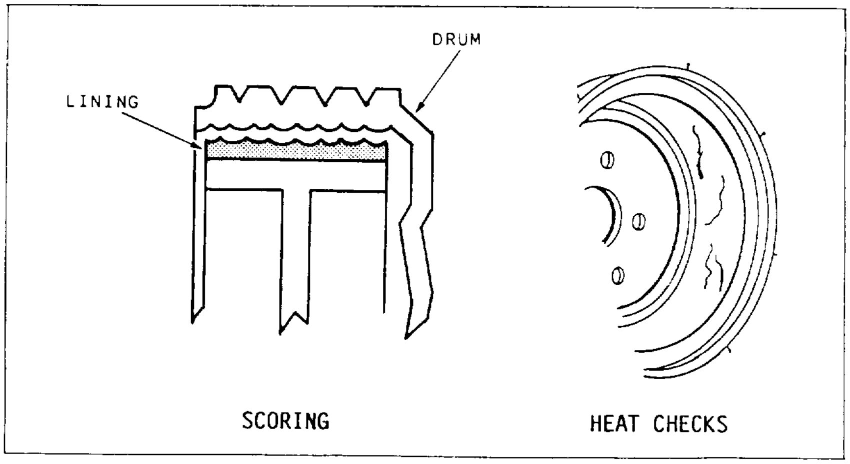


Figure 6-2.-Drum wear patterns.

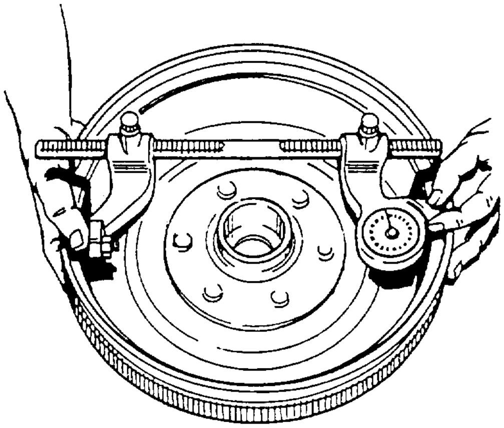


Figure 6-3.-Using a drum micrometer to measure the drum.

ATTENTION

CESO Maintenance Bulletin No. 75 directs the Naval Construction Force to use silicone brake fluid. Silicone brake fluid will not mix with glycol brake fluid and no adverse effects will occur to brake parts if it is combined accidently in small quantities. Some of the advantages of silicone brake fluid are that it will not damage painted surfaces, it has excellent dielectric properties, it will not deteriorate during long periods of system storage or climatic exposure, and it will not absorb or retain moisture.

To comply with requirements for testing brakes, you must see that at least one of the wheels is removed to check the brake lining and drum/rotor. Some

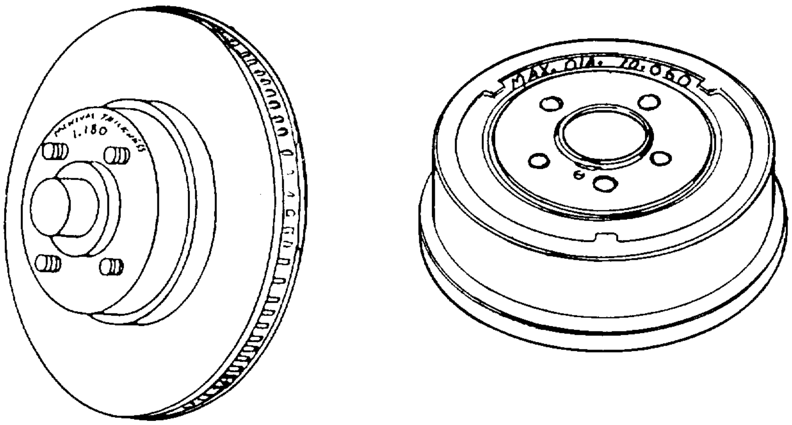


Figure 6-4.-Examples of specifications cast into brake drums.

manufacturers recommend pulling two wheels-one on each side. Look for loose or broken brake shoe retracting springs, worn clevis and cotter pins in the brake operating mechanisms, and grease or oil leaks at the wheel bearing grease retainer. Check for any signs of brake fluid leakage around the wheel cylinders or caliper operating pistons.

Brake linings that pass inspection for wear must be securely fastened to the brake shins and free from grease and oil. Small grease or oil spots can be removed from the lining with a nonoil base solvent. Linings saturated with grease or oil should be replaced only after the source of contamination has been repaired.

Badly worn or scored brake drums/rotors (fig. 6-2) should be machined smooth and true on a lathe or replaced. Cracked brake drums (fig. 6-3), or brake drums that have been machined beyond their maximum allowable diameter should be discarded. Brake drums and discs have the maximum or discard diameters cast into their outer surfaces (fig. 6-4).

Brake shoe and drum trouble not immediately evident when the wheels are pulled, yet that is detected during road tests, may be caused by the wrong kind of lining, ill-fitting brake shoes, or brake drums slightly out of round. The clue to these troubles may be chattering, spongy, or grabbing brakes.

CAUTION

> Before troubleshooting brake systems by road testing, be sure that the vehicle is mechanically sound. Different size tires, low tire pressures, faulty shock absorbers, loose wheel bearings, and worn front-end parts may each indicate brake problems where there are none.

Navy vehicles seldom have the wrong kind of brake lining. However, an inexperienced mechanic may reverse the primary and secondary shoe on one of the wheels or interchange them between wheels so that the shoes are not exactly mated with the drums against which they expand. If you replace shoes or machine the drum/rotor on one side, do the same to the opposite side to prevent pull or loss of control.

The preceding paragraphs apply to most braking systems but do not list all of the problems you will have. For other probable causes of trouble and their remedies in standard hydraulic brake systems, refer to table 6-1.

PEDAL GOES TO THE FLOOR (LOW PEDAL)

Pedal reserve (fig. 6-5) is the distance from the brake pedal to the floorboard with the brakes applied. Low or no pedal reserve indicates brake problems. When there is no pedal reserve or an unlikely occurrence with a dual master cylinder, it could mean anything from a lack of brake fluid, to worn brake linings, a faulty master cylinder, or only a simple brake adjustment. Each of these conditions demands that you closely inspect the brake system.

BRAKES DRAG

Dragging brakes are caused by the following: one or more sets of shoes being adjusted too tightly, broken or weak return springs, a wheel cylinder piston that is stuck, drums that are out of round, defective lining material, loose anchor pins, or clogged lines or hoses. When both rear wheels drag, the cause may be the parking cable linkage being adjusted too tightly or a frozen parking brake cable. All wheels dragging can be the result of a stuck master cylinder pedal linkage or a defective power booster.

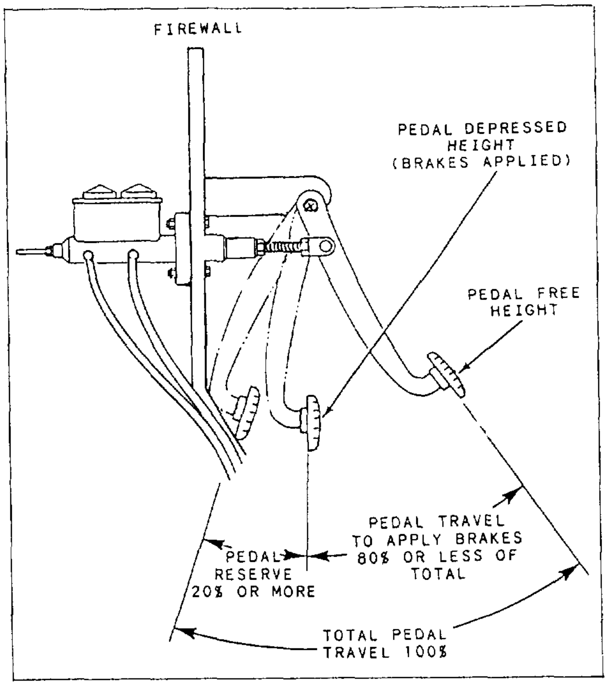


Figure 6-5.-Example of pedal reserve.

Table 6-1.-Troubleshooting Chart for Hydraulic Brakes (Standard)

MALFUNCTION	PROBABLE CAUSE	POSSIBLE REMEDY
A. Low pedal or pedal goes to toeboard.	1. Excessive clearance between linings and drum.	1. Adjust brakes.
	2. Automatic adjusters not working.	2. Make forward and reverse stops. If pedal stays low, repair faulty adjusters.
	3. Weak brake hose.	3. Replace hose.
	4. Leaking brake pipe.	4. Repair or replace faulty parts.
	5. Leaking wheel cylinder.	5. Clean and rebuild.
	6. Leaking master cylinder.	6. Clean and rebuild.
	7. Leaking master cylinder check valve.	7. Replace valve.
	8. Leaking stop light switch.	8. Replace switch.
	9. Air in system.	9. Bleed system.
	10. Plugged master cylinder filler cap.	10. Clean filler cap vent holes; bleed system.
	11. Improper brake fluid.	11. Flush system and replace with correct fluid.
	12. Low fluid level.	12. Fill reservoir; bleed system.
B. Springy, spongy pedal.	1. Air trapped in hydraulic system.	1. Remove air by bleeding.
	2. Improper brake fluid.	2. Flush and bleed system.
	3. Anchor pin adjustment incorrect.	3. Adjust anchor pin.
	4. Improper lining thickness or location.	4. Install specified lining or replace shoe and lining.
	5. Drums worn too thin.	5. Replace drums.
	6. Master cylinder filler vent clogged.	6. Clean vent or replace cap; bleed brakes.
	7. Weak hose.	7. Replace hose.
C. Excessive pedal pressure required to stop car.	1. Brake adjustment not correct.	1. Adjust brakes or repair self adjuster.
	2. Incorrect lining.	2. Install specified lining.
	3. Grease or fluid soaked lining.	3. Repair grease seal, or wheel cylinder. Install new linings.
	4. Improper fluid.	4. Flush out system; fill with correct type fluid.
	5. Frozen master or wheel cylinder pistons.	5. Rebuild or replace.

Table 6-1.—Troubleshooting Chart for Hydraulic Brakes (Standard)–Continued

MALFUNCTION	PROBABLE CAUSE	POSSIBLE REMEDY
C. Excessive pedal pressure required to stop car–Continued.	6. Brake pedal binding on shaft.	6. Lubricate or replace.
	7. Linings installed on wrong shoes.	7. Install primary and secondary linings correctly.
	8. Glazed linings.	8. Sand surface of linings.
D. Light pedal pressure. Brakes too severe.	1. Brake adjustment not correct.	1. Adjust the brakes or repair self adjusters.
	2. Loose backing plate on front axle.	2. Tighten plates.
	3. A small amount of grease or fluid on linings.	3. Replace the linings.
	4. Glazed linings.	4. Sand the surfaces of the linings.
	5. Incorrect lining.	5. Install factory specified linings.
	6. Wheel bearings loose.	6. Adjust wheel bearings.
	7. Lining loose on shoe.	7. Replace lining or shoe and lining.
	8. Excessive dust and dirt in drums.	8. Clean and sand drums and linings.
	9. Bad drum.	9. Turn drums in pairs or replace.
E. Brake pedal travel decreasing.	1. Master cylinder compensating port plugged.	1. Open with compressed air or replace.
	2. Swollen cap in master cylinder.	2. Replace rubber parts; flush system.
	3. Master cylinder piston not returning.	3. Rebuild master cylinder.
	4. Weak shoe retracting springs.	4. Replace springs.
	5. Wheel cylinder pistons sticking.	5. Clean cylinder bores and parts. Replace bad parts.
F. Pulsating brake pedal.	1. Drums out of round.	1. Refinish drums to specifications.
	2. Loose brake drum on hub.	2. Tighten.
	3. Worn or loose wheel bearings.	3. Replace or adjust.
	4. Bent rear axle.	4. Replace axle.

Table 6-1.—Troubleshooting Chart for Hydraulic Brakes (Standard)–Continued

MALFUNCTION	PROBABLE CAUSE	POSSIBLE REMEDY
G. *Brake Fade.	1. Incorrect lining.	1. Replace lining with lining recommended by factory.
	2. Thin drum.	2. Replace drums.
	3. Dragging brakes.	3. Adjust or correct cause.
H. All brakes drag when adjustment is known to be correct.	1. Pedal does not return to stop.	1. Lubricate the pedal.
	2. Improper fluid.	2. Replace rubber parts and refill.
	3. Compensating or bypass part of master cylinder closed.	3. Open with compressed air or replace.
I. One wheel drags.	1. Weak or broken shoe retracting springs.	1. Replace the defective brake shoe springs and lubricate the brake shoe ledges.
	2. Brake shoe to drum clearance too small or the brake shoe eccentric is not adjusted properly.	2. Adjust.
	3. Loose wheel bearings.	3. Adjust wheel bearings.
	4. Wheel cylinder piston cups swollen and distorted or the piston stuck.	4. Rebuild cylinders.
	5. Pistons sticking in wheel cylinder.	5. Clean or replace pistons; clean cylinder bore.
	6. Drum out of round.	6. Grind or turn front or rear drums.
	7. Obstruction in line.	7. Clean out or replace.
	8. Loose anchor pin.	8. Adjust and tighten lock-nut.
	9. Distorted shoe.	9. Replace.
	10. Defective lining.	10. Replace with specified lining.
	11. Parking brake cable frozen.	11. Lubricate.
J. Rear brakes drag.	1. Maladjustment.	1. Adjust brake shoes and parking brake mechanism.
	2. Parking brake cables frozen.	2. Lubricate.
K. Vehicle pulls to one side.	1. Grease or fluid soaked lining.	1. Replace with new linings.
	2. Anchor pin adjustment not correct.	2. Major brake adjustment.

*Fade is a temporary reduction of brake effectiveneess resulting from heat.

Table 6-1.—Troubleshooting Chart for Hydraulic Brakes (Standard)—Continued

MALFUNCTION	PROBABLE CAUSE	POSSIBLE REMEDY
K. Vehicle pulls to one side–Continued	3. Loose wheel bearings; loose backing plate on rear axle or front axle or loose spring bolts.	3. Adjust the wheel bearing; tighten the backing plate on the rear axles and tighten spring bolts.
	4. Linings not of specified kind or primary and secondary shoes reversed.	4. Install specified linings.
	5. Tires not properly inflated or unequal wear of tread. Different tread nonskid design.	5. Inflate the tires to recommended pressures. Rearrange the tires so that a pair of nonskid tread surfaces of similar design and equal wear will be installed on the front wheels and another pair with the tread will be installed on the rear wheels.
	6. Linings glazed.	6. Sand the surfaces of the linings.
	7. Water, mud, etc., in brakes.	7. Remove any foreign materials from all of the brake parts and the inside of the drums. Lubricate the shoe ledges and the rear brake cable ramps.
	8. Wheel cylinder sticking.	8. Repair or replace wheel cylinder.
	9. Weak or broken retracting springs.	9. Check springs. Replace bent, open-coiled or cracked springs.
	10. Out-of-round drums.	10. Re-surface or replace drums in left and right hand pairs (both front and both rear).
	11. Brake dragging.	11. Check for loose lining. Adjust.
	12. Weak chassis springs, loose U–bolts, loose steering gear, etc.	12. Replace spring, tighten U–bolts, adjust steering gear, etc.
	13. Loose steering.	13. Repair and adjust.
	14. Unequal camber.	14. Adjust to spec.
	15. Bad drum.	15. Refinish drums in pairs.
L. One wheel locks.	1. Gummy lining.	1. Reline.
	2. Tire tread slick.	2. Match up tire tread side to side.
	3. Faulty anchor adjustment.	3. Adjust.

Table 6-1.—Troubleshooting Chart for Hydraulic Brakes (Standard)-Continued

MALFUNCTION	PROBABLE CAUSE	POSSIBLE REMEDY
M. Wet weather, brakes grab or won't hold.	1. Linings sensitive to water.	1. Reline.
	2. Dirty brakes.	2. Clean out.
	3. Bent backing plate-opening.	3. Straighten or replace.
	4. Scored drums.	4. Grind or turn in pairs.
N. Brakes squeak.	1. Backing plate bent or shoes twisted.	1. Straighten or replace damaged parts.
	2. Metallic particles or dust embedded in lining.	2. Sand linings and drums. Remove all particles of metal in surface of linings.
	3. Lining rivets loose or lining not held tightly against the shoe at the ends.	3. Replace rivets and/or tighten lining by reriveting.
	4. Drums not square or distorted.	4. Turn or grind or replace drums.
	5. Incorrect lining.	5. Replace lining per factory specs.
	6. Shoes scraping on backing plate ledges.	6. Lube ledges. Replace with new shoe and linings, if distorted.
	7. Weak or broken hold down springs.	7. Replace defective parts.
	8. Loose wheel bearings.	8. Tighten to proper setting.
	9. Loose backing plate, anchor, drum wheel cylinder.	9. Tighten.
	10. Loose shoe links.	10. Tighten.
	11. Linings located wrong on shoes.	11. Install linings correctly.
O. Brakes chatter.	1. Incorrrect lining to drum clearance.	1. Readjust to recommended clearances.
	2. Loose backing plate.	2. Tighten securely.
	3. Grease, fluid, road dust on lining.	3. Clean or reline.
	4. Weak or broken retractor spring.	4. Replace.
	5. Loose wheel bearing.	5. Readjust.
	6. Drums out of round.	6. Grind or turn drums in pairs.
	7. Distorted shoes.	7. Replace shoes.
P. Grinding noise.	1. Shoe hits drum.	1. Switch drums or grind drums.
	2. Foreign material in lining.	2. Remove or replace lining.
	3. Rivets or shoe rubbing drum.	3. Reline. Refinish drums.
	4. Rough drum surface.	4. Refinish drums.

CAR PULLS TO ONE SIDE

Be sure all other parts related to the front end are in good working order before placing blame on the brakes. Loose anchor pins or backing plates, improper lining, wrong adjustment, broken return springs, drums out of round, defective wheel cylinder, a binding disc caliper piston, or a clogged or crimped hydraulic line can all cause a vehicle to pull to one side during braking.

SOFT PEDAL

The most common cause for a soft or spongy brake pedal will be air trapped in the hydraulic lines. This problem may also be caused by a brake drum being cut too thin when it is being resurfaced, and by weak or old flexible brake lines.

BRAKES TOO HARD TO APPLY

his problem may be the result of grease or brake fluid on the lining, pedal linkage binding, a faulty master cylinder, or glazed brake linings.

BRAKES TOO SENSITIVE

Incorrect brake adjustment or brake lines or brake lining fouled with grease or brake fluid maybe the cause of sensitive brakes.

BRAKE NOISE

Before you determine a noise to be coming from the brakes, eliminate all other possible sources, such as body noise, loose front-end parts, loose lug nuts, and so forth. Brake noise may be coming from shoes scraping the backing plate, and also, loose brake lining (riveted), loose anchor pins, loose or weak return springs, and loose backing plates can all cause some sort of brake noise.

BRAKE FLUID LOSS

Brake fluid loss is a serious problem caused by loose fittings, leaking wheel cylinders, master cylinder, brake lines, and hydraulic hoses.

BRAKES DO NOT SELF-ADJUST

The brake drum must be removed to check the self-adjust mechanism. Worn or frozen star wheels, broken or dislodged adjusting cable, or broken hold-down clips will all cause the self-adjuster to malfunction. See figure 6-6 for an illustration of an automatic adjuster components list.

BRAKE WARNING LAMP WILL NOT GO OUT

If the brake failure warning lamp comes on, it is a signal that one of the two hydraulic circuits has malfunctioned. Check the entire system and after you

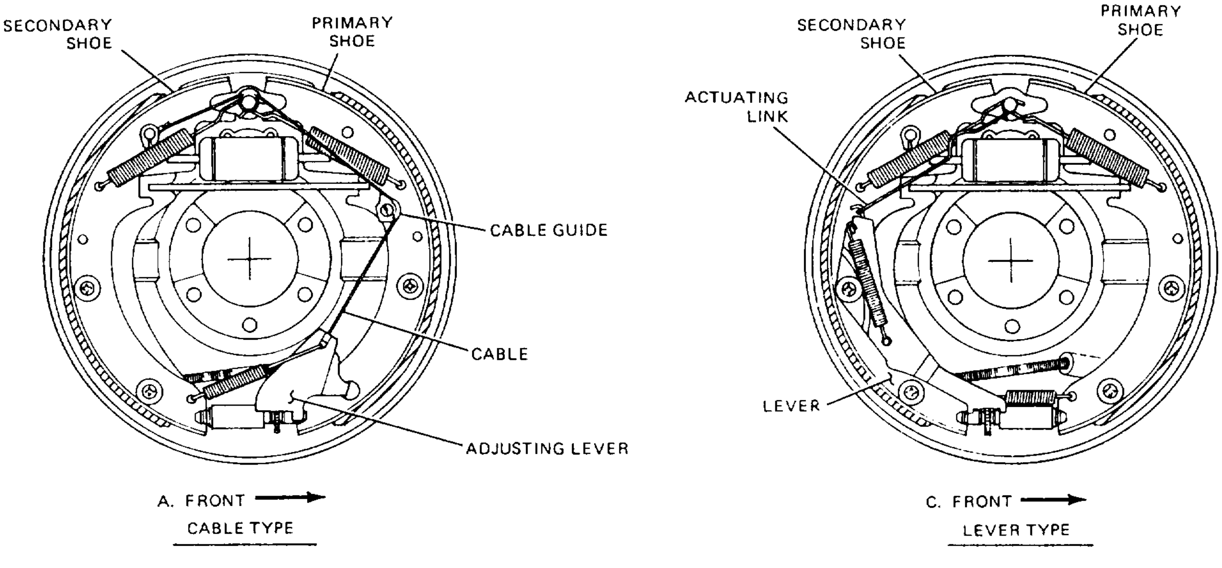


Figure 6-6.—Self-adjusting brake mechanisms.

make any repairs, reset the brake failure warning lamp switch (fig. 6-7).

See table 6-1 for a complete listing of possible brake problems and repairs.

TROUBLESHOOTING VACUUM-ASSISTED HYDRAULIC BRAKES (POWER) SYSTEMS

Aside from the vacuum booster, the same basic inspection procedures given in the hydraulic brake section apply to the vacuum-assisted hydraulic brake system. When you check this system for a source of trouble, refer to the chart for the standard hydraulic brake system (table 6-1). After you isolate possible causes by consulting this chart, check for causes in the troubleshooting chart of table 6-2.

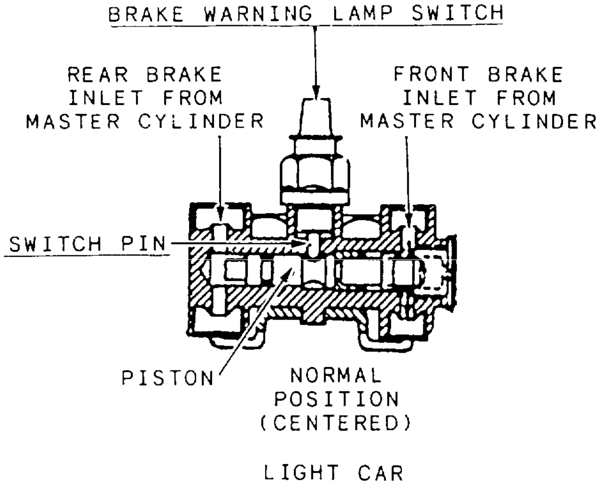


Figure 6-7.—Pressure differential valve with brake tamp warning switch.

NOTE

Conduct the following test BEFORE you check the cause of a hard pedal. With the engine stopped, depress the brake pedal several times to eliminate all vacuum from the system. Apply the brakes, and while holding the foot pressure on the brake pedal, start the engine. If the unit is operating correctly, the brake pedal will move forward when the engine vacuum power is added to the pedal pressure. If this test shows the power unit is not operating, check the probable causes of vacuum failure in table 6-2.

HARD PEDAL

A “hard pedal” means the booster is inoperative and you should suspect and check the following as the cause: collapsed vacuum hoses, faulty vacuum check valves, internal damage to the power booster, or a broken plunger stem.

GRABBY BRAKES

Uncontrolled stopping is a problem that may be caused by grabbing or oversensitive brakes. This symptom may result from a faulty power booster, a damaged vacuum check valve, leaky or incorrectly connected vacuum lines, or a broken plunger stem.

BRAKES FAIL TO RELEASE

When you apply the brakes and they fail to release, the following could be the problem–a broken power booster return spring, a sticking valve plunger in the booster, or a jammed power piston.

LOSS OF FLUID

Loss of brake fluid may occur through the rear seal of the master cylinder past the piston stop plate and into the power booster. The leak is not visible on the backing plates, the wheels, or the frame because the fluid collects in the power booster. Some of the fluid may be drawn through the vacuum lines and burned in the engine. The end result is that you do not see the leak. For a more complete listing of vacuum booster hydraulic brake problems and remedies, see table 6-2. Always consult the specific manufacturer’s manual whenever you replace or repair any vacuum power booster.

HYDROBOOST POWER BRAKE SYSTEMS

Diesel engines do not create enough useable vacuum to actuate the vacuum power brake booster. The alternative is a hydraulic-assisted power brake booster or hydrobcmst. This system is currently found in the 1 1/4-ton CUCV and the 3/4-ton CUCV Blazer, both powered by the 366 cubic inch V8 General Motors diesel engine. Both units are found throughout the NCF and at some public works stations. The hydroboost uses hydraulic pressure developed by the power steering

Table 6-2.—Troubleshooting Chart for Vacuum-Assisted Hydraulic Brakes (Power)

MALFUNCTION	PROBABLE CAUSE	POSSIBLE REMEDY
A. *Hard pedal.	1. Broken or damaged hydraulic brake lines.	1. Inspect and replace as necessary.
	2. Vacuum failure.	2. Check for: a. Faulty vacuum check valve or grommet–replace. b. Collapsed or damaged vacuum hose–replace. c. Plugged or loose vacuum fitting–repair. d. Faulty air valve seal or support place seal–replace. e. Damaged floating control valve–replace. f. Bad stud welds on front or rear housing of power head–replace unless easily repaired.
	3. Defective diaphragm.	3. Replace.
	4. Restricted air filter element.	4. Replace.
	5. Worn or badly distorted reaction disc. (tandem diaphragm).	5. Replace reaction disc.
	6. Cracked or broken power pistons or retainer.	6. Replace power pistons and piston rod retainer.
	7. Incorrect selective reaction piston (tandem diaphragm only).	7. Gauge reaction piston and replace with correct piston.
B. Grabby brakes. (Apparent off-and-on condition).	1. Broken or damaged hydraulic brake lines.	1. Inspect and replace as necessary.
	2. Insufficient fluid in master cylinder.	2. Fill reservoirs with approved brake fluid and check for leaks.
	3. Defective master cylinder seals.	3. Repair or replace as necessary.
	4. Cracking master cylinder casting.	4. Replace.
	5. Air in hydraulic system.	5. Bleed system.
C. Brakes fail to release.	1. Blocked passage in power piston.	1. Inspect and replace as necessary.
	2. Air valve sticking shut.	2. Check for proper lubrication of air valve O ring.
	3. Broken piston return spring.	3. Replace.
	4. Broken air valve spring.	4. Replace.
	5. Tight pedal linkage.	5. Repair or replace as necessary.

*Hard pedal is excessive pedal pressure required to apply the brakes.

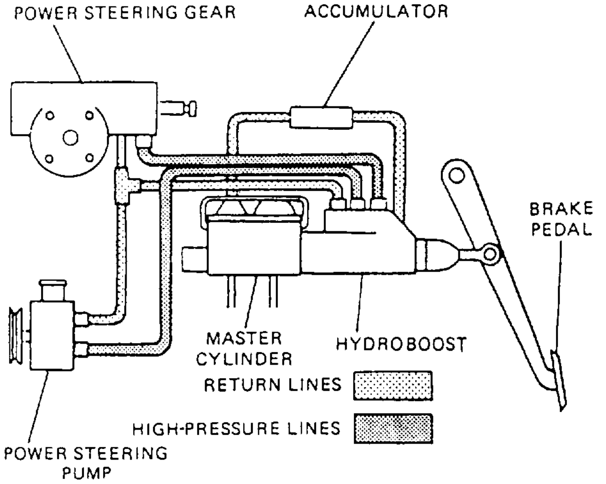


Figure 6-8.—Hydrauiic power booster system.

pump (fig. 6-8) rather than vacuum from the engine. The booster unit contains a spool valve that has an open center that controls the pump pressure as braking occurs. A lever assembly has control over the valve position and the boost piston provides the necessary force that operates the master cylinder. See figure 6-9 for a parts breakdown of the booster assembly.

In the event of hydraulic pressure loss, a spring-loaded accumulator is provided on the unit. This will provide for at least two power brake applications. The brakes will operate without the power assist unit, but the pedal pressure will be noticeably higher. AVOID DRIVING IN THIS CONDITION.

HYDROBOOST TROUBLESHOOTING

Hard Pedal (at an idle):

This problem may be caused by fluid contamination, pedal linkage binding, or a bad hydroboost unit.

High Pedal and Steering Effort:

A loose or broken power steering belt, low pump fluid level, low engine idle, a restriction in one or more hydraulic lines, or a defective power steering pump will cause these symptoms.

Slow Pedal Return:

Slow pedal return can be caused by pedal linkage binding, a restricted booster hydraulic line, or an internal problem with the hydroboost unit.

Pedal Pulsation:

Pedal chatter/pulsation is caused by a loose or slipping drive belt, low power steering fluid level, a defective power steering pump, or a defective hydroboost unit.

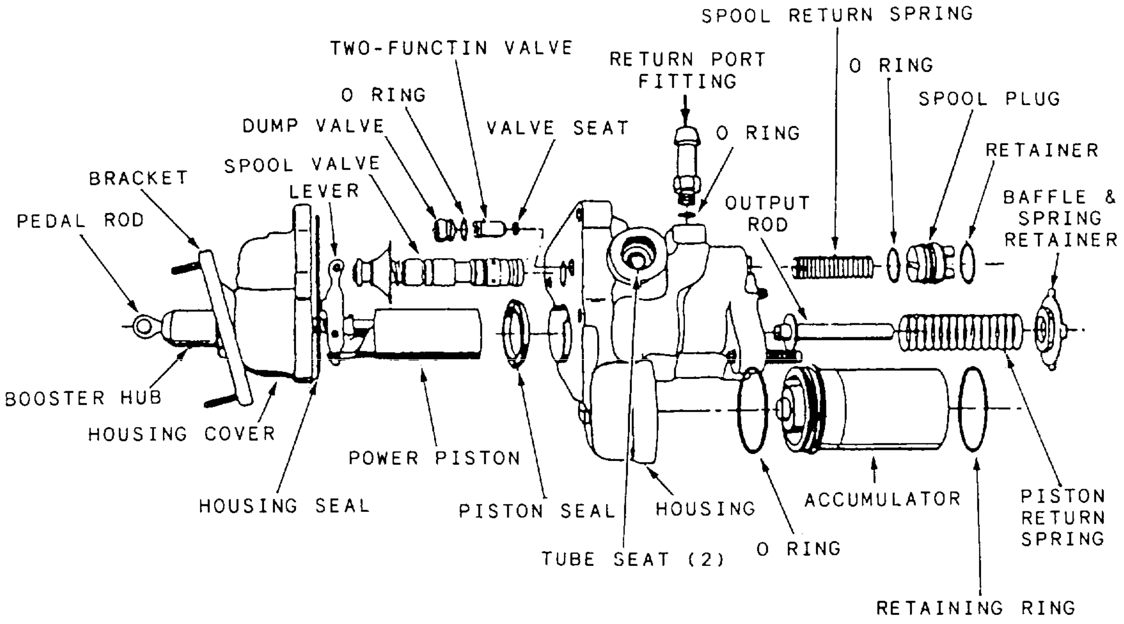


Figure 6-9.—Hydraulic power booster assembly.

Brakes Too Sensitive:

Pedal linkage binding or a defective hydroboost unit will cause this to happen.

Excessive Noise:

Excessive noise originating in the hydroboost unit is an indication of the following problems: low power steering fluid, air in the power steering fluid, a loose power steering belt, or a restriction in the hydraulic hoses.

WARNING

> The interchanging of parts between hydroboost units of different makes of CESE is not recommended. Tolerances of parts and pressure differentials may be different, causing a jerry-rigged hydroboost unit to exceed the normal 1,400 psi accumulator pressure. INJURY TO PERSONNEL AND DAMAGE TO THE VEHICLE COULD BE THE RESULT. PROTECT YOURSELF. USE THE MANUFACTURER’S SPECIFICATIONS WHEN YOU WORK ON THESE UNITS.

The manufacturer recommends that this unit not be rebuilt or overhauled. If the problem is in the booster, replace the booster.

TROUBLESHOOTING AIR BRAKE SYSTEMS

The purpose of air braking systems (fig. 6-10) is to enable the operator to apply sufficient braking action to the wheels of larger and heavier trucks and construction equipment. Considerable force is available for braking since the operating pressure is as high as 110 pounds per square inch. More often, stopping distances will be much greater than those shown in figure 6-1, primarily because of the increased weight of the equipment and load. General information concerning air braking systems can be found in chapter 10 of the *Construction Mechanic 3&2,* NAVEDTRA 10644-G1 .

When you are troubleshooting, first make a visual inspection and check all the obvious things-open air drain cocks, off-track compressor belt, broken air lines, and so forth. Next, perform an air buildup test and an air leakage test.

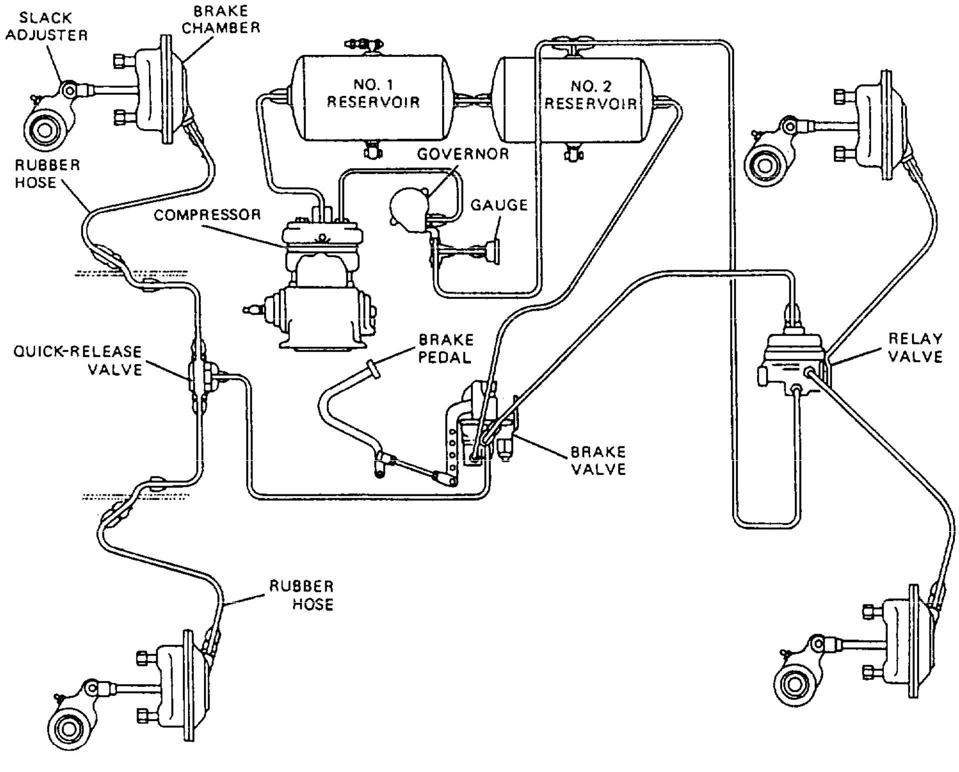


Figure 6-10.—typical air brake system.

Perform the air buildup test in the following sequence:

1. Before starting the engine, open the air drain cocks and release the air pressure from the system.

2. Close the air reservoir air drain cocks (fig. 6- 11).

3. Start the engine and watch the air pressure gauge to see how long it takes to build up to safe operating pressure. If it takes longer than 10 minutes to bring the air pressure from 0 to 60 psi, check the system for leaks, and check the air compressor and relief valves.

Conduct the air leakage test with the air brake system at normal operating pressure and the engine turned off. Hold the air brakes in the maximum applied position and watch the air pressure gauge on the dashboard of the vehicle. The air pressure should not drop more than 3 pounds in 1 minute after the brakes are applied and 2 pounds in 1 minute with the brakes released. If the indicated air pressure drops more rapidly than the times specified here, there is an air leak in the system. Trace the air lines to determine the exact source of the leak. Since air leaks normally make a distinct hissing sound, when you find the source of the noise and you have found the leak. Smaller leaks are not as audible and are harder to detect; however, you can detect these leaks by brushing the hose or tubing connections of the air brake system with a solution of soapy water. Air bubbles indicate a leak.

Air brakes on trailers get an external brake inspection as part of the inspetion required on a truck-trailer combination. They are also tested for holding as if the trailer were suddenly disconnected from the tractor. To conduct this test, first make sure the air lines between the tractor and trailer are coupled properly. Then, after you start the engine so both tractor and trailer air reservoirs are charged, quickly and simultaneously disconnect both air line couplings. The trailer or semitrailer brakes should be automatically applied. Trailer brakes are designed to stop the trailer when it is accidentally disconnected from the towing vehicle. All states require automatic application of trailer brakes in an emergency. Some states go even further for trailers having a chassis and body weight of 1,000 pounds or over; such trailers must be equipped with adequate brakes that will also hold the vehicle for at least 15 minutes after application.

If these inspections and tests do not disclose the fault, consult the troubleshooting chart of table 6-3.

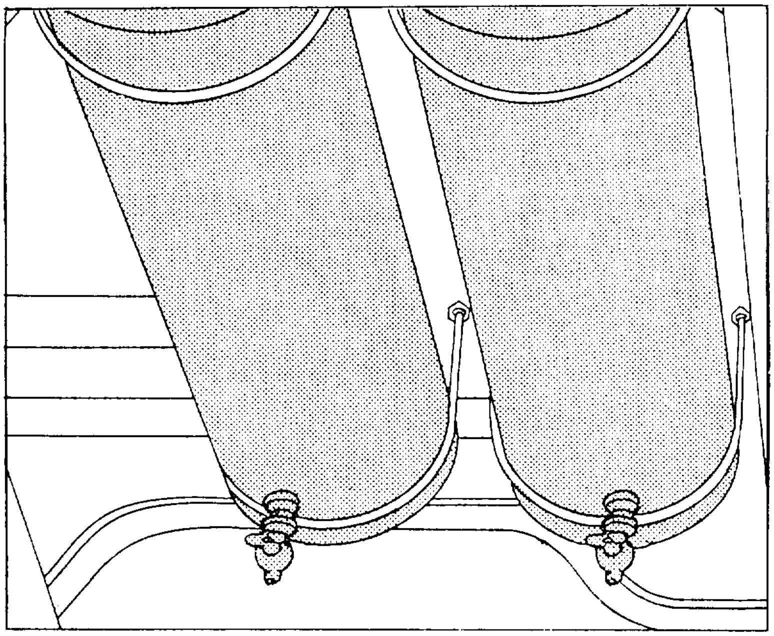


Figure 6-11.—Air reservoir with air drain cock.

Table 6-3.—Air Brake System Troubleshooting Chart

IMPROPER AIR PRESSURE

PROBABLE CAUSE	POSSIBLE REMEDY
Air pressure in system is above normal.	Check governor settings. Adjust air compressor unloading valves. Replace governor if necessary.
Air reservoir damaged.	Inspect air reservoir and replace if necessary.

CARRIER HAND BRAKE DOES NOT HOLD WHEN APPLIED

PROBABLE CAUSE	POSSIBLE REMEDY
Hand brake linkage out of adjustment.	Adjust linkage.

CARRIER HAS NO BRAKE ACTION, INSUFFICIENT ACTION OR BRAKES APPLY SLOWLY

PROBABLE CAUSE	POSSIBLE REMEDY
Improper brake shoe adjustment.	Adjust brake shoes.
Blocked, bent, or broken tubing or hose.	Remove obstruction in line or replace faulty tubing.
Brake valve delivery pressure below normal.	If brake valve is defective, replace unit.
No air pressure.	Replace or repair air compressor.

BRAKES RELEASE TOO SLOWLY WITH PEDAL RELEASED

PROBABLE CAUSE	POSSIBLE REMEDY
Insufficient brake shoe clearance.	Adjust brake shoes if clearance is insufficient.
Weak or broken valve diaphragm return spring.	Replace brake valve.
Defective quick-release valve.	Replace quick-release valve.

ONE BRAKE DRAGS WITH PEDAL RELEASED

PROBABLE CAUSE	POSSIBLE REMEDY
Insufficient brake shoe clearance.	Adjust brake shoe clearance.
Blocked or defective quick-release valve.	Clean or replace faulty unit.
Weak or broken brake shoe return spring.	Replace faulty spring.
Brake shoe binds on anchor pin.	Remove shoe; clean and lubricate anchor pins.

BRAKES GRAB WHEN PEDAL IS DEPRESSED

PROBABLE CAUSE	POSSIBLE REMEDY
Brake shoe clearance too great.	Adjust clearance.
Grease or oil on linings.	Clean linings or replace brake shoes or linings.
Drums out-of-round.	Replace drum.
Defective brake valve.	Replace faulty unit.
Brakes need relining.	Replace brake shoes.
Brake chamber diaphragm leaks.	Tighten all fittings. If caused by broken or faulty unit, replace brake chamber.

AIR-OVER-HYDRAULIC

On vehicles equipped with air-over-hydraulic brakes (fig. 6-12), do a good visual inspection of the air compressor, the air reservoir, the air lines, the brake pedal and linkage, the wheel brakes, the master cylinder, and the hydraulic line from the master cylinder to the air-hydraulic-power cylinder and from the air-hydraulic power cylinder to the wheel brakes.

Operating troubles resulting from malfunction of the air-over-hydraulic power cylinder are hard pedal (excessive pedal pressure required to apply the brakes) and dragging brakes (power cylinder fails to return to released position when the brake pedal is released).

To test a sluggish or inoperative power cylinder, first install an air pressure gauge in the control valve housing and a hydraulic gauge at both the hydraulic fluid inlet line and the hydraulic brake line output port. Then slowly depress the brake pedal and observe the gauges. When the air control pressure gauge shows between 1 and 5 psi, the hydraulic pressure at the hydraulic inlet should not exceed 40 psi. Excessive hydraulic pressure indicates a sticking relay piston (caused by swollen or damaged piston scaling cups or a corroded or damaged relay piston sleeve) or sticking control valve poppets (caused by corrosion of the poppets, poppet seats, or damaged poppets).

With the brake pedal completely depressed in the fully applied position, the air control pressure gauge should show 90 psi and the hydraulic output pressure gauge should show full power (runout) pressure of 1,400 to 1,600 psi. Low pressure or no pressure on the air pressure gauge indicates air leakage or an inoperative control valve. Low hydraulic output pressure indicates hydraulic fluid leakage, a sticking hydraulic piston, or an inoperative check valve (in the hydraulic piston), or a residual line check valve.

To test for internal and external air leakage or hydraulic leakage, fast depress the brake pedal and apply soapsuds at the air control line and its connections, the double check valve (if so equipped), and the cylinder body and end plate. Bubbles appearing at any of these points indicate external air leaks. While the pedal is depressed, check for hydraulic fluid leakage at the outlet fitting cap and around the jam nut on the slave cylinder housing. Internal air leakage is indicated by a pressure drop in excess of 2 psi in 15 seconds. The trouble is a worn or damaged piston packing, a scored cylinder body, or leakage at the poppets in the control valve. Internal hydraulic pressure leakage can also be indicated by hydraulic pressure drop at both hydraulic pressure gauges while the brake pedal is depressed.

Dragging brakes can be tested by releasing the brake pedal and observing the air pressure gauge and the two

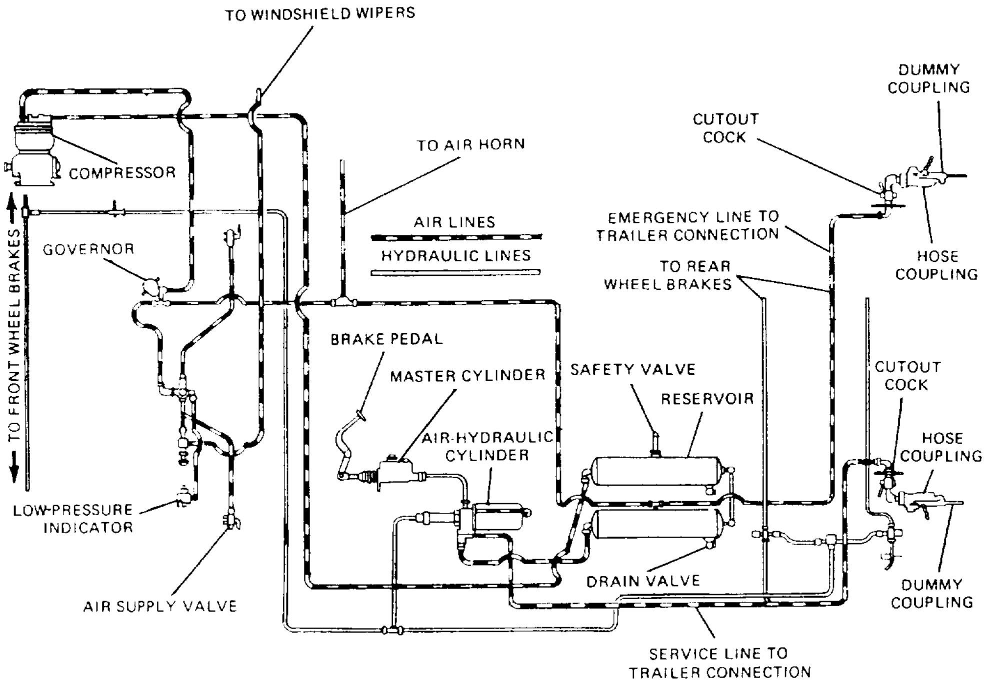


Figure 6-12.—Air-over-hydraulic brake system.

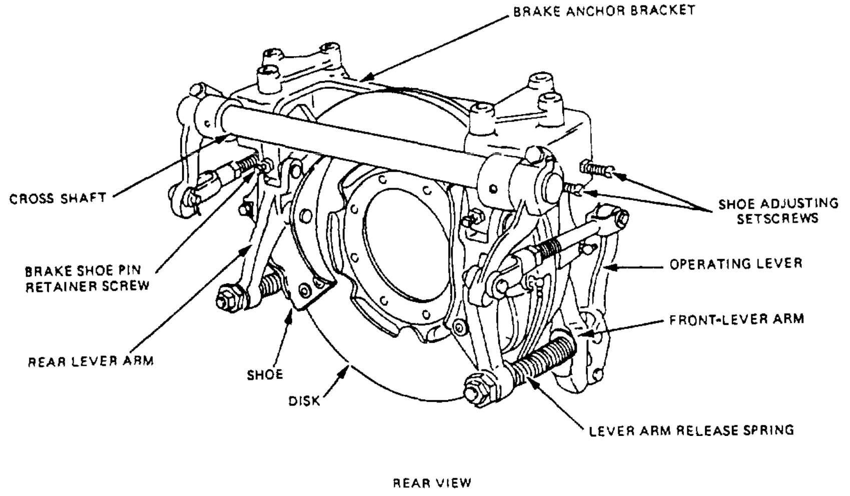
hydraulic pressure gauges. All gauges should register zero without lagging. When pressure is noted at the air pressure gauge, a sticking relay piston, damaged or corroded control valve poppet, or a ruptured control valve diaphragm exists. Pressure at the hydraulic pressure gauges indicates a sticking hydraulic piston, a sticking power piston, or a weak or broken piston return spring. If the hydraulic pressure gauges show a slow pressure drop, it indicates a defective check valve (in the hydraulic piston) or a defective residual line check valve.

If the tests indicate external air leakage, tighten the control line connections, and or replace a damaged control line, control line gasket, or double check the valve. For internal air leakage you must remove the unit to replace worn or damaged power piston packing or end plate gasket, and repair or replace the cylinder body or end plate.

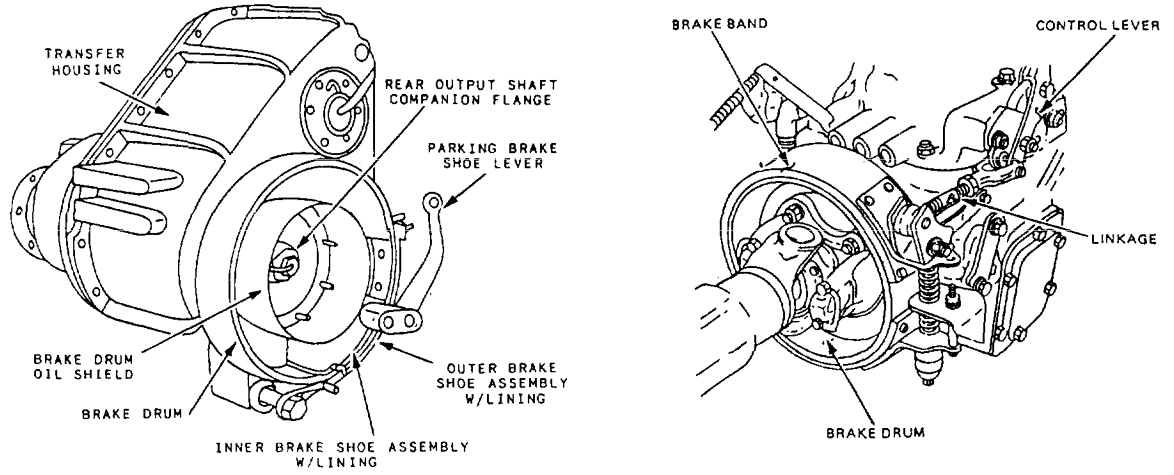
If the tests indicate hydraulic fluid leakage, an inoperative control valve, sticking power piston, relay piston, or hydraulic piston, remove the unit for disassembly and repair or replace the worn or damaged parts.

PARKING/EMERGENCY BRAKES

Serviceable parking/emergency brakes are essential to the safe operation of any piece of automotive or construction equipment. Several types of these brakes are manufactured, such as the external contraction, drum, and disk types (fig. 6-13). These are drive line brakes common to heavy construction equipment. These



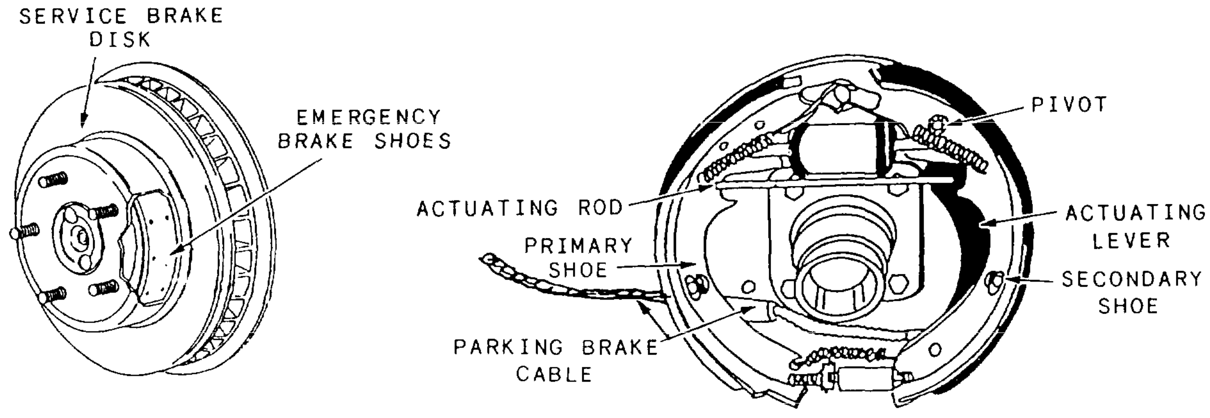
DISK TRANSMISSION BRAKE



DRUM TYPE TRANSMISSION BRAKE

CONTRACTING TRANSMISSION BRAKE

Figure 6-13.—Examples of drive line emergency/parking brakes, transmission mounted.



DISK TYPE DRUM TYPE

Figure 6-14.—Automotive type emergency/parking brake axle mounted.

are usually mounted on the output shaft of the transmission or transfer case directly in the drive line. Theoretically, this type of system is preferred for heavy equipment because the braking force is multiplied through the drive line by the final drive ratio and the braking action is equalized perfectly through the differential. Drawbacks are that severe strain is placed on the power transmission system, and also that the vehicle may move while it is being lifted since the differential is not locked out.

Parking brakes interconnected with service brakes are usually found on automotive types of equipment (fig. 6-14). This type of emergency/parking brake is actuated by a foot pedal or a dash mounted handle assembly and is connected through linkage to an equalizer lever (fig. 6-15), rod assembly, and cables connected to the emergency/parking brake mechanism within the drums/discs (fig. 6-14) at the rear wheels.

When you test parking brakes, stop the vehicle on a road graded at about 30 percent. Set the parking brake and release the service brakes. The vehicle should maintain its position and not roll or inch backwards. Repeat the test in the opposite direction. Again, the vehicle should hold its position. If there is no hill close by, you may test parking brakes by setting the brake, placing the vehicle in first gear (low), and slowly releasing the clutch with the engine idling (do not rev the engine while doing this exercise). This action should stall the engine of the vehicle you are testing. In the case of an automatic transmission, the vehicle should not move in any gear. In either of these tests, if the vehicle does move, it is an indication that there is a parking brake malfunction.

Once you determine there is a problem, proceed as follows. First, inspect the condition of the emergency brake linings and contact surfaces just as you would for service brakes and just as carefully. Pay attention to the ratchet and paw] or any other automatic locking device that holds the brake in the applied position to make sure it is operating properly. In addition, when inspecting the drive line type brake, examine the universal joints and splines for loose bolts and grease leaks. Loose bolts are not uncommon for vehicles having brakes mounted in the drive line.

The emergency brake must hold the vehicle on any grade. This requirement covers both passenger and commercial motor vehicles equipped with either the enclosed type of emergency brake at each rear wheel or a single emergency brake mounted on the drive line. The

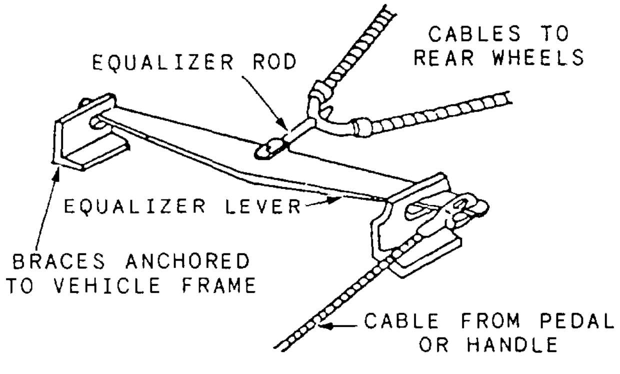


Figure 6-15.—Equalizer linkage.

Federal Motor Carrier Safety Regulations Pocketbook, par. 393-52, lists emergency brake requirements.

ANTILOCK BRAKES

The first antilock brake systems (ABSs) were developed and used in aircraft in the early 1950s. Certain automobiles had the systems in the experimental stages in the mid 1950s and in the production stages in the early 1970s. The ABSs are common today in many production cars and trucks.

Why wc use ABS is simple, CONTROL. A high percentage of vehicle accidents on the highway are caused by skidding. Since braking is most effective and steering is not lost when the wheels are still rotating, the antilock brake system prevents skidding by allowing the wheels to continue turning during maximum braking effort. On wet pavement, hydroplaning of the tires is cut to a minimum. One final benefit is that of extended tire wear by the elimination of flat spots caused by brake lockup during panic stops.

All ABS (either two wheel or four wheel) operate on the same principle. That is, the system is monitored by an electronic control module for the rate of reduction of vehicle wheel speed during brake system operation. If the system feels that lockup is about to occur at one or more wheels, modulated hydraulic pressure is fed to that brake caliper by a hydraulic control unit or an electro-hydraulic valve. In this way, even if hydraulic pressure is not the same at each wheel, maximum tire adhesion to the road surface is maintained. Once again, the way the modulated hydraulic pressure is maintained is different with each manufacturer. Before going any further, get a copy of the manufacturer's maintenance and repair manual of the vehicle that you are working on.

While these systems are not yet common in the Naval Construction Force, the first equipment you arc most likely to see the system used on is automotive type CESE. Very little should malfunction on the system. If the ABS is in need of repair, you should take the following precautions before working on it:

1. Repressurize the system before attempting to make repairs.
2. Do not work on an antilock brake system with the ignition turned on. (Damage to the system computer can result.)
3. Do not substitute parts. Use parts that are approved for the system you are working on.
4. Keep the correct size tires on your vehicle. Mismatched tire sizes will give the computer false readings.
5. Check the speed sensors for cleanliness. A dirty speed sensor will give the computer a false, or zero reading.
6. Wheel lugs must be torqued to the correct foot pounds and in proper sequence. Your failure to do so may distort the wheel and sensor, thus sending incorrect readings to the antilockbrake system computer.
7. An incorrect air gap on the wheel sensors will lead to false input to the antilock brake system computer.
8. DO NOT USE SILICONE BRAKE FLUID in a vehicle equipped with an antilock brake system.
9. If electric arc welding must be done to the vehicle you are working on, disconnect the antilock brake system computer first.
10. A low battery caused by a faulty charging system will cause the antilock brake system to malfunction.
11. Antennas for transmitting type radios should not be located near the computer of antilock brake system.

CAUTION

Using an improper test method on these systems can lead to damage to the system or personal injury to yourself or to the personnel working for you.

CAUTION

All antilock brake systems have special system bleeding instructions. Your failure to follow these instructions will lead to an inoperative or a faulty system.

For further reading concerning antilock braking systems, consult your manufacturer's service and repair manual of the vehicle you are working on.

ASSIGNMENT 6

Textbook Assignment: “Fuel System Overhaul,” and “Inspecting and Troubleshooting Brake Systems,” pages 5-27 through 6-18.

6-1. When you are rebuilding a PT type of fuel pump, parts should be discarded at what time?

1. When they show minor wear
2. Only after they break
3. When they are worn beyond replacement limits
4. At each overhaul

6-2. To prevent goring of the PT fuel pump and pump parts in reassembly, the mechanic should use which of the following means?

1. Spring steel lock washers
2. Flat steel washers
3. Extreme pressure lubricant
4. Torque wrench

6-3. When a PT pump has been rebuilt, it should be run at 1,500 rpm for how long to allow the bearings to seat?

1. 2 minutes
2. 5 minutes
3. 10 minutes
4. 1 hour

6-4. While being tested, a PT fuel pump fails to develop specified manifold pressure. Which of the following conditions could contribute to the failure?

1. An air leak in the suction line
2. A closed valve in suction line
3. A fuel oil temperature higher than 100°F
4. Each of the above

6-5. You are trying to find maximum manifold pressure at full throttle of a newly rebuilt PT fuel pump. With the pump running at 1,500 rpm, you should take which of the following actions?

1. Turn the rear throttle stop screw
2. Turn the shims under the idle spring
3. Turn the idle spring to new position
4. Turn the idle speed screw until the idle spring is compressed

6-6. After setting the PT fuel pump idle speed, the mechanic can change its idle pressure by taking which of the following actions?

1. Adding or removing shims from the idle spring
2. Turning the idle speed screw
3. Turning the throttle screws
4. Locking the throttle in the shutoff position

6-7. The amount of fuel a PT injector delivers to the combustion chamber will be affected by changes in which of the following areas?

1. The fuel pressure
2. The size or shape of injector orifices
3. Timing
4. Each of the above

66-8. When servicing a PT fuel injector, you should NOT take which of the following actions?

1. Plug the inlet and drain connection holes of the injector before mounting on the test stand
2. Clean injector orifices with wire
3. Dip a solvent-cleaned injector into mineral spirits
4. Insert a new gasket between the cup and body of the injector during assembly

6-9. When the fuel is flowing upward through the cup spray holes, the maximum pressure applied to check plunger clearance should not exceed what maximum amount?

1. 500 psi
2. 1,000 psi
3. 1,500 psi
4. 2,000 psi

6-10. In a PT type of fuel injector, the plunger and cup is not lapped for what reason?

1. It disturbs the fuel metering
2. It will cause the injector to clog
3. It will ruin the plunger bore
4. It will cause the cup to cock to one side

6-11. Superchargers and turbochargers pump a greater amount of air into an engine than could be supplied by normal atmospheric pressure. What is the effect on fuel consumption and power?

1. More fuel is burned; power is decreased
2. Less fuel is burned; power is decreased
3. More fuel is burned; power is increased
4. Less fuel is burned; power is increased

6-12. Before a blower-equipped air induction system can be inspected, what component, if any, must be removed?

1. The air inlet housing or air silencer
2. The flywheel housing
3. The freshwater pump
4. None

6-13. The rotors of a blower are burred but not badly scored. If the burrs interfere with operation of the blower, the mechanic should take which of the following actions?

1. Dress down the rotors after removing the blower from the engine
2. Dress down the rotors without removing the blower from the engine
3. Remove the blower from the engine and replace the rotors

6-14. When a gearset of a General Motors diesel blower is removed, damage is avoided in what way?

1. By your removing the right gear first
2. By your removing the left gear first
3. By your removing both gears at the same time

6-15. After washing a blower ball bearing with cleaning solvent, the mechanic should clean the balls and races of the bearing by using which of the following procedures?

1. Spinning them dry with compressed air
2. Directing air through the bearing and rotating it by hand
3. Wiping them with a clean cloth

IN ANSWERING QUESTIONS 6-16 THROUGH 6-19, SELECT FROM COLUMN B THE CAUSE OF THE BLOWER CONDITION SHOWN IN COLUMN A. RESPONSES IN COLUMN B MAY BE USED ONCE, MORE THAN ONCE, OR NOT AT ALL.

A. CONDITIONS

6-16. Inside surface of the blower housing covered with oil

6-17. Rotor lobes rubbing throughout their entire length

6-18. Liquid on air box floor

6-19. Scoring between rotors and blower housing

B. CAUSES

1. Plugged drain tube
2. Loose rotor shafts or damaged bearings
3. Leaking seal
4. Excessive backlash in blower timing gears

6-20. If worn or damaged, which of the following blower parts must be replaced as a matched set?

1. Oil seals
2. Double-row bearing
3. Timing gears
4. End plates

6-21. The mechanic should replace blower parts that an inspection shows to be worn or excessively damaged.

1. True
2. False

6-22. Supercharger seals must be changed in which of the following situations?

1. When wet oil appears at the ends of the rotors
2. When wet oil appears at the ends of the supercharger outlet connectors
3. When oil from the vapor tube shows on the rotors
4. At any time oil appears inside the supercharger housing

6-23. When the rotors, rotor shafts, and end plates of a supercharger are cracked and broken, the mechanic should take which of the following actions?

1. Discard the supercharger and replace it with a new one
2. Replace only the rotors and shafts; repair the end plates
3. Replace the damaged parts separately except for the rotors and shafts, which are replaced as a matched set

6-24. The drive coupling of the supercharger should be replaced under which of the following conditions?

1. The coupling pins are worn
2. The hub surface is grooved
3. The rotors and gears are not within the required tolerances

6-25. When, if ever, should engine lubricating oil be added to the gear end plate of a supercharger that is being reconditioned?

1. After it is completely reassembled, but before it is installed on the engine
2. After it is completely reassembled and installed on the engine
3. As it is being reassembled
4. Never

6-26. The overheating of the thrust and journal bearings of a supercharger can result from which of the following causes?

1. Foreign particles in the exhaust system
2. Lack of lubricating oil
3. Foreign matter in the air induction system
4. Each of the above

6-27. When oil contamination has caused damage to a turbocharger, where should you look for the cause?

1. A clogged oil filter
2. An open turbocharger lubrication valve
3. A malfunctioning filter bypass valve
4. Each of the above

6-28. The turbine and compressor wheels on a turbocharger may rotate at up to what speeds in mph?

1. 75
2. 100
3. 150
4. 200

6-29. To remove carbon deposits that remain on turbocharger parts after they have soaked in mineral spirits, a mechanic should use which of the following methods?

1. Steam
2. Wire brush
3. Soft bristle brush
4. Compressed air

6-30. If damaged, the replacement of the main turbocharger main casing may be required for which of the following parts?

1. The exhaust casing
2. The turbine casing
3. The floating bearing

6-31. The oil seal plates of a turbocharger are replaced often since they wear out fast.

1. True
2. False

6-32. The rotor assembly of a turbocharger must be rebalanced when which of the following parts are replaced?

1. The turbine wheel and shaft
2. The sleeve and compressor wheel
3. The thrust washer and locknut
4. All of the above

6-33. When mounting the turbocharger, the mechanic can make sure it is in the proper operating position on the engine by following which of the following procedures?

1. Locating the air inlet to the right of the turbocharger vertical center line
2. Locating the air inlet to the left on the turbocharger vertical center line
3. Locating the oil outlet 45° or more below the turbocharger horizontal center line
4. Locating the oil outlet 45° or more above the turbocharger horizontal center line

6-34. Engines are hard to start in cold weather for which of the following reasons?

1. Reduced fuel flow
2. Low fuel volatility
3. High fuel volatility

6-35. In a gasoline fuel injected engine, extra fuel for cold weather starting is introduced by which of the following devices?

1. The fuel injector
2. The air heated choke
3. The electric choke
4. The thermistor

6-36. In the actuation of the choke device, the electronic control module provides what type of voltage to the thermistor?

1. A high-voltage impulse
2. A low-voltage signal
3. A high-voltage signal

6-37. Some diesel engines have a glow plug that is turned on by the ignition switch. The glow plug is turned off by what means?

1. By the ignition switch
2. By your releasing the glow plug switch
3. By a timed relay

6-38. In a manifold flame heating system, two solenoids ensure that fuel is delivered at which of the following times?

1. Only when the system is operating
2. Before the engine turns over
3. Just before and just after the heater is activated

6-39. When may ether be used as a diesel engine cold starting aid?

1. In extreme cold weather only
2. In extreme emergencies only
3. At any time

6-40. Braking systems are usually inspected yearly after what maximum number of miles?

1. 6,000
2. 8,000
3. 12,000
4. 15,000

6-41. In the field, you discover a brake problem on a vehicle. What should you do with the vehicle?

1. Drive it to the CM shop
2. Drive it to the dispatch yard
3. Tow it to the CM shop
4. Tow it to the deadline

6-42. Under what circumstances would copper tubing be used in a brake system?

1. Under no circumstance
2. For use on augment equipment only
3. For use on construction equipment only
4. For use on equipment without power brakes

6-43. When testing for leakage in a hydraulic brake system, you must depress and hold the brake pedal for at least how long?

1. 1 minute
2. 2 minutes
3. 4 minutes
4. 5 minutes

6-44. CESO maintenance bulletin #75 directs the Naval Construction Force to use which of the following fluids or materials?

1. Glycol brake fluid
2. Silicone brake fluid
3. Non-asbestos brake pads

6-45. Brake drums that have been worn or machined past their discard diameter or thickness must not be used.

1. True
2. False

6-46. Which of the following conditions could indicate brake problems where none, in fact, exist?

1. Loose wheel bearings
2. Worn front end parts
3. Low tire pressure
4. All of the above

IN ANSWERING QUESTIONS 6-47 THROUGH 6-51, REFER TO FIGURE 6-1 IN YOUR TRAMAN.

6-47. Excessive clearance between the linings and drums would be indicated by which of the following conditions?

1. A low pedal
2. A high pedal
3. A soft pedal
4. A hard pedal

6-48. A springy brake pedal could be an indication of which of the following problems?

1. Grease on the brake lining
2. Air trapped in the system
3. A plugged master cylinder fill cap
4. Each of the above

6-49. A pulsating brake pedal could be caused by which of the following problems?

1. Drums out of round
2. A bent rear axle
3. Loose wheel bearings
4. All of the above

6-50. The locking up of a single wheel when you are braking could result from which of the following causes?

1. Worn and slick tire tread
2. A defective master cylinder
3. Air trapped in the hydraulic system
4. Improper brake fluid

6-51. Which of the following problems could cause brake squeak?

1. Dirty brakes
2. Scored drums
3. Loose lining rivets, or lining not held tightly against the shoe
4. Out-of-round drums

6-52. Which of the following statements provides a good description of pedal reserve?

1. The full travel of the brake pedal
2. 1/4 travel of the brake pedal
3. 1/2 travel of the brake pedal
4. The distance from the pedal to the floorboard with the brakes applied

6-53. Both rear brakes may drag as a result of which of the following problems?

1. A frozen emergency brake cable
2. An over-full master cylinder
3. A jammed wheel cylinder

6-54. A brake drum that is cut too thin will cause which of the following problems?

1. No brakes
2. A soft brake pedal
3. A pulsating brake pedal
4. A hard brake pedal

6-55. After completing repairs to a brake system, you should take which of the following actions first?

1. Close out the ERO
2. Road test the vehicle
3. Reset the brake failure warning light

6-56. On a power brake system with a vacuum booster, if the air valve sticks, what, if anything, will occur?

1. The brakes will fail to release
2. Slow braking application
3. The brakes will not function at all
4. Nothing

6-57. In a brake system that uses a vacuum booster, a hard pedal could indicate which of the following situations?

1. Normal brakes
2. Internal damage to the vacuum booster
3. Worn brake linings

6-58. In a brake system using a vacuum booster, a hydraulic leak may not be seen for which of the following reasons?

1. The brake fluid evaporates
2. The fluid is drawn into the intake manifold and burnt in the engine
3. The brake fluid collects in the power booster
4. Both 2 and 3 above

6-59. A standard power booster will not work with a diesel engine for which of the following reasons?

1. Not enough usable vacuum is created
2. Too high a vacuum is created
3. Low volume vacuum is created

6-60. On a vehicle using a hydroboost power brake system, hydraulic pressure is created by which of the following means?

1. A separate hydraulic pump
2. A power steering pump
3. A power boost cylinder

6-61. In the event of a hydroboost power brake system failure, the spring-loaded accumulator will provide for a total of how many power brake applications?

1. Five
2. Two
3. Three
4. Four

6-62. When the power steering belt breaks in a hydroboost power brake system, which of the following situations will occur?

1. There will be no braking action
2. A high pedal effort will be felt
3. A soft pedal effort will be felt
4. The pedal will travel to the floor

6-63. Excessive noise in a hydroboost power brake system could be caused by which of the following problems?

1. Air in the system
2. A loose fan belt
3. A loose power steering belt
4. Wrong fluid in the system

6-64. What is the normal accumulator pressure of a hydroboost power brake system?

1. 600 psi
2. 1,000 psi
3. 1,400 psi
4. 1,800 psi

6-65. The stopping distance of construction equipment and heavy trucks is greater due to which of the following factors?

1. Increased weight of the equipment
2. Increased payload weight
3. Increased length of the equipment
4. Both 1 and 2 above

6-66. An air brake system should build up to safe operating pressure in what maximum number of minutes?

1. 5
2. 7
3. 10
4. 12

6-67. When you are applying the brakes during an air leakage test, the air pressure should NOT drop more than (a) what number of pounds in (b) how many minutes?

1. (a) 1 (b) 1
2. (a) 2 (b) 2
3. (a) 3 (b) 1
4. (a) 5 (b) 5

6-68. You should check for air leaks that are not audible by using which of the following means?

1. Your hand
2. Soapy water and a brush while watching for bubbles
3. A light oil and a brush while watching for bubbles

6-69. The automatic application trailer brakes must hold a vehicle for what length of time?

1. 5 minutes
2. 10 minutes
3. 15 minutes
4. 20 minutes

6-70. In an air-over-hydraulic power braking cylinder, excessive hydraulic pressure would likely be caused by which of the following parts?

1. A damaged relay piston sleeve
2. Swollen piston sealing cups
3. A striking relay piston

6-71. In an air-over-hydraulic power braking cylinder, internal air leakage is considered excessive if there is a pressure drop of 2 psi in what number of seconds?

1. 10
2. 15
3. 20
4. 25

6-72. On construction equipment, the drive line brakes are usually mounted in which of the following locations?

1. A parking pawl located inside the transmission case
2. Directly on the drive line
3. On the wheel

6-73. When compared to an emergency braking system that is interconnected with the rear service brakes, a drive line emergency braking system has greater holding power for what reason?

1. Larger brake shoes
2. The braking force is multiplied through the final drive system
3. They use a disc brake system

6-74. A parking brake that is interconnected with the service brake is usually found on what type of equipment?

1. Construction
2. Automotive
3. MHE
4. Augment

6-75. Emergency brake requirements may be found in which of the following publications?

1. NAVFAC P-300
2. NAVFAC P-404
3. Federal Motor Carrier Safety Handbook
4. NAVFAC P-314

CHAPTER 7

CLUTCHES AND AUTOMATIC TRANSMISSIONS

This chapter provides information about the clutch and the automatic transmission to enable you to understand the operation of these units, to diagnose problems, and to prescribe corrective action. To obtain more detailed information on the operation and repair of specific units, refer to the specific manufacturer's maintenance and repair manual.

To make practical use of engine power, a coupling device, or clutch, is needed to connect and disconnect the engine from the drive line, as necessary. The clutch or torque converter provides for complete separation of power or at least slippage at an idle. The automatic transmission, like manual transmissions, matches load requirements of the vehicle to the power and speed of the engine.

CLUTCH SYSTEMS

It is important to briefly review the purpose of the clutch and also the various types of clutches. The clutch permits the operator to couple and uncouple the engine and transmission. When the clutch is in the coupling (or normal running) position, power flows through it from the engine to the transmission. If the transmission is in gear, power flows through to the vehicle wheels, so the vehicle moves. Essentially, the clutch enables the operator to uncouple the engine temporarily, so the gears can be shifted from one forward gear position to another or into reverse or neutral. The flow of power must be interrupted before the gears are shifted; otherwise, gear shifting is extremely difficult if not impossible.

The clutch assembly (fig. 7-1) contains a friction disk (fig. 7-2), or driven plate about a foot in diameter.

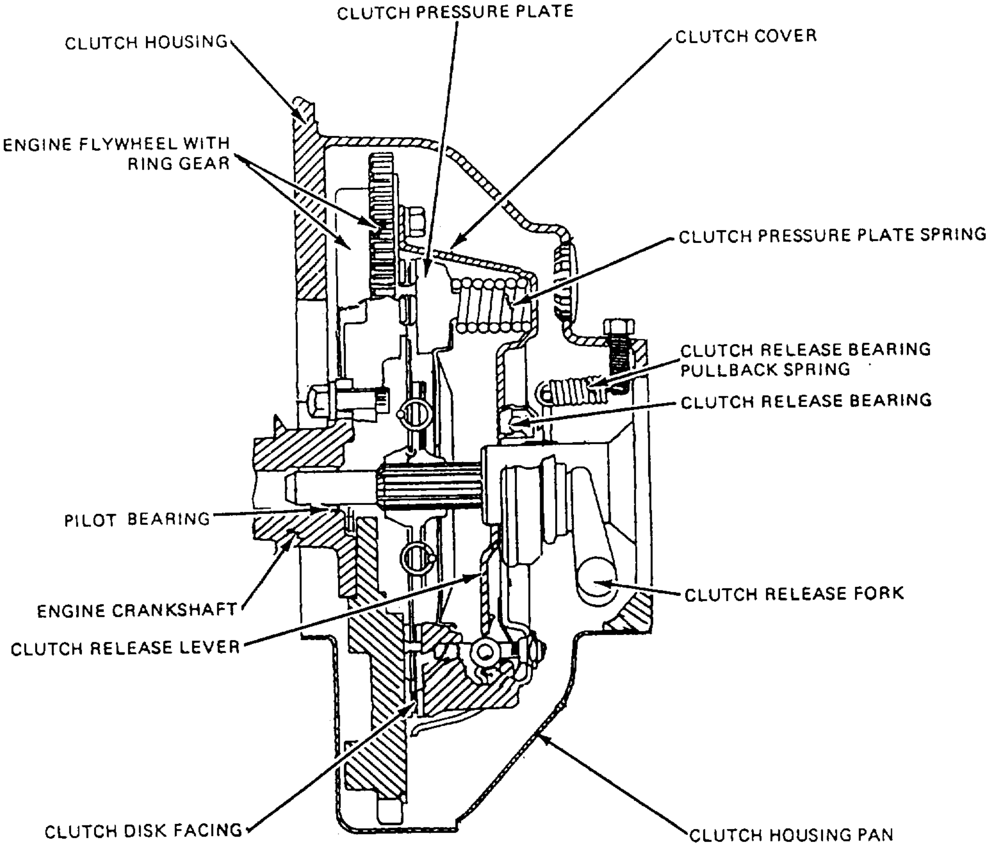


Figure 7-1.—Typical clutch assembly.

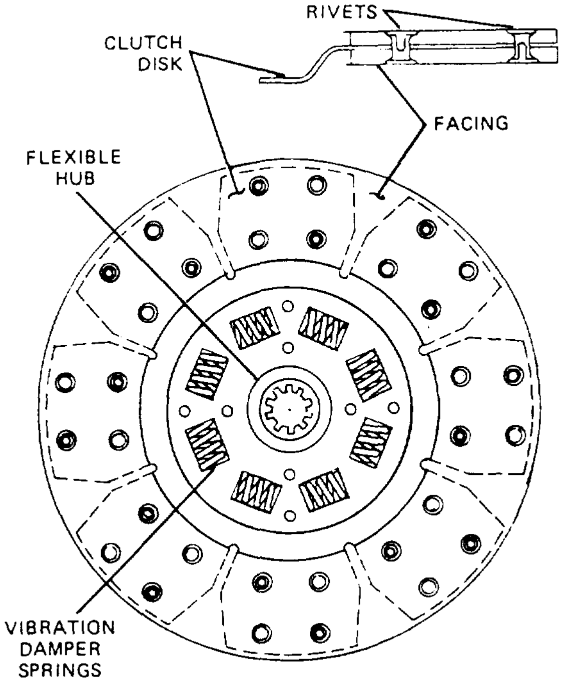


Figure 7-2.—Friction disk clutch with flexible center.

It also contains a spring arrangement and a pressure plate (fig. 7-3) for pressing the disk tightly against the face of the flywheel. The friction disk is splined to the clutch shaft. The splines consist of two sets of teeth: an internal set on the hub of the friction disk and a matching external set on the clutch shaft. They permit the friction disk to slide back and forth along the shaft but force the disk and the shaft to rotate together.

The flywheel, attached to the end of the engine crankshaft, rotates when the engine is running. When the clutch is engaged in the coupling position, the friction disk is held tightly against the flywheel by the pressure plate springs, so that it rotates with the flywheel. This rotary motion is carried through the friction disk and clutch shaft to the transmission.

To disengage (or uncouple) the clutch, the clutch operator presses the clutch pedal down. This causes the clutch fork to pivot so the clutch release bearing is forced inward. As the release bearing is moved inward, it operates the pressure plate release levers (fig. 7-4). The release levers take up the spring pressure and lift the pressure plate away from the friction disk. The friction disk is no longer pressed against the flywheel face, and the engine can run independently of the power train. Releasing the clutch pedal permits the clutch fork to disengage the release bearing, so the springs will again cause the pressure plate to force the friction disk against the flywheel face to rotate together.

There are two types of clutch operating systems: mechanical and hydraulic. The mechanical system is the most common and uses a rod type of linkage (fig. 7-5);

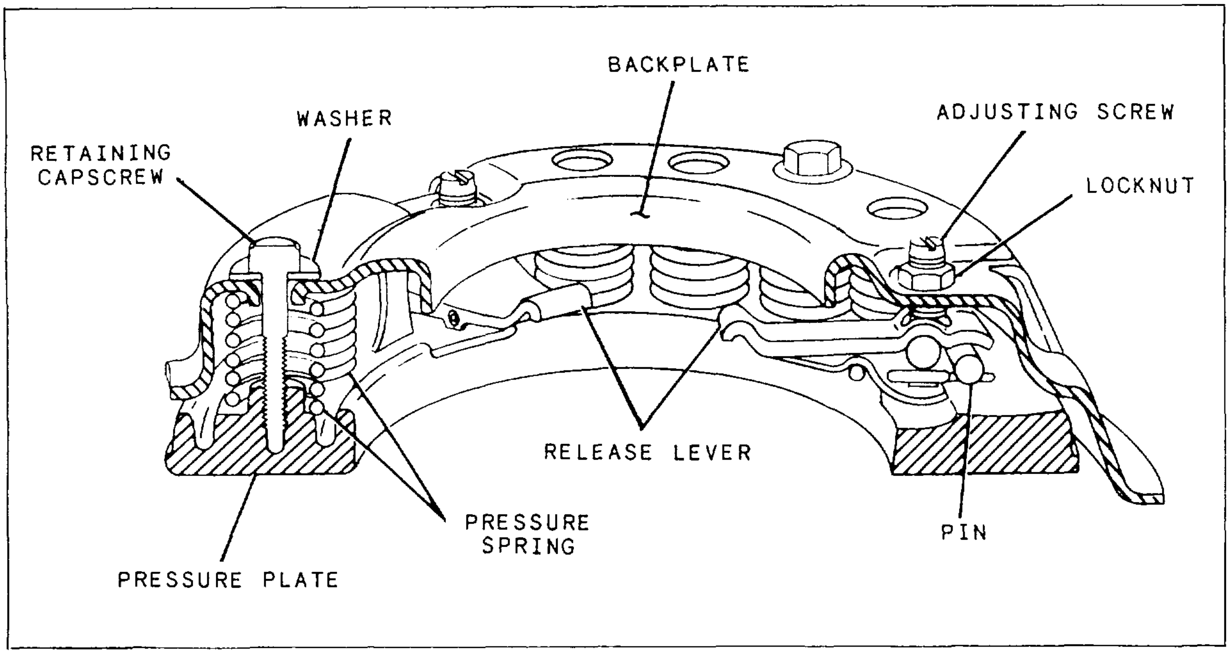


Figure 7-3.—Pressure plate and related parts.

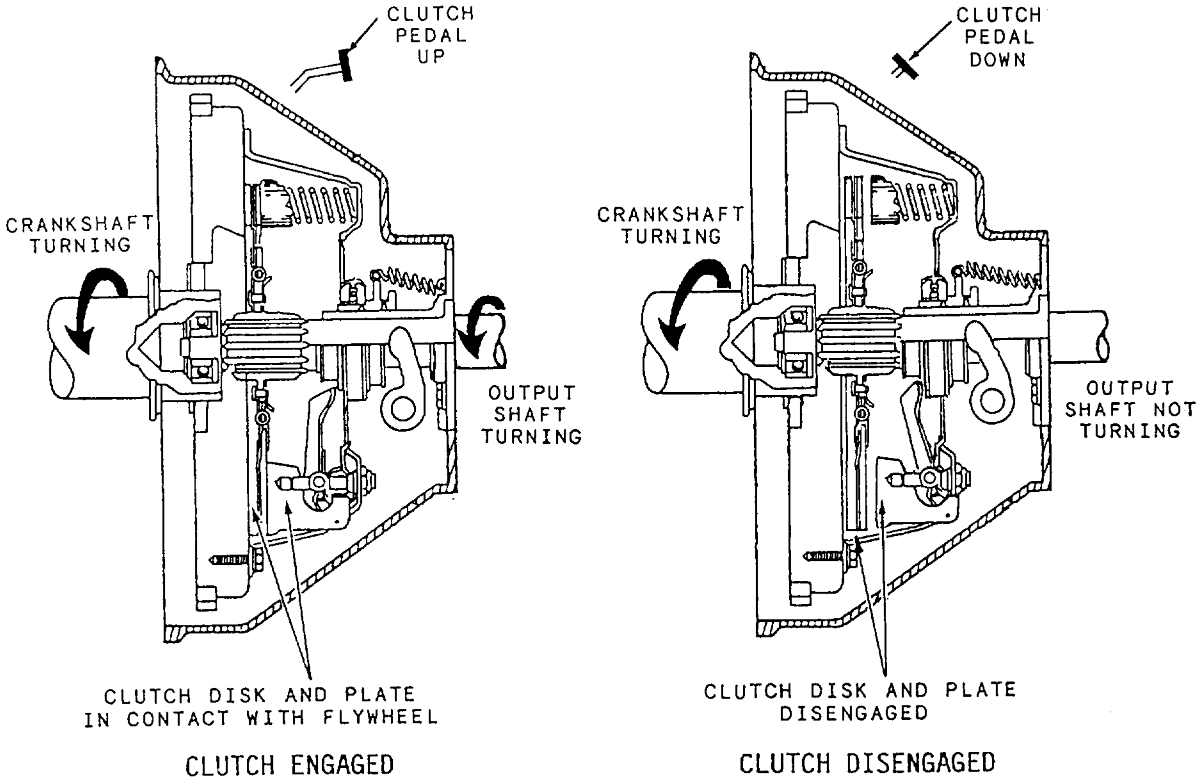


Figure 7-4.—Clutch operation.

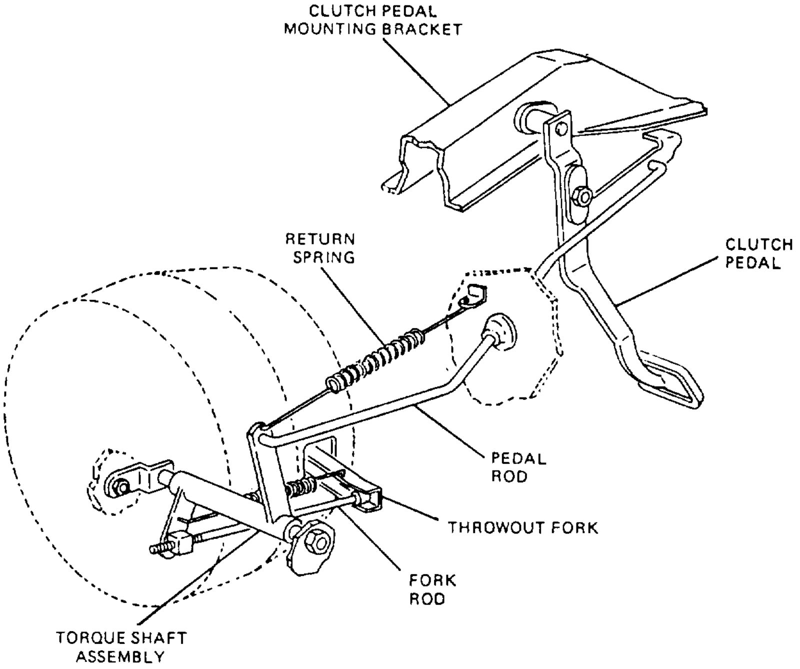


Figure7-5.—Mechanical clutch operating systems (rod type of linkage).

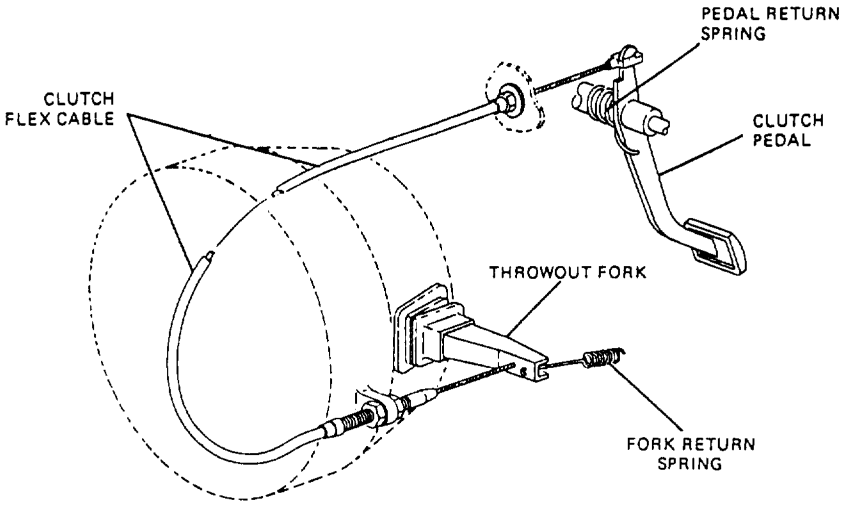


Figure 7-6.—Mechanical clutch operating systems (cable type of linkage).

other mechanical systems use a flexible type of cable (fig. 7-6). These systems are normally found in automotive applications. The hydraulic operating system (fig. 7-7) moves the release lever by hydraulic pressure. Depressing the clutch pedal creates pressure in the clutch master cylinder, actuating the slave cylinder which, in turn, moves the release arm and disengages the clutch. Hydraulic types of clutch operating systems are normally found in heavy construction equipment where extreme pressure is required to operate the clutch.

Most automotive and construction equipment clutches work on the same principle and are similar in

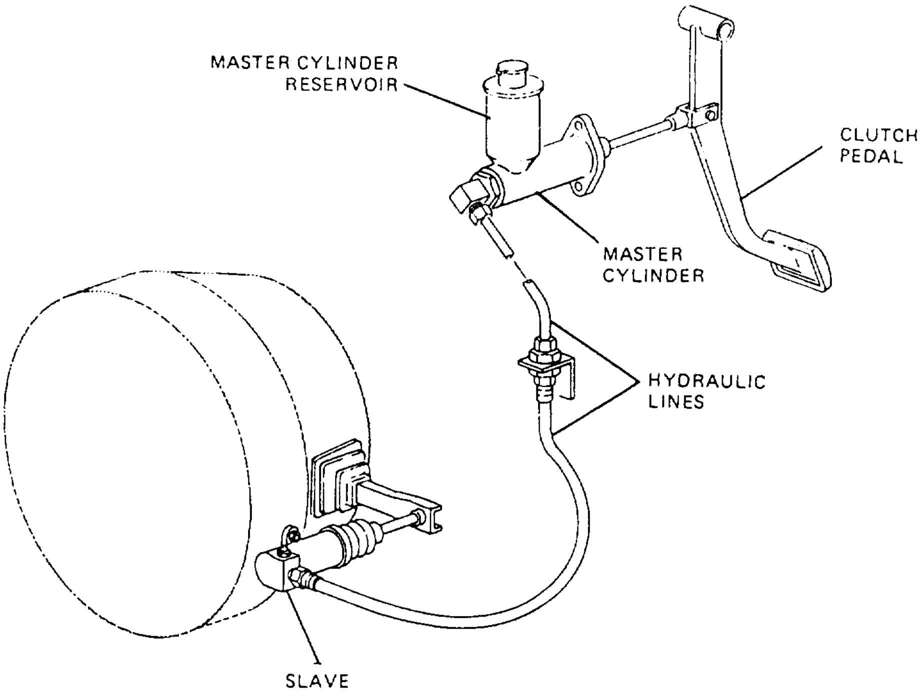


Figure 7-7.—Hydraulic clutch operating system.

construction. The differences are mainly in pressure plate assemblies, linkages, and overall size.

Of the different types of clutch assemblies, the one shown in figure 7-8 is known as the plate clutch. The plate clutch is a simple clutch with two plates and one disk, clamped between the two plates. Another type (fig. 7-9) is the double-disk clutch. The driving members of the single-disk clutch consist of the flywheel and driving (pressure) plate. The driven member consists of a single disk splined to the clutch shaft and faced on both sides with friction material. When the clutch is fully engaged, the driven disk is firmly clamped between the flywheel and the driving plate by the pressure of the pressure plate springs, and a direct, nonslipping connection between the driving and driven members of the clutch is formed. In this position, the driven disk rotates the clutch shaft to which it is splined. The clutch shaft is connected to the driving wheels through the power train.

The double-disk clutch is substantially the same as the single-disk clutch described in the section above, except that an additional driven disk and intermediate driving plate are added.

For more basic information concerning clutches refer to your Construction Mechanic 3&2 TRAMAN NAVEDTRA 10644-G1.

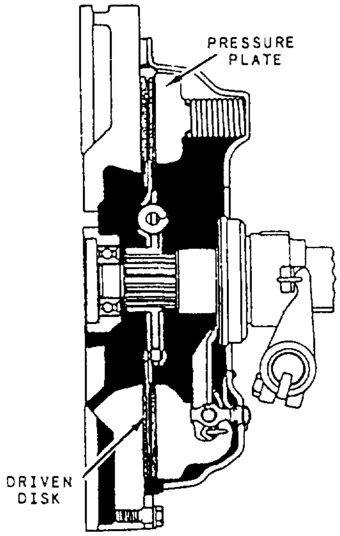


Figure 7-8.—Single-disk clutch assembly.

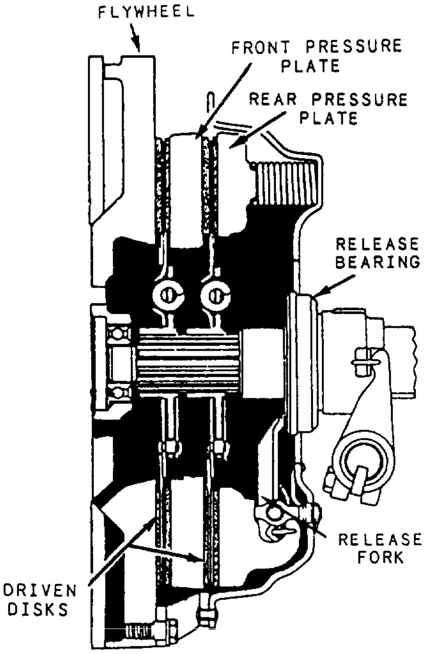


Figure 7-9.—Doubledisk clutch assembly.

CLUTCH MALFUNCTIONS

The information given in this section is general and may be applied to nearly every type of clutch you are likely to encounter. Refer to the manufacturer's repair manuals for problems not listed here.

The most common symptoms of clutch malfunctions are dragging, slipping, and noise. Improper adjustment is one condition that leads to clutch problems. You should always adjust the clutch according to the manufacturer's specifications. An improperly adjusted clutch can cause clutch slippage and hard shifting.

Dragging

This condition results when the clutch disk does not completely disengage from the flywheel or pressure plate when the clutch pedal is depressed. As a result, the clutch disk tends to continue turning with the engine and attempts to drive the transmission.

Dragging may be caused by any of the following conditions:

1. Excessive free travel in the clutch linkage.
2. The clutch disk binding on the transmission input shaft.
3. A warped or damaged pressure plate.

4. Improper adjustment of the pressure plate release lever. (Some pressure plates require this adjustment before the part is installed.)

To correct clutch dragging, adjust the free travel. Make this adjustment according to the manufacturer's specifications. If the problem is not corrected with this adjustment, you may need to remove the clutch for repairs or replacement.

Slipping

Because of heat generation, slipping of the clutch (while it is engaged) can severely damage the clutch disk facings. The contact surfaces on the pressure plate and the flywheel may also be damaged. If a clutch is allowed to continue to slip, complete clutch failure may result. Clutch slipping is most obvious when you are just starting out from a dead stop or upon sudden acceleration in a low gear. Slipping will be very noticeable in a vehicle with a heavy load.

Causes of clutch slippage include incorrect clutch pedal free travel, binding in the clutch linkage, and "riding the clutch. " If the free travel is insufficient, there is a tendency for the release bearing to contact the release levers, even though the operator's foot is off the clutch pedal. As a result, the clutch disk may not be clamped tightly between the flywheel and the pressure plate. Readjustment of the pedal free travel will solve this problem. If you do not adjust the free travel at once, the release bearing, as well as the clutch disk, will wear rapidly.

If a binding condition exists in the clutch linkage, the pedal will be reluctant to return when it is released. So again, you may encounter clutch slippage. To solve this problem, "free up" the linkage that is binding by simply lubricating or aligning the clutch linkage. If this fails to correct the problem, you may have to remove the clutch for further inspection and repair.

"Riding the clutch" is an operator problem whereby the operator steadily drives with a foot on the clutch pedal. As a result, the pedal may be partially depressed and cause clutch slippage. If this form of operator abuse is suspected, contact the transportation supervisor. The problem should be corrected through proper operator training.

Grabbing

Occasionally, you may encounter a clutch that grabs or chatters, no matter how evenly or gradually you try to engage it. If the linkage operates satisfactorily and the engine and clutch mountings are not loose, you may have to remove the clutch assembly from the vehicle to cure the trouble. The probable causes are loose, glazed, oily, or greasy disk facings; binding of the disk on the clutch shaft; broken or otherwise defective pressure plate springs; or a broken or otherwise defective pressure plate.

A careful inspection of all clutch parts should reveal any defective items. In any case, replace any damaged parts and rebuild the clutch as specified by the manufacturer. In most cases, it is best that you install the clutch as a unit which includes replacing the clutch disk, pressure plate, release bearing, pilot bearing and resurfacing the flywheel. Replacing the complete assembly prevents the need for rework

Clutch Noises

A noisy clutch may be caused by a number of conditions. Most of these conditions can be corrected only after you have removed the assembly from the vehicle. Start your inspection by noting whether or not the noise occurs when the clutch is engaged or disengaged. Do this with the engine idling since the noise is likely to be most apparent at this time.

To begin with, when you have the clutch disengaged, you may discover that the noise coming from the clutch is due to lack of lubrication or to defects in the assembly. For instance, a dry or binding release bearing is likely to squeal when it is placed in operation. If it does, you will usually need to replace the bearing. On some vehicles, however, provisions are made for lubricating this bearing. If so, you can generally lubricate or replace the bearing without removing the clutch assembly. Still, you may need to remove the transmission and the lower cover from the flywheel housing to get to the bearing. However, it usually pays for you to go a little further and inspect the entire clutch assembly if you must remove the transmission for any reason.

Noise may also come from a worn or dry pilot bearing. Such a bearing tends to "whine" when it is out of grease. This noise usually occurs when the vehicle is stationary, with the engine running, the transmission in gear, and the clutch disengaged. To remedy this, replace the bearing and make sure it is properly lubricated if it is not a prepacked bearing.

Still other clutch noises may occur when you have the clutch disengaged. Any one of several conditions can be responsible for noisy operation. For example, the clutch disk may be loose on the transmission shaft (disk hub loose on shaft splines). If this is the case, depending on the amount of wear, you may have to replace the input shaft and the clutch disk. Another condition involving noise and necessitating disk replacement is loose or weak torsional springs surrounding the disk hub. You may also find that the antirattle springs on the pressure plate assembly are weak and require replacement. A hose or misaligned transmission will cause noisy clutch operation. You can easily correct this by loosening the transmission, shifting it into proper alignment, and retightening it.

Stiff Clutch Pedal

A stiff clutch pedal or a pedal that is hard to depress is likely to result from lack of lubricant in the clutch linkage, from binding of the clutch pedal shaft in the floorboard seal, or from misaligned linkage parts that are binding. In addition, the overcenter spring (on vehicles so equipped) may be out of adjustment, Also, the clutch pedal may be bent so that it rubs on the floorboard and is hard to operate. To correct these conditions, you must realign, readjust, or lubricate the parts, as required.

Clutch Pedal Pulsation

Movement felt on the clutch pedal or operating lever when the clutch is being disengaged is called clutch pedal pulsation. These pulsations are noticeable when a slight pressure is applied to the clutch pedal. This is an indication of trouble that could result in serious damage if not immediately corrected Several conditions could cause these pulsations. One is misalignment of the engine and transmission.

If the engine and transmission are not in line, detach the transmission and remove the clutch assembly. Check the clutch housing alignment with the engine and crankshaft. At the same time, check the flywheel for wobble. A bent crankshaft flange or an improperly seated flywheel produces clutch pedal pulsations. After the flywheel is properly seated, check it using a dial indicator. If the crankshaft flange is bent, the crankshaft must be remachined or replaced.

Other causes of clutch pedal pulsations include uneven release lever adjustments, warped pressure plate, or a warped clutch disk. If the clutch disk or pressure plate is warped, it should be replaced.

It would be impractical to list every possible clutch problem and its remedy for repair in this training manual. Table 7-1 lists other possible clutch problems and their corrective action. Consult the manufacturer's operation and repair manual before making adjustments to any clutch system.

AUTOMATIC TRANSMISSIONS

Automatic transmissions (fig. 7-10) are found in all types of automotive and construction equipment. The

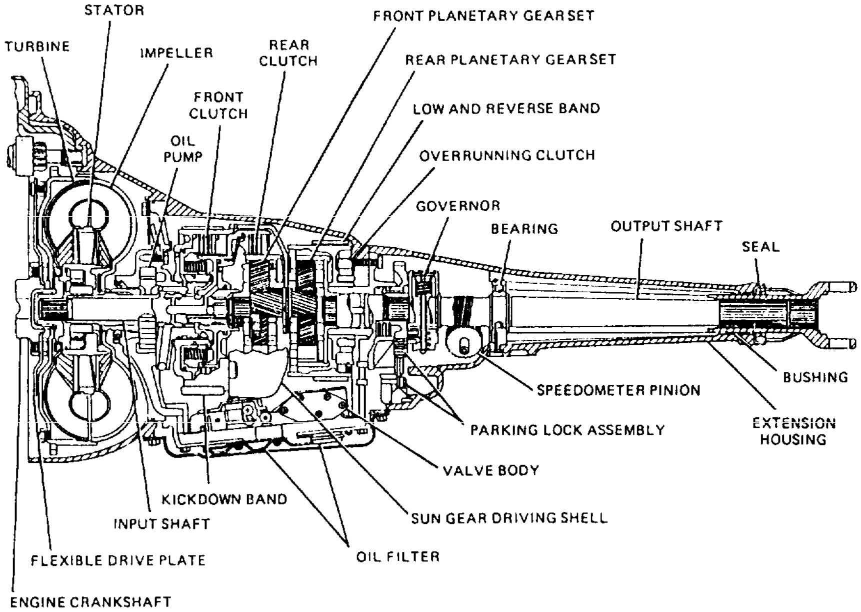


Figure 7-10.—Typical automatic transmission, cross-sectional view.

Table 7-1.—Clutch Assembly Troubleshooting Chart

PROBLEM	REMEDY
Clutch fails to release	
1. wrong linkage adjustment	1. readjust clutch linkage
2. broken linkage	2. repair linkage
3. pilot bearing is seized on the transmission input shaft	3. replace pilot bearing
4. broken release levers on pressure plate	4. replace pressure plate
5. broken clutch release cable	5. replace cable
the following is for hydraulic clutch operating systems	
6. low or no hydraulic fluid in the clutch master cylinder	6. repair the master cylinder
7. faulty clutch slave cylinder	7. rebuild or replace master cylinder
8. broken hydraulic lines	8. repair or replace hydraulic lines
Slipping Clutch	
1. excessive free play in clutch linkage	1. readjust clutch linkage
2. clutch drive plate worn	2. replace drive plate
3. diaphram spring broken	3. replace pressure plate
4. clutch plate is oil soaked	4. replace the clutch plate
5. drive plate is overheated	5. let the plate cool and recheck adjustment
6. warped pressure plate	6. replace pressure plate
Grabbing clutch	
1. broken engine mounts	1. repair or replace engine mounts
2. clutch plate facing charred or oil soaked	2. replace clutch plate
3. broken damper springs in the clutch plate	3. replace clutch plate
4. worn splines on transmission input shaft	4. replace the transmission shaft
5. flywheel or pressure plate is warped	5. reface flywheel or replace the pressure plate
6. cracked or broken release bearing collar	6. replace collar
Noisy, clutch engaged; transmission in neutral	
1. clutch plate damper springs worn or broken	1. replace clutch disk
2. clutch release arm spring loose or missing	2. replace spring
3. clutch linkage loose	3. repair and readjust
Noisy, when clutch is engaged and disengaged	
1. worn release bearing	1. replace release bearing
2. clutch linkage or assist springs are not properly lubricated..	2. lubricate linkage and springs
3. release arm is installed improperly	3. remove and reinstall
4. release bearing is loose on the release lever	4. remove and reinstall
Clutch pedal is hard to depress or does not return when disengaged	
1. faulty clutch pressure plate	1. replace pressure plate
2. jammed or binding clutch linkage	2. repair, lubricate, and readjust clutch linkage
3. broken or weak clutch return spring	3. replace return spring
4. binding clutch release cable	4. replace cable
the following is for hydraulic clutch operating systems	
5. faulty clutch master cylinder	5. rebuild or replace master cylinder

purpose of the automatic transmission is the same as standard transmissions-to match the load requirements of a vehicle to the power and speed of the engine. Changing the gear ratio automatically is controlled by throttle position, shift control lever position, and vehicle speed. It relieves the operator of the responsibility of selecting the best possible gear ratio for each condition and makes driving easier and safer.

Many different models of automatic transmissions are manufactured today. Automotive applications usually have three speeds forward and one reverse. More recently the automotive industry has added a lockup clutch to the torque converter, and on some models, an overdrive gear. Automatic transmissions for material handling and construction equipment will normally have a lower gear ratio, be considerable y larger, and may have over six speeds forward and more than one reverse gear.

Whatever the case and regardless of design or construction, all automatic transmissions have the following six basic systems that enable them to function:

1. A torque converter or fluid coupling
2. A hydraulic system
3. A planetary gearset (usually more than one)
4. One or more spool valves used to direct fluid flow
5. Multidisk clutch packs or lockup bands
6. A control valve or a combination of control valves

In automatic transmissions, these systems all serve the same purposes. For this reason, we will only discuss one type of automatic transmission in this TRAMAN. If you want information on a specific type, use the manufacturer's maintenance and repair manual for that unit.

TURBO HYDRA-MATIC MODEL 400

The Model 400 Hydra-Matic transmission (fig. 7-1 1) is a fully automatic unit consisting of a three element torque converter and a compound planetary

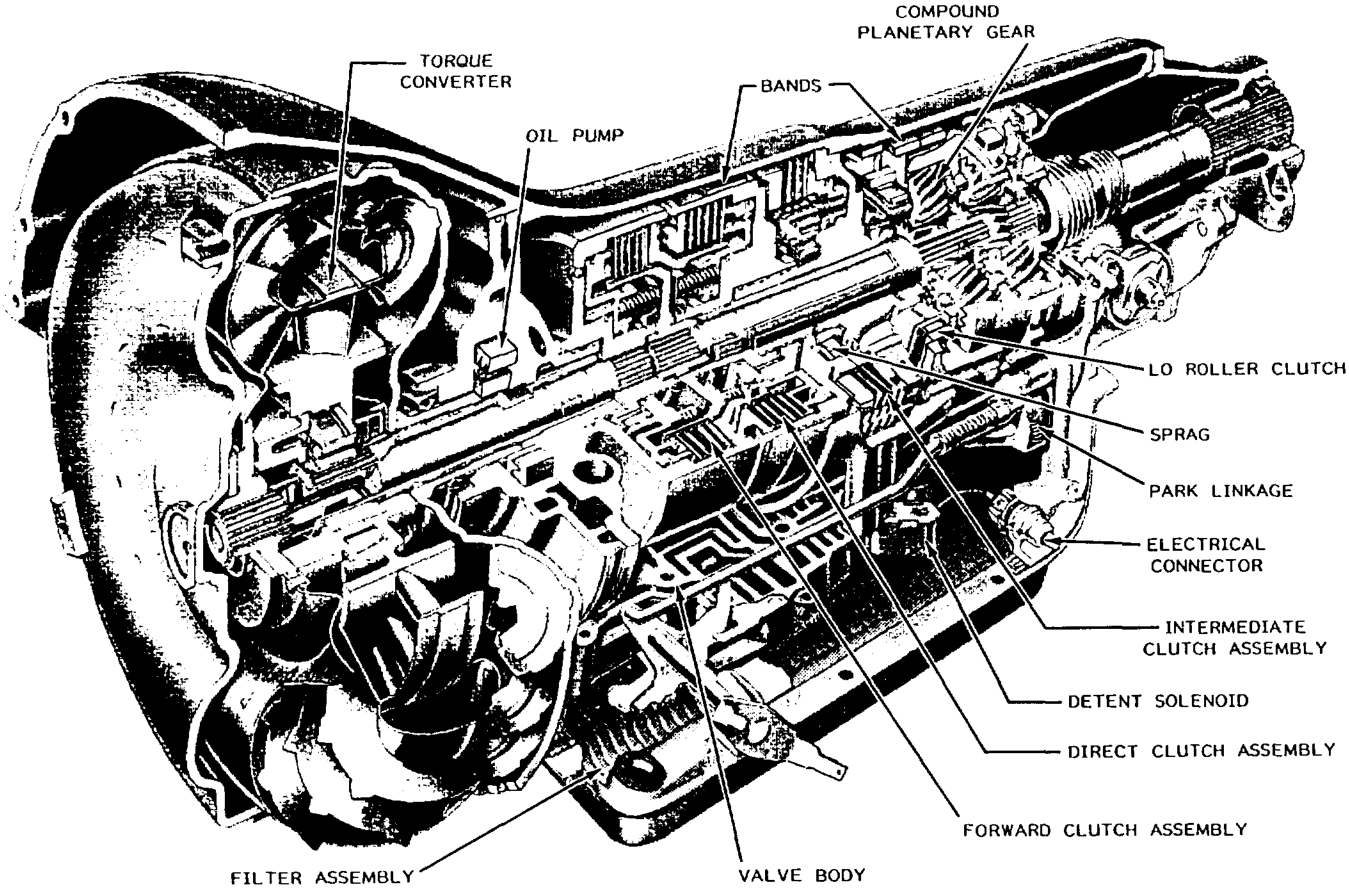


Figure 7-11.—Cutaway view of Model 400 Hydra-Matic transmission.

gearset. Three multiple-disk clutches-one sprag, one roller clutch, and two bands–provide the reaction elements required to obtain the desired function of the compound planetary gearset.

The torque converter smoothly couples the engine to the planetary gear through oil and hydraulically y provides additional torque mulitplication when required. The torque converter consists of a pump (driving member), a turbine (driven member), and a reaction member, known as a stator.

The compound planetary gearset gives three foward ratios and one reverse. Changing of the gear ratios is fully automatic in relation to vehicle speed and load.

Planetary Gears

Planetary gears are used in the Hydra-Matic 400 transmission as a basic means of multiplying the torque from the engine. The name is derived from the physical arrangement of the gears. They are always in mesh and thus cannot "clash" like other gears that go in and out of mesh. The gears are so designed so several teeth are in mesh or in contact at one time. This distributes the forces over several teeth at one time for greater strength. Because the shafts generally used with planetary gear trains can be arranged on the same centerline, a compact system can be obtained.

A planetary gear train consists of a center or sun gear, an internal or ring gear, and a planetary carrier assembly which includes and supports the smaller planet gears or pinions (fig. 7-12). A planetary gearset can be used to increase speed increase torque, reverse the direction of rotation, or function as a coupling for direct drive. Increasing the torque is known as operating in reduction because there is always a decrease in the speed of the output member proportional to the increase in the output of torque. This means that with a constant input speed, the output torque increases as the output speed decreases.

Reduction can be obtained in several ways. In a simple reduction, the sun gear is held stationary, and the power is applied to the internal gear in a clockwise direction. The planetary pinions rotate in a clockwise direction and "walk" around the stationary sun gear, thus rotating the carrier assembly clockwise in reduction (fig. 7-13).

Direct drive results when any two members of the planetary gear train rotate in the same direction at the same speed. In this condition, the pinions do not rotate on their pins but act as wedges to lock the entire unit together as one rotating assembly.

To obtain reverse, restrain the carrier from turning freely and power is applied to either the sun or the internal gear. This causes the planet pinions to act as idlers, thus driving the output member in the opposite

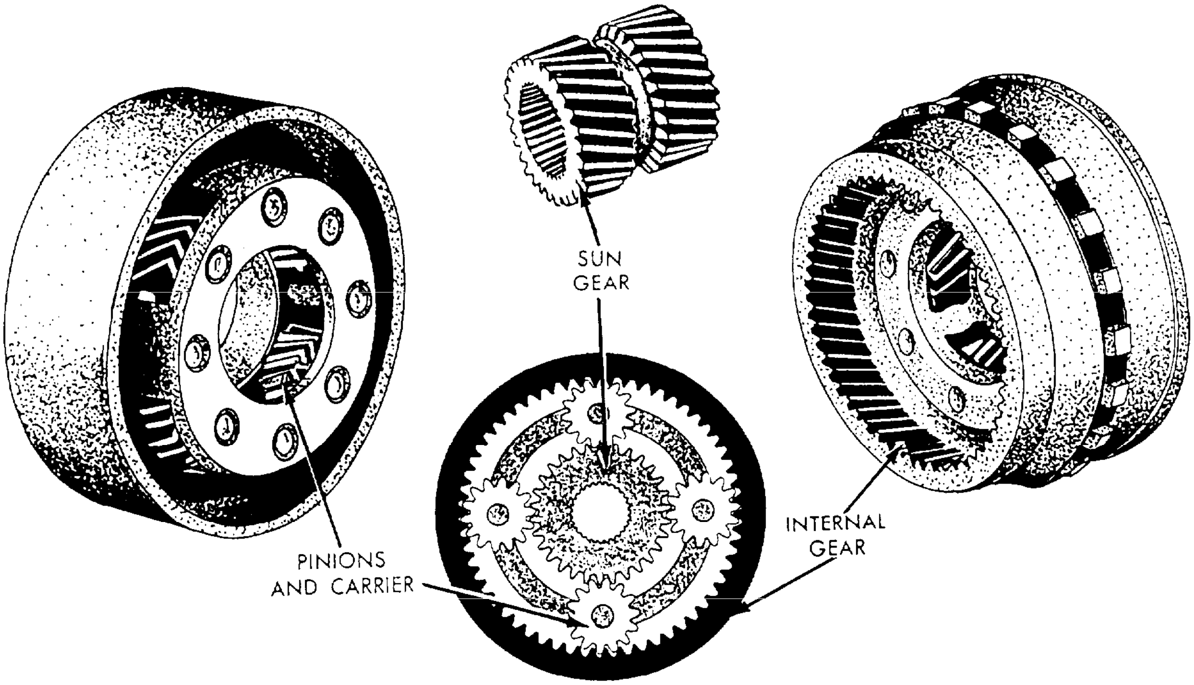


Figure 7-12.—Planetary gearset.

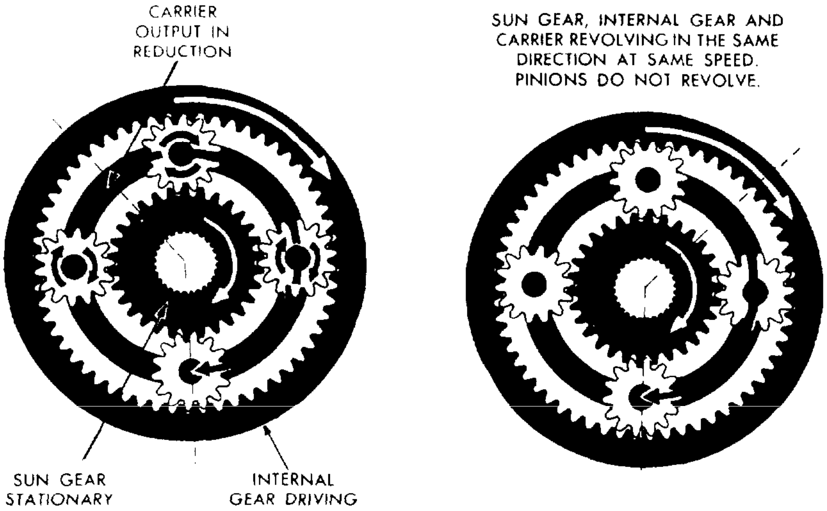


Figure 7-13.—Simple reduction-direct drive.

direction (fig. 7-14). In both cases, the output member is turning in the opposite direction of the input member.

Coupling ((Torque Converter Operation)

The automatic transmission is coupled to the engine through a torque converter. The torque converter is used with the automatic transmission because it does not have to be manually disengaged by the operator each time the vehicle is stopped. The cushioning effect of the fluid coupling within the torque converter allows for shifting without interruption of engine torque application.

The torque converter serves two primary functions. First, it acts as a fluid coupling to connect engine power smoothly through oil to the transmission gear train. Second, it multiplies the torque from the engine when additional performance is desired.

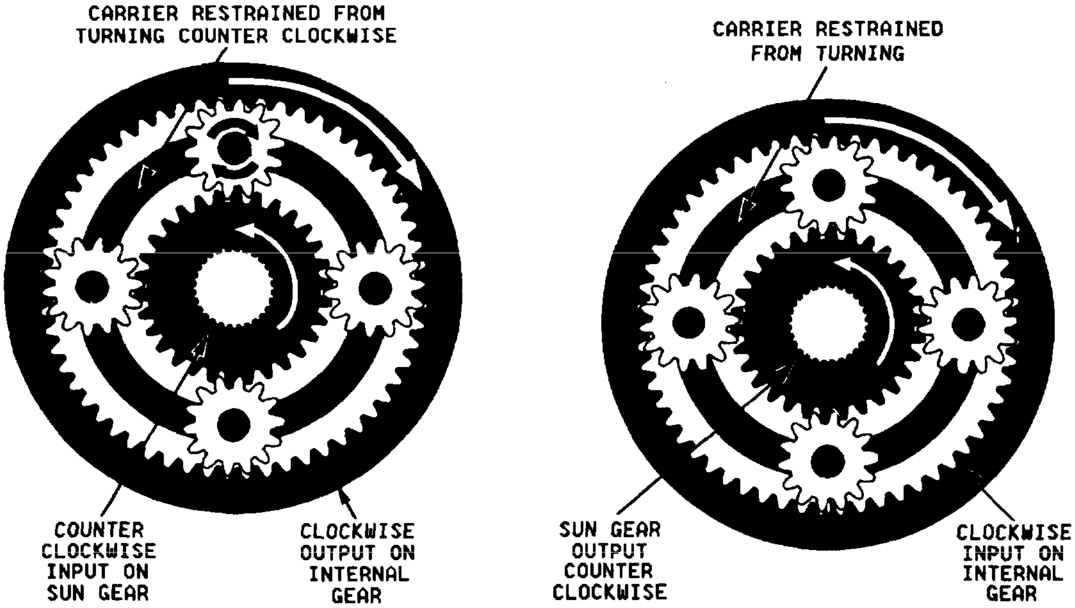


Figure 7-14.—Reverse drive.

The torque converter, as shown in figure 7-15, consists of the pump (driving member), the turbine (driven or output member), and the stator (reaction member). The converter cover is welded (some maybe bolted) to the pump to seal all three members in an oil-filled housing. The converter cover is bolted to the engine flex-plate which is bolted directly to the engine crankshaft. The converter pump is, therefore, mechanically connected to the engine and turns at engine speed whenever the engine is operating.

When the engine is running and the converter pump is spinning, it acts as a centrifugal pump, picking up oil at the center and discharging this oil at its rim between the blades. The shape of the converter pump shells and blades causes this oil to leave the pump, spinning in a clockwise direction toward the blades of the turbine. As the oil strikes the turbine blades, it imparts a force to the turbine, causing it to turn. Figure 7-16 shows the torque converter in the coupling stage. When the engine is idling and the converter is not spinning fast, the force of the oil is not great enough to turn the turbine with any efficiency. This allows the vehicle to stand in gear with the engine idling. As the throttle is opened and the pump speed is increased, the force of the oil increases and the engine power is more efficiently transmitted to the turbine member and the gear train. After the oil has imparted its force to the turbine, the oil follows the contour of the turbine shell and blades so that it leaves the center section of the turbine spinning counterclock-wise.

Because the turbine member has absorbed the force required to reverse the direction of the clockwise spinning of oil, it now has greater force than is being delivered by the engine. The process of multiplying

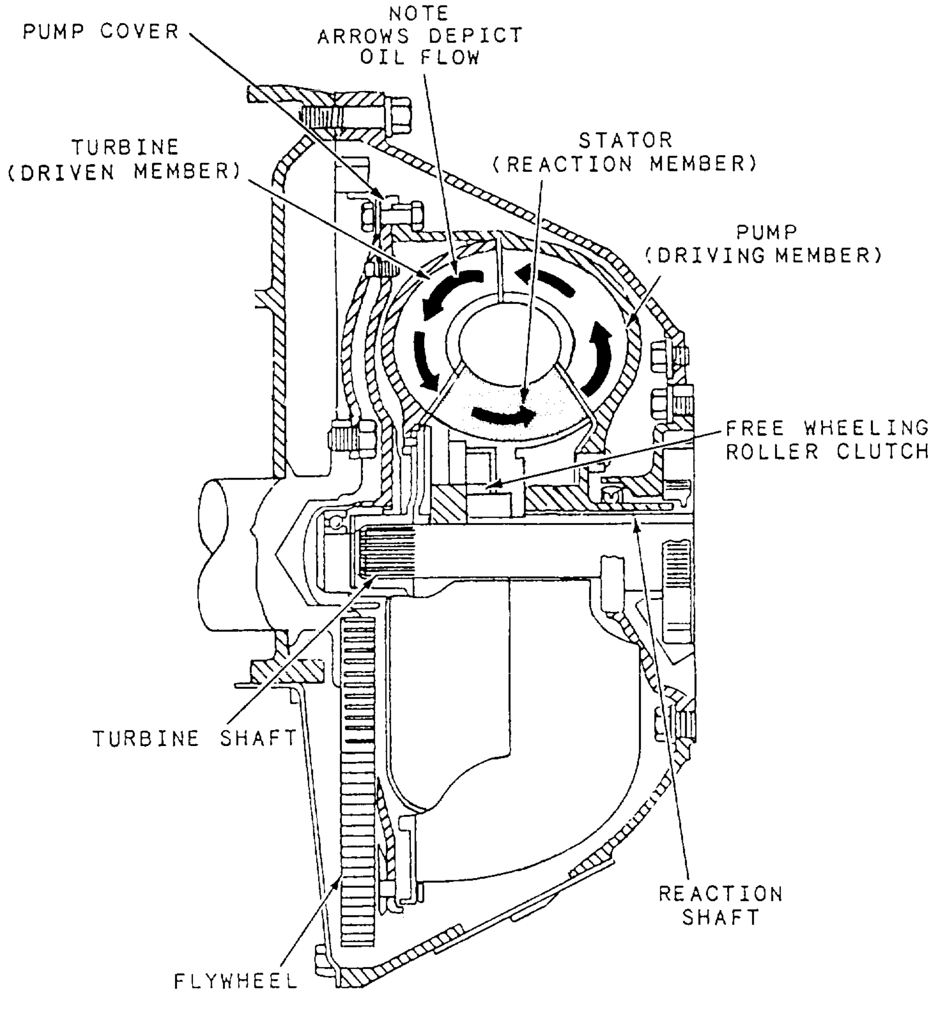


Figure 7-15.—Torque converter, partial cutaway view.

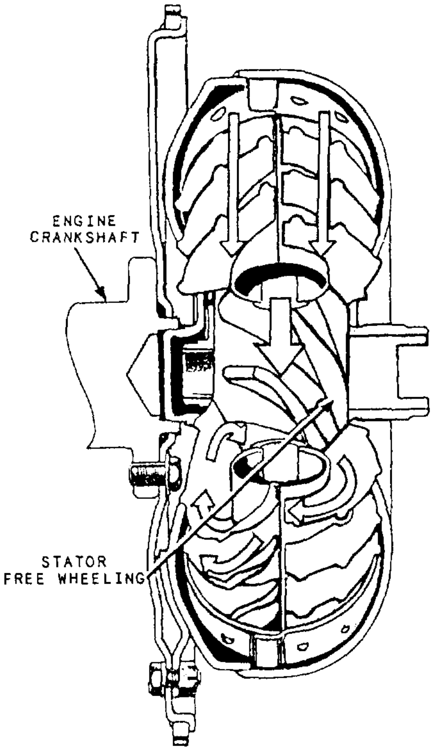


Figure 7-16.—Torque converter in fluid coupling stage.

engine torque through the converter has begun. If the counterclockwise spinning oil was allowed to continue to the section of the pump member, the oil would strike the blades of the pump in a direction that would hinder its rotation and cancel any gains obtained in torque. To prevent this, a stator assembly is added (fig, 7- 17).

The stator is located between the pump and the turbine and is mounted on a one way or roller clutch which allows it to rotate clockwise but not counterclockwise. The purpose of the stator is to redirect the oil returning from the turbine and change its direction of rotation back to that of the pump member. The energy of the oil is then used to assist the engine in turning the pump. This increases the force of the oil, driving the turbine, and as a result, multiplying the torque. The force of the oil flowing from the turbine to the blades of the stator tends to rotate the stator counterclockwise, but the one way roller clutch prevents this from happening.

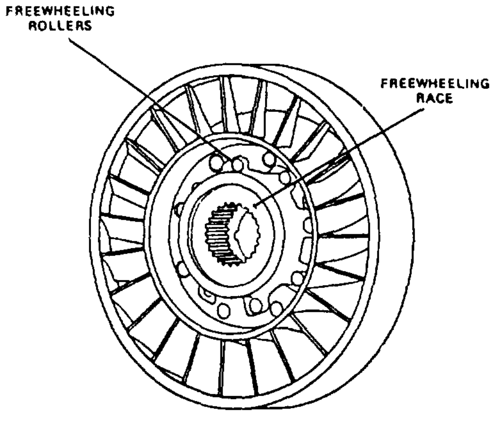


Figure 7-17.—Stator assembly.

With the engine operating at full throttle, the transmission in gear, and the vehicle standing still, the torque converter is capable of multiplying engine torque by approximately 2:1. As turbine and vehicle speed increase, the direction of the oil leaving the turbine changes (fig. 7-18). The oil flows against the rear side of the stator vanes in a clockwise direction. Since the stator is now impeding the smooth flow of oil, its roller clutch automatically releases, and the stator revolves freely on its shaft. Once the stator becomes inactive, there is no further multiplication of engine torque within the converter. At this point, the converter is merely acting as a fluid coupling as both the converter pump and the turbine are turning at the same speed or at a 1:1 ratio.

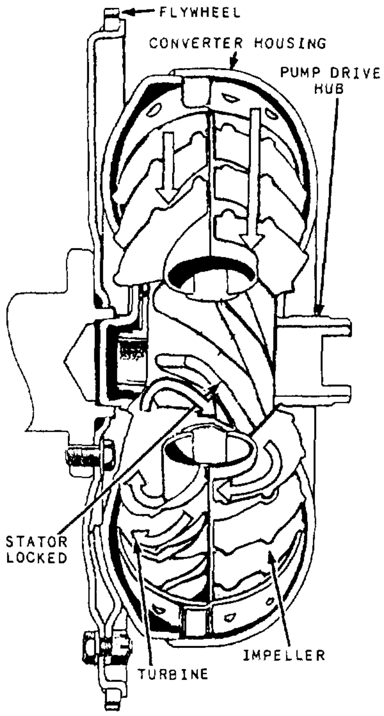


Figure 7-18.—Torque converter in torque multiplication stage.

Hydraulic System Operation

The hydraulic system shown in figure 7-19 has the following five basic functions.

1. The planetary holding devices are all actuated by hydraulic pressure from hydraulic slave systems (fig. 7-20).
2. It keeps the torque converter charged with fluid at all times.
3. The shifting pattern is controlled by the hydraulic system by switching hydraulic line pressure to programmed shifting devices according to vehicle speed and load.
4. It circulates the oil through a remote oil cooler to remove excess heat that is generated in the transmission and torque converter.

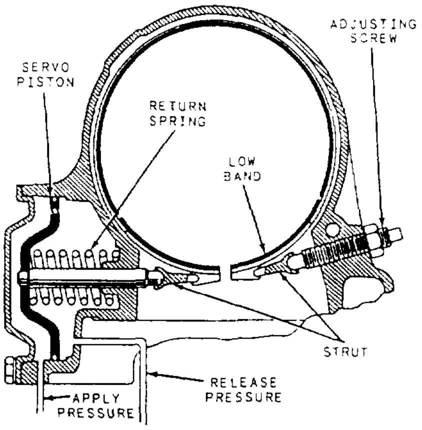


Figure 7-20.—Lockup band actuated by hydraulic pressure.

5. The hydraulic system provides a constant supply of lubricating oil to all critical wearing surfaces of the transmission.

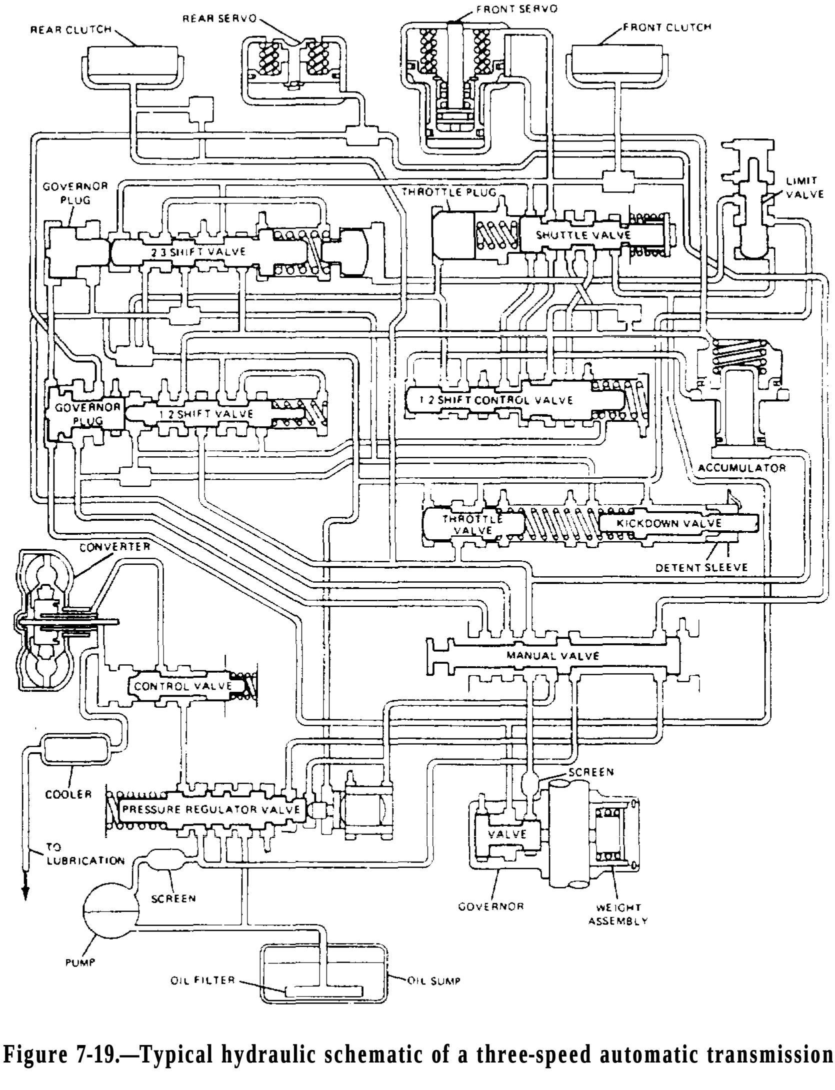


Figure 7-19.—Typical hydraulic schematic of a three-speed automatic transmission.

A hydraulic system requires a source of clean hydraulic fluid and a pump to pressurize the fluid. The Hydra-Matic Model 400 uses an interred gear type of pump (fig. 7-21) with its oil intake connected to a strainer assembly. The oil is drawn through the strainer from the transmission sump. The pump drive gear is geared or keyed to the driven member of the torque converter; therefore, whenever the engine is in operation, the pump is functioning. As the pump drive gear rotates, it rotates the pump driven gear causing the oil to be lifted from the sump into the oil pump. As the pump gears turn, oil is carried past the crescent section of the pump. Beyond the crescent, the gear teeth begin to come together again forcing the oil out of the pump and into the hydraulic system under pressure. At this point, the oil is delivered to the pressure control system.

Oil pressure is controlled by the pressure regulator valve. As the pressure builds, oil is directed through an orifice to the top of the pressure regulator valve. When the desired pressure is reached, the valve moves down against the spring, thus opening a passage to feed the ‘converter. When the converter is tilled, oil returning from it is directed to the transmission cooler in the engine radiator. As the pressure continues to increase, the pressure regulator valve moves to expose a port that directs excess oil to the suction side of the pump. The pressure regulator valve is spring-balanced to maintain line pressure at approximately 70 psi at an idle.

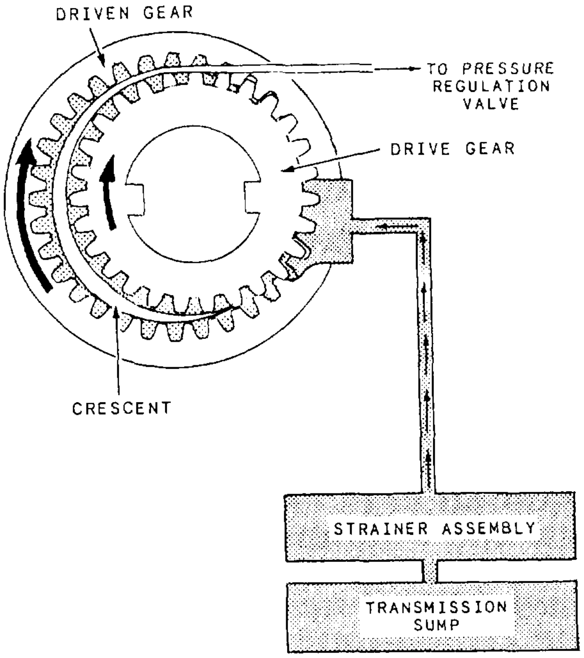


Figure 7-21.—Internal gear type of pump assembly.

When the transmission selector valve is moved to the D position, the manual valve moves to allow line pressure to be delivered to the forward clutch pack. The oil enters the small area first to provide a smooth initial takeup. The larger area is then filled gradually by oil metered through an orifice to provide the final holding force required

With the forward clutch applied, the mechanical connection for torque transmission between the turbine shaft and the main shaft has been provided. The LO roller clutch assembly becomes effective as a result of the power flow through the compound planetary gearset, and the transmission is in first gear, ready for the vehicle to start moving. As the vehicle begins to accelerate and first gear reduction is no longer required, the transmission automatically shifts to second gear. The vehicle speed signal for the shift is supplied by the transmission governor which is driven by the output shaft. The governor assembly consists of a regulating valve, a pair of primary weights, a pair of secondary weights, the secondary springs, the body, and the driven gear. The governor weights are so arranged that the secondary weights act only on the regulating valve. Because the centrifugal force varies with weight and speed, small changes in output shaft rpm at low speed result in small governor pressure changes. To give even greater change in pressure, the primary weights add force to the secondary weights. As the primary weight moves out at greater vehicle speed, it finally reaches a stop and is no longer effective. From this point on, only the secondary weights and secondary springs are used to apply the force to the governor valve.

Drive oil pressure is fed to the governor. This, in turn, is regulated by the governor valve and gives a governor pressure that is proportional to vehicle speed. To initate the shift from first to second gear, governor oil pressure is directed to the end of the 1-2 shift valve. It acts against the spring pressure holding the valve in the closed position, blocking drive oil. As vehicle speed and governor pressure increase sufficiently to overcome spring force, the 1-2 valve opens, allowing drive oil to flow into the intermediate clutch passage and through an orifice to apply the intermediate sprag effectively which shifts the transmission into second gear. Further increases in vehicle speed and governor pressure will cause the transmission to shift to third gear.

The operation of the 2-3 shift valve is similar to the 1-2 shift valve operation. Springs acting on the valve tend to keep the shift valve closed while governor pressure attempts to open the valve. When speed and governor pressure become great enough to open the 2-3 shift valve, intermediate clutch oil passes through the shift valve and enters the direct clutch, thus shifting the transmission into third gear. Oil pressure to the direct clutch piston is applied only to the small inner area in third gear.

When the accelerator is released and the vehicle is allowed to decelerate to a stop, the transmission automatically downshifts 3-2 and 2-1. This results from the decrease in governor pressure as the vehicle slows and the springs closing the shift valves in sequence.

In this system, shifts would always take place at the same vehicle speeds when the governor pressure overcomes the force of the springs on the shift valves. When you accelerate under a heavy load or for maximum performance, it is desirable to have the shifts occur at higher vehicle speeds. To make the transmission shift at higher vehicle speeds with greater throttle opening, variable oil pressure, called modulation pressure is used. Modulator pressure is regulated by engine vacuum which is an indicator of engine load and throttle setting. The engine vacuum signal is provided to the transmission by the vacuum modulator which consists of an evacuated metal bellow, a diaphram, and springs. These are so arranged that, when installed, the bellows and one spring apply a force that acts on the modulator valve to increase modulator pressure. Engine vacuum and the other spring act in the opposite direction to decrease modulator pressure which results in low-engine vacuum and gives a high-torque signal and high modulator pressure. High-engine vacuum gives a low-torque signal and low modulator pressure.

Modulator pressure is directed to the 1-2 regulator valve which regulates modulator pressure to a lesser pressure that is proportional to modulator pressure. his tends to keep the 1-2 shift valve in the closed or downshift position. Modulator pressure is also directed to the 2-3 modulator valve to apply a variable force proportional to modulator pressure. This tends to hold the 2-3 shift valve in a the closed or downshift position. The shifts can now be delayed to take place at higher vehicle speeds with heavy throttle operation.

Line pressure is controlled in D (drive) range so that it will vary with torque input to the transmission. Since torque input is a product of engine torque and converter ratio, modulator pressure is directed to a pressure regulator boost valve to adjust the line pressure for changes in either engine torque or converter ratio.

To regulate modulator pressure, and, in turn, line pressure with the torque converter torque ratio that decreases as vehicle speed increases, governor pressure is directed to the modulator valve to reduce modulator pressure with increases in vehicle speed. In this way, line pressure is regulated to vary with torque input to the transmission for smooth shifts with sufficient capacity for both heavy and light acceleration.

The 1-2 shift feel and the durability of the intermediate clutch are dependent on the apply pressure that locks the clutch pack. At minimum or light throttle operation, the engine develops a small amount of torque and as a result, the clutch requires less apply pressure to engage or lock. At heavy throttle, the engine develops a great amount of torque which requires a higher apply pressure to lock the clutch pack. If the clutch locks too quickly, the shift will be too agressive. If it locks too slowly, it will slip excessively and eventually burn and ruin the clutches due to the heat created by the slippage.

Automatic Transmission Service

Automatic transmission service can be easily divided into the following three parts: preventive maintenance, troubleshooting, and major overhaul. Before you perform any maintenance or repairs on an automatic transmission, consult the maintenance manual for instructions and proper specifications.

PREVENTIVE MAINTENANCE.— Normal preventive maintenance includes:

1. Checking the transmission fluid daily
2. Adjusting the shifting and kickdown linkages
3. Adjusting lockup bands
4. Changing the transmission fluid and filter at recommended service intervals (Example: 15,000 miles or yearly for heavy or severe service)

Checking the Fluid.— The operator is responsible for first echelon's (operator's) maintenance. They should not only be trained to know how to look for the proper fluid level but also to know how to look for discoloration of the fluid and debris on the dip stick. Fluid levels in automatic transmissions are almost always checked at operating temperature. This is important to know since the level of the fluid may vary as much as three-fourths of an inch between hot and cold. The fluid color should be pink and clear. The color varies due to the type of fluid. (Example: construction equipment using OE-10 will not have color to it but still should be clear.) A burnt smell or brown coloration of the fluid is a sign of overheated oil from extra heavy use or slipping bands or clutch packs. The unit should be sent to the shop for inspection for possible trouble.

CAUTION

Not all transmission fluids are the same. Before you add fluid, check the manufacturer's recommendations fast. The use of the wrong fluid will lead to early internal parts failure and costly overhaul.

Overfilling the transmission can result in fluid foaming and the fluid being driven out through the vent tube. The air that is trapped in the fluid is drawn into the hydraulic system by the pump and distributed to all parts of the transmission. This situation will cause air to be in place of oil and, in turn, cause slow application and burning of clutch plates and facings. Slippage occurs, heat results, and failure of the transmission follows.

Another possible, but remote, problem is water, indicated by the fluid having a "milky" appearance. A damaged fluid cooling tube in the radiator (automotive) or a damaged oil cooler (construction) could be the problem. The remedy is simple. Pressure test the suspected components and repair them as required. After reassembly, refill the transmission with fresh fluid.

Linkage and Band Adjustment.— The types of linkages found on an automatic transmission are gear shift selection and throttle kickdown. The system can be a cable or a series of rods and levers. Whichever the type, they do not normally present a problem, and preventive maintenance usually involves only a visual inspection and lubrication of the pivot points of linkages or the cable. Adjustment of these linkages should only be done according to manufacturer's specifications.

If an automatic transmission is being used in severe service, the manufacturer may suggest periodic band adjustment. Lockup bands are always adjusted to the manufacturer's specifications after an overhaul. Bands are adjusted by loosening the locknut and tightening down the adjusting screw to a specified value. Then the band adjusting screw is backed off a specified amount of turns and the locking nut is tightened down. Not all bands are adjustable. For example, the General Motors turbo Hydra-Matic Model 400 does not have a band adjustment. If the band is worn to the point where it cannot perform its function, you should replace it.

Fluid Replacement.— The Naval Construction Force (NCF), the COMCBPAC/COMCBLANTINST 11200.1 series, recommends maintenance be performed according to the manufacturer's specifications. These recommendations vary considerably for different makes and models. When you change automatic transmission fluid, read the repair manual first.

Service intervals depend on the type of use the transmission receives. In the NCF, because of the operating environment, more than a few of our vehicles are subjected to severe service. Severe service includes the following: hot and dusty conditions, constant stop and go driving (taxi service), trailer towing, constant heavy hauling, and around the clock operations (contingency). Any CESE operating in these conditions should have its automatic transmission fluid and falter changed on a regular schedule, based on the manufacturer's specifications for severe service.

Draining the transmission can be done in three ways. By removing the drain plug, loosening the dip stick tube, or by removing the oil pan. Have the vehicle on level ground or on a lift and let the oil drain into a proper catchment device.

CAUTION

Oil drained from automatic transmissions contains heavy metals and is considered hazardous waste and should be disposed of according to local naval station instructions.

Once the oil is drained, remove the pan completely for cleaning. By paying close attention to any debris in the bottom of the pan, you may able be to detect a possible problem. The presence of a high number of metal particles could indicate serious internal problems. Clean the pan; set it aside. All automatic transmissions have a filter or a screen located in the oil pan. The screen is cleanable; the falter is a disposable type and should always be replaced when removed. These are retained in different ways: retaining screws, metal retaining clamps, or O rings made of neoprene. Clean a screen with solvent and use low pressure air to blow-dry it. Do not use rags to wipe a screen dry as it tends to leave lint behind that will be ingested into the transmission hydraulic system. Any screen with a hole in it or any screen that is abnormally hard to clean should be replaced.

Draining the oil from the oil pan of the transmission does not remove all of the oil: the process is completed by draining the oil from the torque converter. To do this, remove the torque converter cover and remove the drain plug if the converter is so equipped. (Most modern automotive torque converters do not have a drain plug. Special draining instructions may be found in the manufacturer's repair manuals. Before performing this operation, clear it with your maintenance supervisor.)

Refilling the Transmission.— Reinstall the transmission oil pan, the oil plug, and fill tube. Fill the transmission with the fluid prescribed by the manufacturer to the proper level. With the brakes applied, start the engine and let it idle for a couple of minutes. Move the gear selector through all positions several times, allowing the fluid to flow through the entire hydraulic system to release any trapped air. Return the selector lever to park or neutral and recheck the fluid level. Bring the fluid to the proper level. Run the vehicle until the operating temperature has been reached, and check for leaks in the process. At operating temperature, recheck the fluid and adjust the level, as necessary.

CAUTION

Overfilling an automatic transmission will cause foaming of the fluid. This condition prevents the interred working parts of the automatic transmission from being correctly lubricated and causes slow actuation of the bands and clutches. Eventual burning of the clutches and bands results. DO NOT OVERFILL AN AUTOMATIC TRANSMISSION.

TROUBLESHOOTING.— Good troubleshooting practices save a lot of time and money for the Navy. If you know what you are doing when you troubleshoot an automatic transmission, you should be able to pinpoint the problem before you remove it from the vehicle. In some cases, you may be able to make the repairs without removing the transmission.

Next, before troubleshooting the transmission, make sure the engine is in good running condition. An engine that is not operating properly will not allow the transmission to function normally.

Locate the transmission serial number (fig. 7-22). This is important for finding the correct troubleshooting information and in obtaining repair parts.

The information (table 7-2) included here will assist you in locating and correcting the troubles that could develop in the Turbo Hydra-Matic Model 400 series automatic transmission, a type found throughout the NCF in M-1008, M-1009, and M-1010 series trucks.

NOTE

A malfunction may have more than one probable cause. Complete all the tests and inspections for each cause to find the correct cause.

Keep in mind that it is impossible to list each and every malfunction and its possible corrective action in this training manual. The problems listed are the most common. If you have a problem occurring in your transmission that is not listed here, see your supervisor for advice.

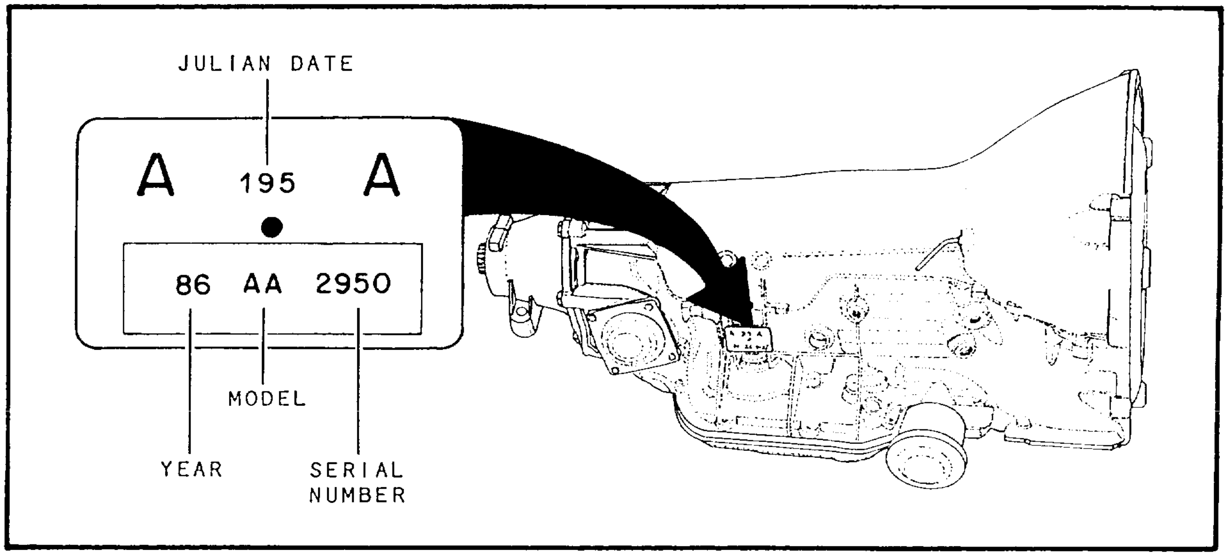


Figure 7-22.—Typical example of the data plate location on an automatic transmission.

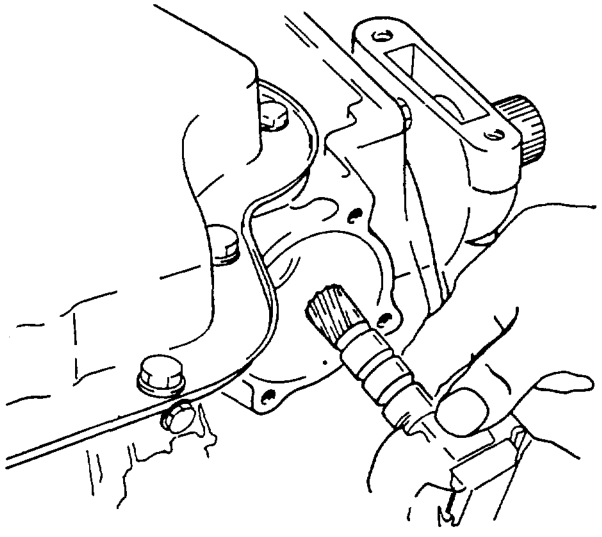


Figure 7-23.—Removing the governor assembly.

TRANSMISSION OVERHAUL.—Because of the complexity of automatic transmissions, the need for special tools, and personnel skills, overhauling these major components is usually done at a Construction Equipment Department located at a Construction Battalion Center. Overhaul of automatic transmissions is not a job for an inexperienced person. If the job must be performed in the field, it is recommended that only a highly capable mechanic be assigned to this type of work NCIC, Port Hueneme, Calif., and NCTC, Gulfport, Miss., both offer training in automatic transmission overhaul as part of the 12 week CM-C-1 advance course.

The following disassembly instructions apply to the General Motors Turbo Hydra-Matic Model 400 series automatic transmission. This type of transmission is commonly found in CESE throughout the NCF and in many public works stations. It is likely to be in manufacture for years to come.

Before preceding with automatic transmission disassemble y or reassembly, get the applicable repair instructions and have them on hand. READ THIS INFORMATION !!!!! Incorrect disassembly procedures can lead to severe parts damage, causing unnecessary equipment downtime. Have a workplace away from the main CM shop. A dust-free air-conditioned room is the best, but this is not always available. Obtain the cleanest work space possible! Have on hand any special tools needed for the job, such as snap ring pliers, torque wrenches, or special pullers. It is also a good idea to have an air compressor available for test purposes and for blowdrying individual parts.

CAUTION

Compressed air used for cleaning purposes should not exceed 30 psi. Wear goggles and other appropriate protective equipment when you use compressed air.

Clean the outside of the transmission and drain out as much fluid as possible. Remove the torque converter and set it aside for separate cleaning and testing. Place the transmission on the workbench and remove the governor (fig. 7-23). Next, remove the oil pan, oil filter, and intake pipe (fig. 7-24). The type of debris found in the bottom of the oil pan is indicative of the type of internal damage you may find in the transmission. Remove the vacuum modulator and valve (fig. 7-25);

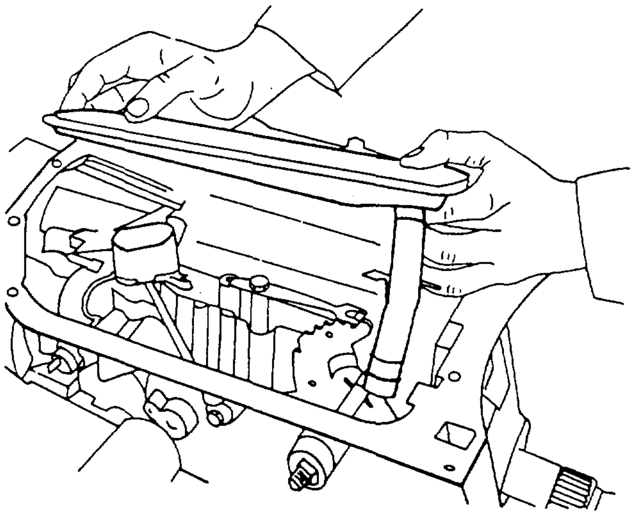


Figure 7-24.—Removing the filter assembly.

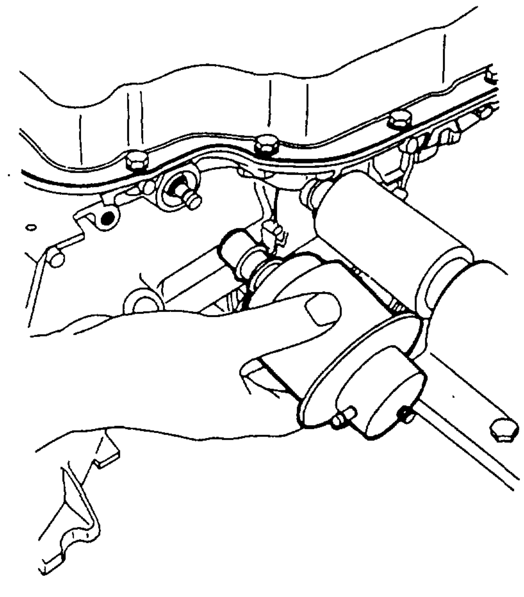


Figure 7-25.—Removing the vacuum modulator.

Table 7-2.-Turbo Hydra-Matic Model 400 Troubleshooting List

PROBLEM	POSSIBLE CAUSE
1. No drive in drive range	1. Low or no oil in the transmission
	2. Linkage improperly adjusted
	3. Low oil pressure
	4. Defective control valve
	5. Forward clutch inoperative
2. Oil pressure too high or low	1. Defective vacuum modulator
	2. Defective pressure regulator
	3. Defective oil pump
	4. Governor inoperative
	5. Modulator valve sticking
	6. Leaking vacuum lines
3. 1-2 shift, full throttle only	1. Faulty detent valve or detent solenoid
	2. Vacuum lines leaking
	3. 1-2 spool valve in valve body is sticking
4. First speed only, no 1-2 shift	1. Faulty governor, or governor drive gear
	2. Intermediate clutch not operating properly
	3. Governor feed channel is blocked
	4. Faulty control valve assembly
5. First and second speeds only, no 2-3 shift	1. Faulty detent switch
	2. Detent solenoid sticking open
	3. 1-2 spool control valve body sticking
	4. Control valve body spacer-plate-to-cover gasket leaking or incorrectly installed
	5. Defective direct clutch
6. Drive in neutral	1. Manual linkage improperly adjusted
	2. Forward clutch not releasing
7. No drive or slipping in reverse	1. Low or no oil in the transmission
	2. Manual linkage out of adjustment
	3. Faulty control valve assembly
	4. Direct clutch slipping or inoperative
	5. Forward clutch slipping or inoperative
	6. Defective reverse or low lockup band
8. Slips in all gear selections	1. Low or no oil in the transmission
	2. Clogged transmission oil filter
	3. Vacuum modulator valve is sticking
	4. Forward clutch is slipping

Table 7-2.—Turbo Hydra-Matic Model 400 Troublesbooting List-Contiued

PROBLEM	POSSIBLE CAUSE
9. Slips 1-2 shift	1. Low oil pressure
	2. Rear servo accumulator unserviceable
	3. 1-2 accumulator unserviceable
	4. Defective intermediate clutch
	5. Improperly positioned pump to case gasket
10. Rough 1-2 shift	1. Incorrect oil pressure
	2. Valve body assembly loose on transmission case
	3. Intermediate clutch ball in valve body not functioning
	4. Faulty 1-2 accumulator assembly
11. Slips 1-2 shift	1. Low oil level
	2. Incorrect oil pressure
	3. Defective direct clutch
	4. Modulator valve damaged
12. Slips 2-3 shift	1. Low oil level
	2. Direct clutch defective
	3. Modulator valve defective or inoperative
	4. Pump pressure regulator valve or booster valve damaged
	5. Transmission case leaking between channels
13. Rough 2-3 shift	1. Vacuum modulator defective
	2. Valve body pressure regulator is inoperative
	3. Faulty rear servo accumulator assembly
14. No engine braking lst gear	1. Pressure regulator or boost valve is stuck
	2. Manual valve is stuck
	3. Rear band inoperative or damaged
	4. Check ball missing from case
15. No engine braking in 2nd gear	1. Front band inoperative or damaged
16. No part throttle downshift	1. Low oil pressure
	2. Faulty detent valve
	3. 2-3 shift valve sticking
17. No detent downshift	1. 2-3 shift valve sticking
	2. Sticking detent valve

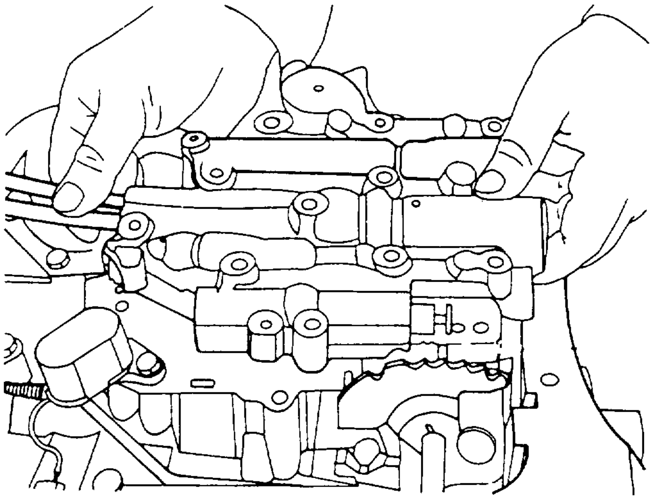


Figure 7-26.—Removing the control valve assembly.

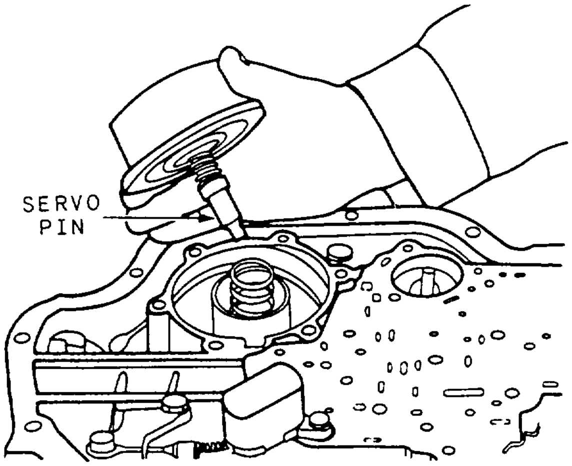


Figure 7-27.—Removing the rear servo assembly.

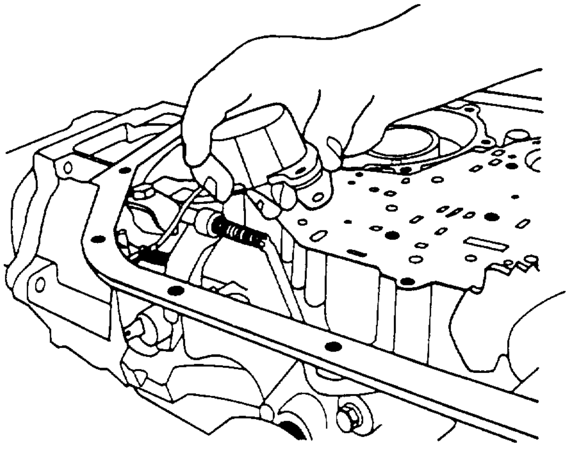


Figure 7-28.—Removing the pressure switch/detent solenoid.

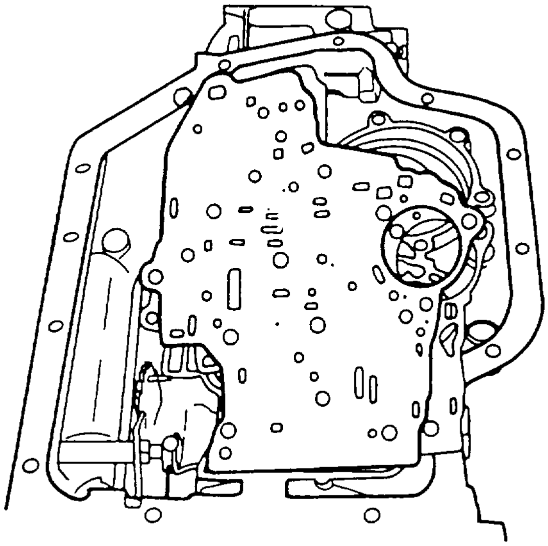


Figure 7-29.—Removing the control valve spacer. (The check balls are here.)

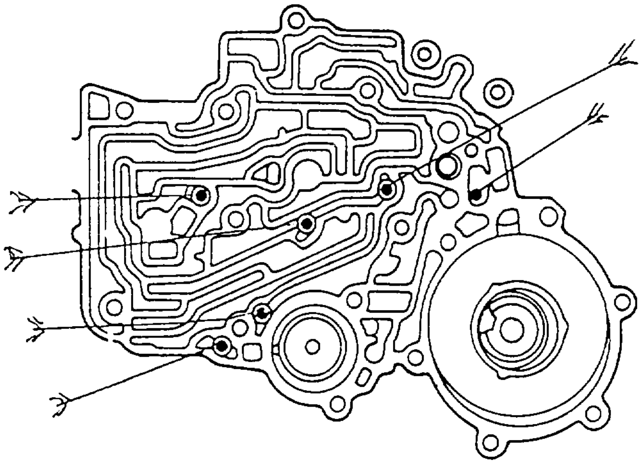


Figure 7-30.—Location of the six check balls in the transmission body.

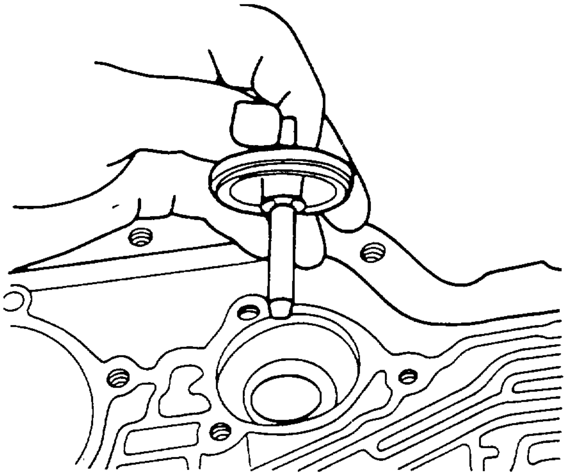


Figure 7-31.—Removing the front servo.

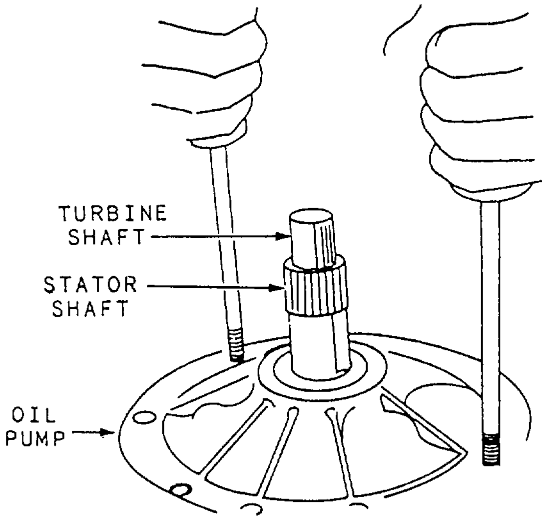


Figure 7-32.—Removing the pump assembly.

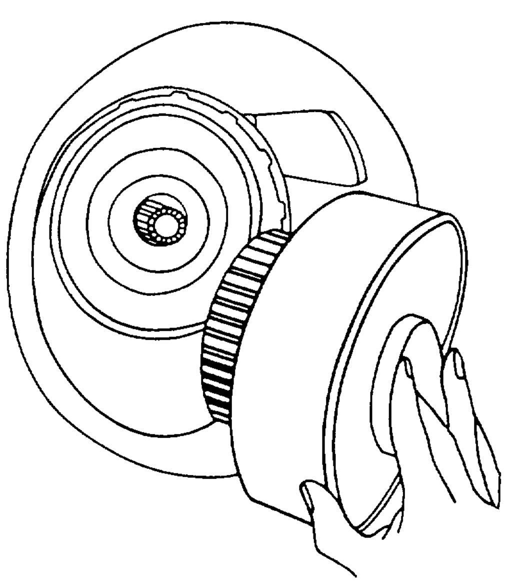


Figure 7-34.—Removing the direct clutch assembly.

this must be done before the valve body may be removed. Unbolt the control valve assembly and carefully lift it to free the governor pipes from the transmission case (fig. 7-26). Do not bend the governor pipes. Remove the rear servo assembly by taking out the six screws that attach it to the transmission body (fig. 7-27). Next, remove the pressure switch/detent solenoid by unclipping the wires and unbolting the device (fig. 7-28). (This varies to application.) Next, lift the control valve spacer away from the transmission body (fig. 7-29). Notice the position of the six check balls located in the transmission case (fig. 7-30); remove these with a magnet and retain them in a safe place for reinstallation during reassembly. Remove the front servo piston and servo piston spring from the case (fig. 7-31). If this item appears to be in satisfactory condition, do not disassemble it. After removing the bolts that retain the oil pump, use two slide hammers to remove the oil pump from the transmission housing (fig. 7-32). Set the pump aside for later attention. Next, grasp the turbine shaft and remove the forward clutch assembly from the transmission case (fig. 7-33). Figure 7-34 shows the direct clutch being removed from the transmission housing followed by the removal of the front band (fig. 7-35). Unclip the snap ring retaining the intermediate

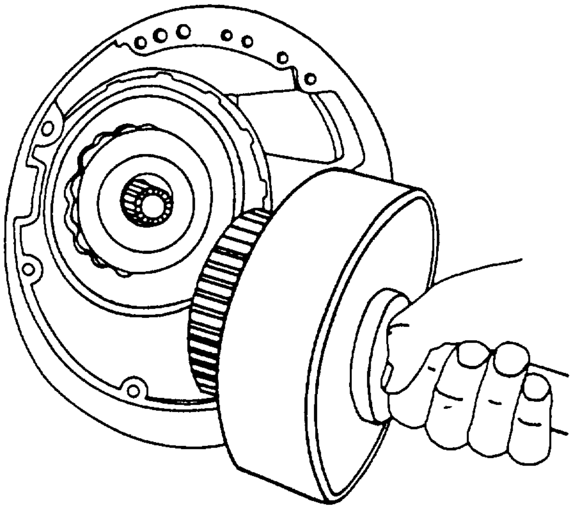


Figure 7-33.—Removing the forward clutch assembly.

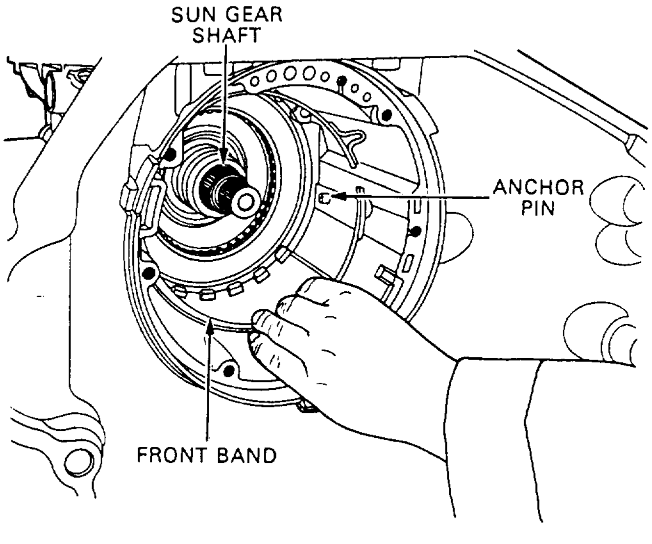


Figure 7-35.—Removing the front band.

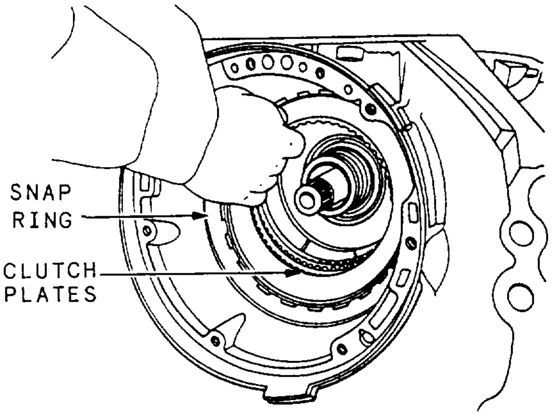


Figure 7-36.—Removing the intermediate backing plate and clutch plate.

clutch pack (fig. 7-36) and remove it. Remove the center support-to-case snap ring (fig. 7-37). At this point the center support bolt should be removed (fig. 7-38). A thin wall twelve point three-eighths inch socket is required to do this; no other tool will work This is a hollow bolt that is used as art oil supply passage for the intermediate clutch assembly. Place the transmission in a vertical position and extract the center support, gear assembly, and output shaft (fig. 7-39). Use care when doing this, the gearset is quite heavy. The rear unit selective washer, center support-to-case spacer, and the rear band may now be removed (fig. 7-40).

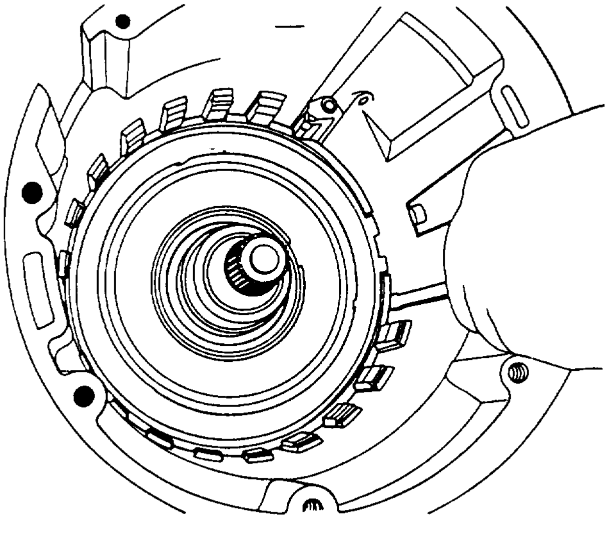


Figure 7-37.—Removing the center support snap ring.

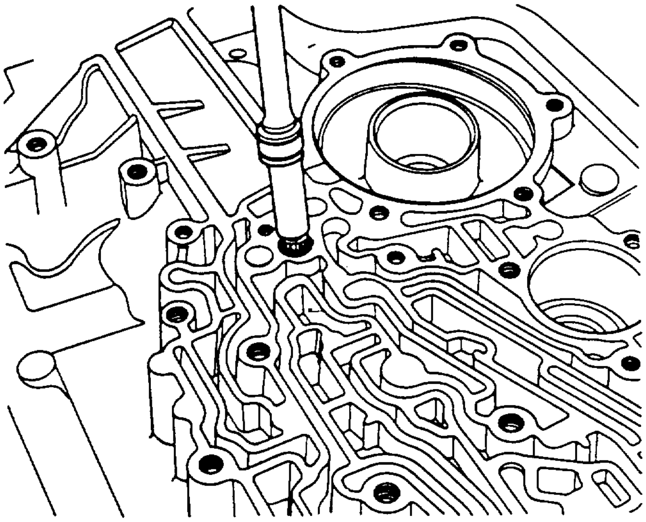


Figure 7-38.—Removing the center support bolt.

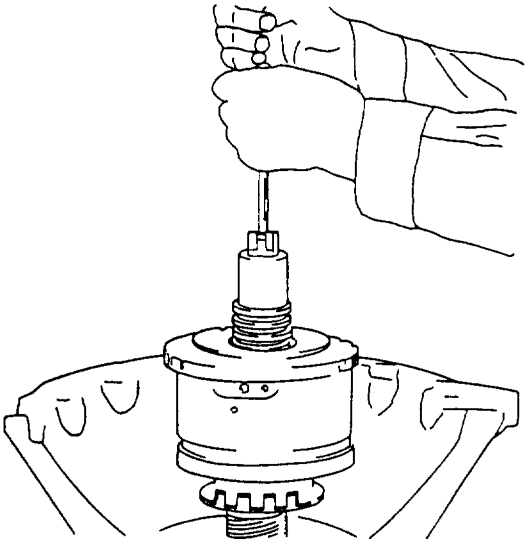


Figure 7-39.—Removing the center support and gear unit.

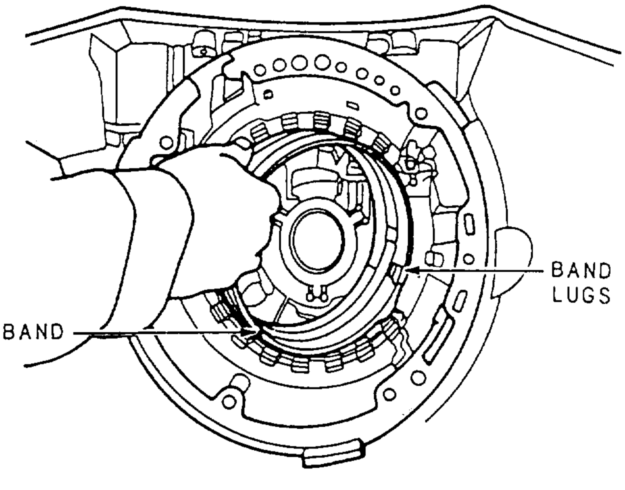


Figure 7-40.—Removing the rear band.

With the major components removed, the transmission case is ready to be thoroughly cleaned out and inspected for wear or damage.

All assemblies that have been removed from the transmission, such as the oil pump, clutch packs, valve body, servos, etc., should all be disassembled, inspected, and rebuilt to the manufacturer's specifications. Always replace all seals and gaskets before reassembly. Look for any worn thrust washers and replace them as required. Check the condition and proper operation of all vacuum or electronic devices connected to the unit. The automotive type of torque converter is usually a welded unit and can only be flushed out, usually with solvent, and pressure tested. If this type of torque converter proves to be the problem, replace it. Because of size and expense, construction equipment torque converters are made to be disassembled and repaired.

Remember, the instructions for disassembly given here are for one type of transmission and only of one model of that type. The information is only to give you an idea of the complexities involved in automatic transmission overhaul, not to make you an expert in this field. Be sure to check the transmission serial numbers to ensure you are getting the correct overhaul parts.

Aside from size and weight, construction equipment automatic transmissions are the same in many respects as automotive automatic transmissions and only specific instructions for that particular unit will be different. For these "specific" instructions, go to your technical library and check out the correct repair manual.

ASSIGNMENT 7

Textbook Assignment: "Clutches and Automatic Transmissions," pages 7-1 through 7-25.

7-1. The automatic transmission of a vehicle matches power and speed to what factor?

1. RPM
2. Maximum torque
3. Load requirements
4. Minimum torque required

7-2. The pressure plate of a clutch assembly is held tightly against the flywheel by what means?

1. Spring pressure
2. Hydraulic pressure
3. Threaded bolts
4. Lever links

7-3. A flexible cable clutch release mechanism is most commonly used with what type of equipment?

1. Construction
2. Automotive
3. Allied
4. MHE

7-4. A hydraulic type of clutch release mechanism is normally found on heavy construction equipment for which of the following reasons?

1. Low-release pressure is required to operate the clutch
2. A slow-release action is required to operate the clutch
3. Extreme pressure is required to operate the clutch

7-5. A double–disk clutch has an additional driven disk and what other part?

1. A clutch disk
2. A pressure plate
3. A driving plate

7-6. Which of the following symptoms is common to clutch malfunction?

1. Dragging
2. Slipping
3. Noise
4. Each of the above

7-7. Clutch slippage is most noticeable during which of the following conditions?

1. When the vehicle is cold
2. When the vehicle is hot
3. When the vehicle is heavily loaded
4. When the vehicle is traveling at high speeds

7-8. When you notice insufficient clutch pedal free travel, you should check which of the following items?

1. The linkage for proper adjustment
2. The release bearing for wear or dryness
3. The friction disk facing for normal surface condition

7-9. To avoid the need for rework, you should replace the complete clutch assembly.

1. True
2. False

7-10. Which of the following practices is recommended to correct a stiff clutch pedal?

1. Oiling the disk facings
2. Riding the clutch
3. Lubricating the clutch linkage
4. Adjusting free travel of the pedal

7-11. When the clutch is being uncoupled, a series of slight movements (pulsations) can be felt on the clutch pedal. The trouble indicated may be caused by which of the following conditions?

1. A warped pressure plate or warped clutch disk
2. The flywheel not being seated on the crankshaft flange
3. Misalignment of the engine and transmission
4. Each of the above

IN ANSWERING QUESTIONS 7-12 THROUGH 7-21, SELECT FROM COLUMN B THE TYPE OF CLUTCH TROUBLE CAUSED BY THE CONDITION IN COLUMN A. RESPONSES IN COLUMN B MAY BE USED ONCE OR MORE THAN ONCE. USE TABLE 7-1 IN YOUR TRAMAN AS A REFERENCE.

	A. CONDITIONS		B. TYPES OF TROUBLE
7-12.	Faulty clutch master cylinder	1.	Clutch slippage
7-13.	Improperly installed release arm	2.	Clutch release failure
7-14.	Excessive free play in clutch pedal linkage	3.	Clutch grab or chatter
7-15.	Seized pilot bearing on transmission shaft	4.	Clutch noise
7-16.	Binding clutch linkage		
7-17.	Oil-soaked clutch plate		
7-18.	Broken engine mounts		
7-19.	Worn clutch drive plate		
7-20.	Warped pressure plate		
7-21.	Worn clutch release bearing		

7-22. Which of the following is the reaction member in a Turbo Hydra-matic 400 transmission torque converter?

1. The pump
2. The turbine
3. The stator
4. The lock up clutch

7-23. In automatic transmissions, gears are designed so several teeth are in contact with one another at one time. This design is used for which of the following reasons?

1. To provide greater strength
2. To provide greater gear reduction
3. To reduce gear clash
4. To increase torque

7-24. When torque is increased during the operation of a planetary transmission, what will happen to the output speed?

1. It will remain the same
2. It will increase
3. It will decrease

7-25. Your holding the sun gear stationary and applying power to the internal gear in a clockwise direction will produce what result in gearing?

1. Overdrive
2. Reverse
3. Direct drive
4. Reduction

7-26. What results when two members of a planetary gearset rotate together?

1. Reverse
2. Low gearing
3. High gearing
4. Direct drive

7-27. What means or device within the torque converter allows for shifting without interruption of engine torque application?

1. The turbine
2. The fluid coupling
3. The stator
4. The impeller

7-28. In an automotive application, the converter cover is normally attached to the engine by what means?

1. Bolted to a slotted drive
2. Bolted to a flex-plate
3. Bolted to a flywheel ring
4. Bolted to a clutch plate

7-29. When the engine is running, the converter pump is operational.

1. True
2. False

7-30. With the engine operating at full throttle, the transmission in gear, and the vehicle standing still, the converter is capable of multiplying engine torque by approximately what ratio?

1. 4:1
2. 1:2
3. 2:1
4. 1:4

7-31. The torque converter acts as a fluid coupling during which of the following events?

1. When the stator is active
2. When the impeller and the turbine are rotating about the same speed
3. When the transmission is in reverse gear

7-32. The Turbo Hydra-matic 400 uses what type of hydraulic pump to build pressure?

1. Positive diaphragm
2. Piston
3. Rotary vane
4. Internal gear

7-33. Oil returning from the converter is directed to which of the following locations?

1. The transmission cooler
2. The transmission sump
3. The transmission pump inlet
4. The converter inlet

7-34. The pressure regulator of a Turbo Hydra-matic 400 type of transmission maintains approximately what line pressure at idle?

1. 35 psi
2. 60 psi
3. 70 psi
4. 100 psi

7-35. The small area of the forward clutch serves what purpose?

1. To provide final holding force
2. To provide line pressure
3. To provide smooth, initial takeup
4. To release pressure

7-36. The secondary weights of the governor act on which of the following components?

1. The regulating valve
2. The output shaft
3. The vacuum gear

7-37. A variable oil pressure is used to control upshift at a higher vehicle speed. This pressure is also known by what other terminology?

1. Governor pressure
2. Torque pressure
3. Modulator pressure
4. Vacuum pressure

7-38. Modulator pressure is regulated by engine vacuum and is an indicator of which of the following settings?

1. Throttle
2. Shift valve
3. Regulator valve

7-39. Higher clutch pack apply pressure is required during what engine event?

1. Idle
2. Half speed
3. Full throttle

7-40. Between hot and cold, the automatic transmission fluid level will vary what maximum measure?

1. 1/4 inch
2. 1/2 inch
3. 3/4 inch
4. 1 inch

7-41. In addition to giving off a burnt smell, overheated transmission fluid will turn what color?

1. Brown
2. Black
3. Red
4. Milky

7-42. Your using transmission fluid that is incompatible with the unit you are working on may lead to which of the following problems?

1. Early transmission failure
2. Damage resulting in transmission overhaul
3. Both 1 and 2 above
4. Transmission overheating problems

7-43. Air trapped in the hydraulic system of an automatic transmission will cause which of the following problems?

1. Slow application of the clutch packs
2. High-line pressure
3. Hardshifting
4. Low-torque output

7-44. Water mixed with automatic transmission fluid will turn the fluid what color?

1. Brown
2. Milky
3. Pink

7-45. When a lock up band on a Turbo Hydra-matic 400 transmission does not meet required specifications, what action should you take?

1. Tighten the adjusting nut to 125-inch pounds and back it off 1 1/2 turns
2. Tighten the adjusting nut to 100-inch pounds and lock it in place
3. Replace the band

7-46. “Severe service” includes which of the following conditions?

1. Taxi service
2. Trailer towing
3. Stop and go driving
4. All of the above

7-47. Rags are an acceptable item to dry a screen in an automatic transmission.

1. True
2. False

7-48. Most modern torque converters do NOT have which of the following parts?

1. A drain plug
2. A stator
3. A turbine
4. A pump

7-49. Which of the following methods should you use to remove air trapped in a transmission hydraulic system?

1. Road testing the vehicle and rechecking the fluid upon returning from the test
2. Moving the gear selector through all positions several times with the engine running and the brakes applied
3. Letting the unit sit for 10 minutes while the fluid settles

7-50. What would most likely cause the fluid in an automatic transmission to foam?

1. Underfilling
2. Wrong fluid
3. Overfilling

7-51. To complete any repairs on an automotive transmission, you must remove the transmission from the vehicle.

1. True
2. False

IN ANSWERING QUESTIONS 7-52 THROUGH 7-58, SELECT FROM COLUMN B THE TYPE OF TRANSMISSION TROUBLE CAUSED BY THE CONDITION IN COLUMN A. RESPONSES IN COLUMN B MAY BE USED ONCE OR MORE THAN ONCE. USE TABLE 7–2 IN YOUR TRAMAN AS A REFERENCE.

A. CONDITIONS	B. TYPES OF TROUBLE
7-52. No drive in drive range	1. Vacuum modulator sticking
7-53. No part throttle downshift	2. Rear band inoperative
7-54. No engine braking in first gear	3. Forward clutch inoperative or slipping
7-55. No detent downshift	
7-56. High or low oil pressure	4. Two-three shift valve sticking
7-57. Slipping in reverse	
7-58. No engine braking in second gear	

7-59. For you to troubleshoot an automatic transmission, an engine does not have to be in good running condition.

1. True
2. False

7-60. During overhaul, the incorrect disassembly of an automatic transmission may cause what result?

1. Minor parts damage only
2. Severe parts damage only
3. Unnecessary equipment down time only
4. Severe parts damage and unnecessary equipment down time

7-61. During an automatic transmission overhaul, an air compressor is used for which of the following purposes?

1. To conduct tests
2. To blow-dry parts
3. Both 1 and 2 above
4. To disassemble clutch packs

7-62. When you disassemble an automatic transmission, you must remove what component before removing the valve body?

1. The control valve spacer
2. The vacuum modulator
3. The rear servo
4. The check balls

7-63. The hollow bolt used in the assembly of a Turbo Hydra-matic 400 transmission is an oil passage for what component?

1. The rear band
2. The intermediate clutch
3. The rear clutch
4. The forward clutch

7-64. After troubleshooting, what action should you take if the torque converter of a Turbo Hydra-matic 400 transmission proves to be the problem?

1. Rebuild the torque converter
2. Replace the torque converter
3. Reuse the torque converter after flushing

CHAPTER 8

AIR COMPRESSOR OVERHAUL

CAUTION

THE OPERATION OF AIR COMPRESSORS IS DANGEROUS!!!! The chance of fatal injury is high. High pressure air escaping from air valves during testing or normal operation is of such a high pitch sound that PERMANENT EAR INJURY AND HEARING LOSS ARE A DIRECT RESULT. High pressure air can CUT THROUGH THE SKIN, DESTROY TISSUE, CAUSE AIR EMBOLISM, AND DEATH.

Air compressors are used throughout the Naval Construction Force (NCF). They supply compressed air for numerous pneumatic tools, rock drilling, well drilling, diving, and cleaning operations. Certain automotive and construction equipment use air-brake systems in which you will find an air compressor (fig. 8-1) and air compressor controls. In these systems the compressor may be smaller than others described in this chapter, but the operating principles are the same. As a CM-1, it is your job to make sure these units are maintained properly and to troubleshoot, repair, and overhaul them. In the *Construction Mechanic 3 & 2,*

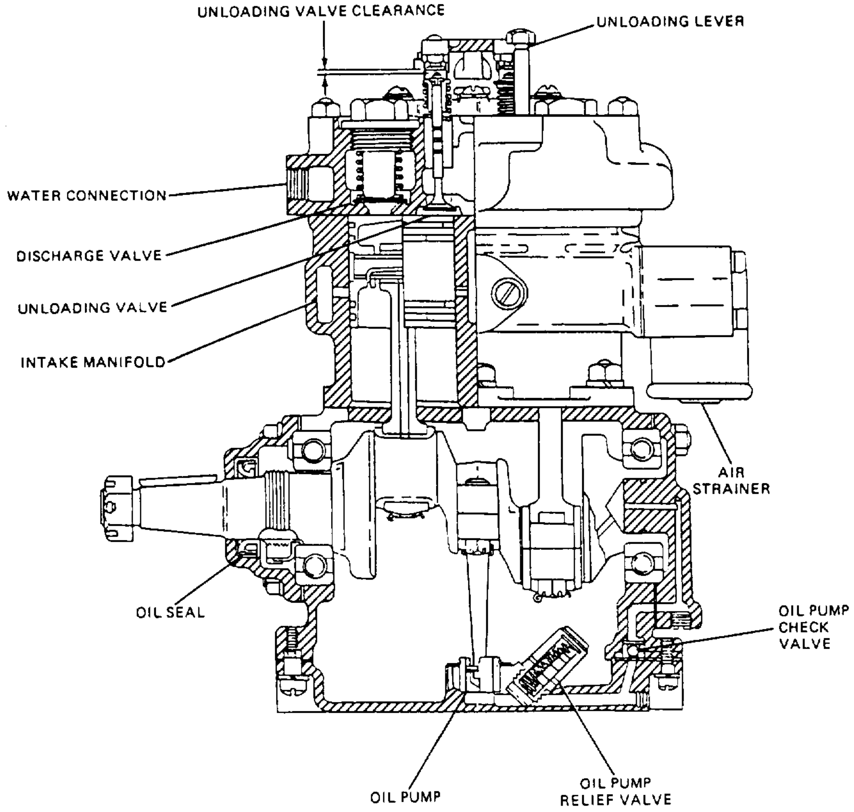


Figure 8-1.—Typical reciprocating air compressor used in vehicular air-brake systems.

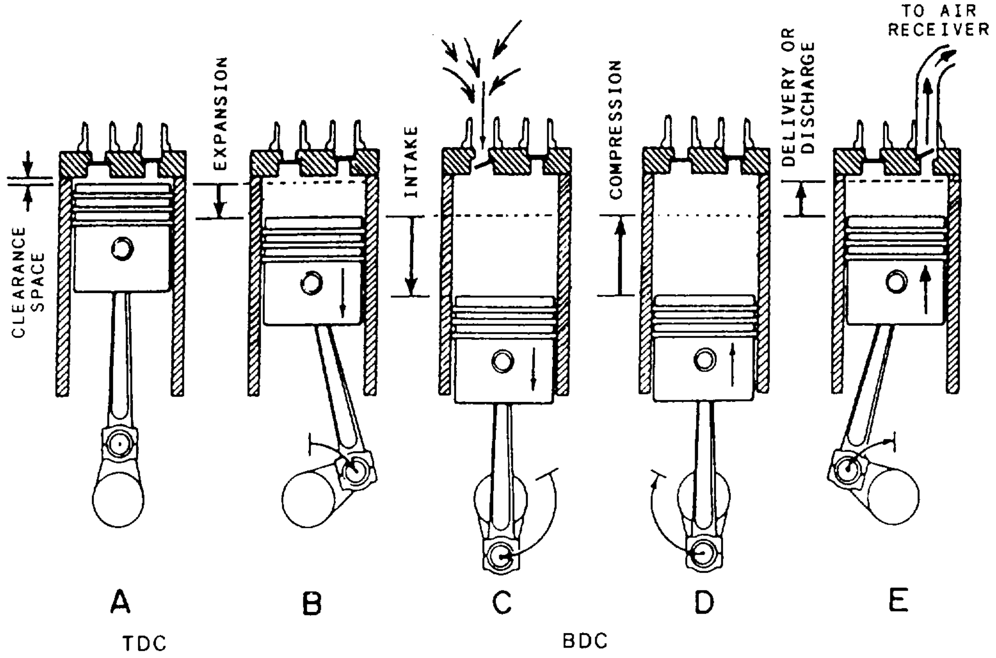


Figure 8-2.—Compression cycle in a reciprocating air compressor.

NAVEDTRA 10644-G1, air compression systems are described as to basic design, operation, and preventive maintenance. In this chapter we will review some of the earlier material and discuss troubleshooting and overhaul of air compressors and their related controls. So put your ear protection on and come with me.

TYPES OF AIR COMPRESSORS

The three types of air compressors are reciprocating, sliding vane, and screw design. The driving unit provides power to operate the air compressor and is usually a diesel engine. Air

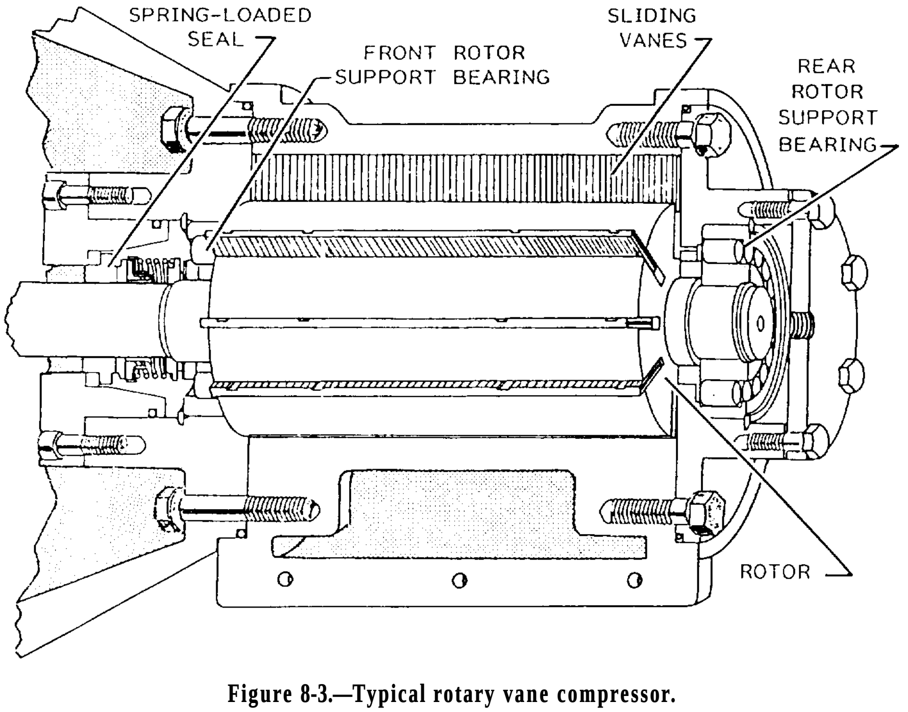


Figure 8-3.—Typical rotary vane compressor.

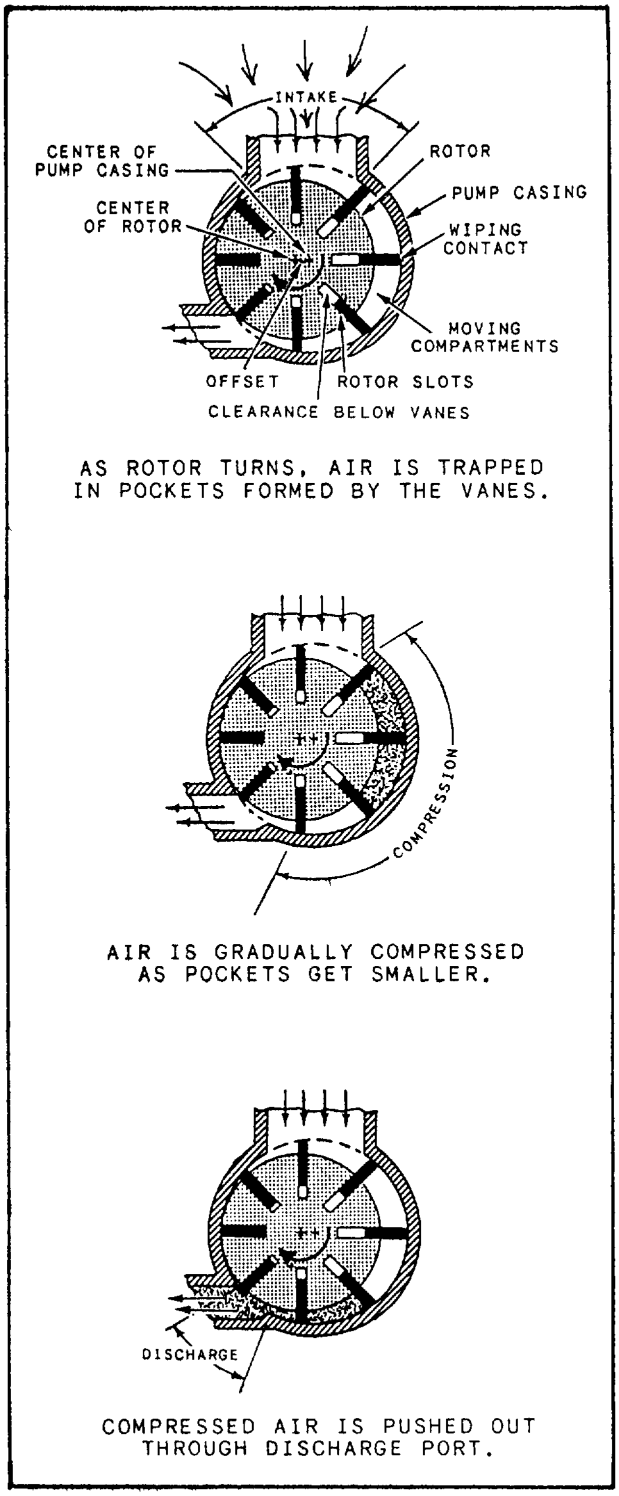
compressors may be air or liquid-cooled. The compressors used by the NCF are almost identical to those used in private industry. The difference is not in the compressor, but in the trailer that carries the unit. For example, a Sullair 750 cfm 250 psi unit is carried on a specially modified trailer. This is done to allow the unit to be mobile loaded on a C-130 type of aircraft for air detachment exercises and other contingency purposes.

RECIPROCATING COMPRESSOR

The cylinder block of the reciprocating compressor is designed much like that of an internal combustion engine found in most automobiles. The similarity ends at the cylinder head that is constructed specifically for air compression purposes. Figure 8-2 shows the basic movement of air through the reciprocating unit. As the piston moves down, air is drawn into the cylinder through a one-way intake valve. Once the piston reverses direction and begins upward motion, the intake valve is forced closed, and the compression of air forces the discharge valve open, passing the air out of the cylinder and into the air receiver. The most common intake and discharge valves are simple spring-loaded devices, varying in design and size according to the size of the air compressor. The reciprocating compressor is most likely to be found at public works stations, in a shop supplying air for industrial use, or under the hood of CESE with air actuated brakes

SLIDING VANE (ROTARY) COMPRESSOR

Currently, the most common industrial air compressor in the NCF is the oil-injected rotary vane type. This particular type of air compressor, simple in design, has fewer moving parts than the reciprocating unit, making maintenance less of a problem. It gives a more constant flow of compressed air, is compact, and is almost vibration-free. The common sizes range from 125 to 750 cfm. Figure 8-3 shows an oblique view of the rotor with the vanes in place, and figure 8-4 shows the basic operation. The rotor turns about the center of its shaft which is offset from the center of the compressor casing. Centrifugal force keeps the vanes extended, maintaining a wiping contact between the compressor casing and the edge of the vanes. This action forces the vanes to slide in and out as the rotor rotates (fig. 8-4). The crescent-shaped space between the compressor casing and the rotor is divided into compartments which increase and decrease in size as the rotor rotates. Thus, when free air enters each compartment as it passes the air intake opening, it is trapped as the compartment rotates closed. The air is then carried around in each successive compartment and is discharged at a higher pressure due to the decreasing volume of the moving compartments as they progress from one end to the other of the crescent-shaped space. Oil is injected into and circulated through the air compressor to seal the vanes against the casing walls, to lubricate the internal parts,

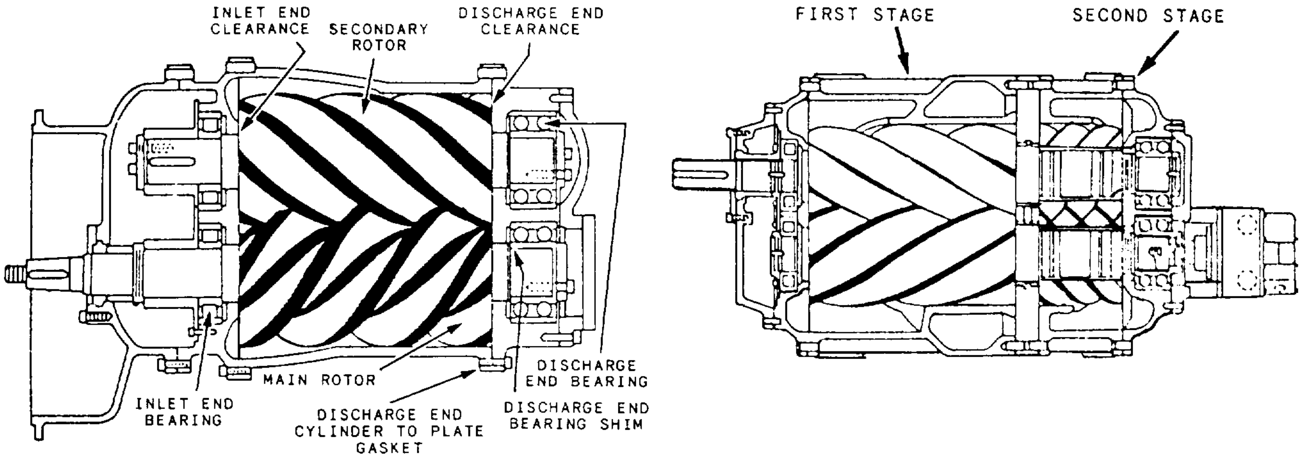


AS ROTOR TURNS, AIR IS TRAPPED IN POCKETS FORMED BY THE VANES.

AIR IS GRADUALLY COMPRESSED AS POCKETS GET SMALLER.

COMPRESSED AIR IS PUSHED OUT THROUGH DISCHARGE PORT.

Figure 8-4.—Steps in the compression cycle of a rotary vane compressor.



TYPICAL SINGLE-STAGE DESIGN

TYPICAL TWO-STAGE DESIGN

Figure 8-5.—Typical screw type of air compressor.

and to cool the air during the compression cycle. Oil is removed from the compressed air by an oil separator before it leaves the service valves.

SCREW TYPE OF COMPRESSOR

The screw type of air compressor is an oil-injected, helical screw, direct drive, positive displacement air compressor. It maybe single or dual stage (fig. 8-5). The design is relatively simple, being a pair of precisely matched spiral-grooved rotors (fig. 8-6) turning within a single-piece twin-bore cylinder. The rotors provide positive-displacement-internal compression-smoothly, without surging. The matched rotors, one lobed and one grooved, intermesh in the twin bores of the single-piece cylinder. As the rotors turn and unmesh at one end, air is taken in, compressed, and moved through the twin-bore cylinder by the rotors as they rotate. Figure 8-7 shows the steps of airflow past the rotors; figure 8-8 shows aside view of the airflow through the compressor. Compression takes place within the twin-bore cylinder

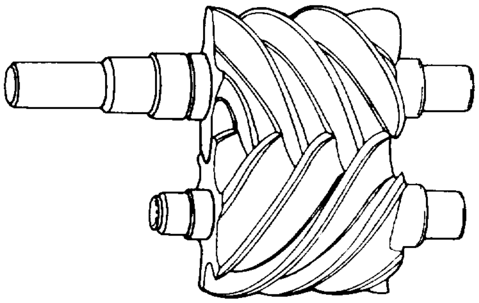


Figure 8-6.—Male and female screw type of air compressor rotors (matched set).

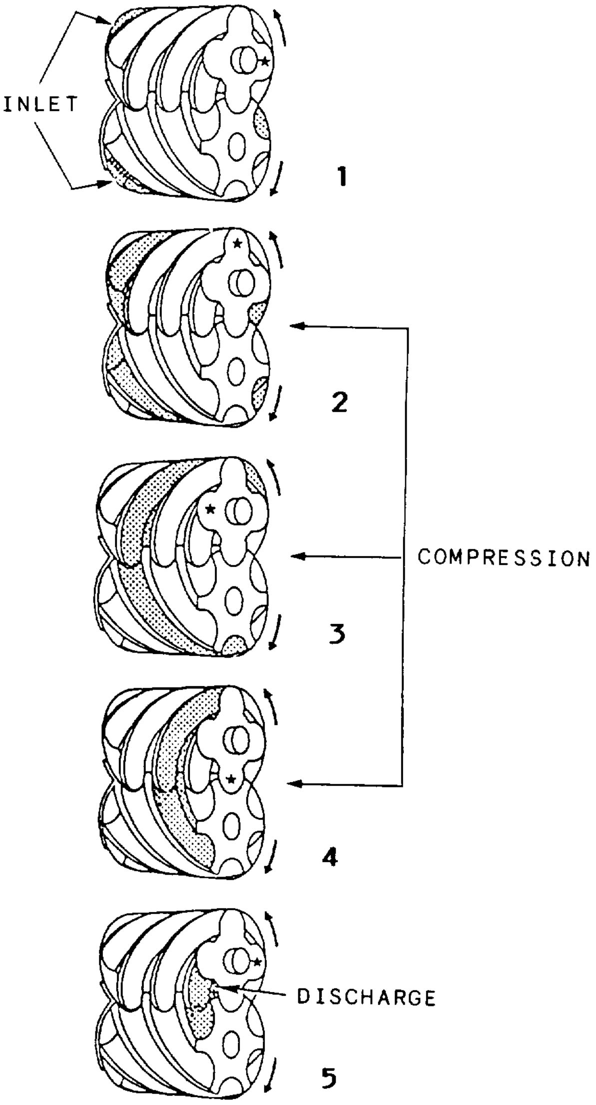


Figure 8-7.—The compression cycle of a screw type of air compressor.

as the volume decreases between the turning mated rotors. Compression is completed as the air is passed out of the discharge end of the twin-bore cylinder. The process is continuous as long as the rotors turn; thus we have an extremely smooth flow of compressed air. As with the vane type of unit, compressor oil is injected into the twin-bore cylinder and picked up by the mating rotors. The oil serves to seal the rotor surfaces and to cool the air in its compression stages. The oil that mixes with the air during compression is passed into a receiver separator where it is removed and returned to the oil sump.

COMPONENTS OF COMPRESSORS

Air compressors consist of basic systems and components such as the air filter, the air control system, the compressing element, and the air receiver and lubrication systems. Other components are safety devices, cooling systems, and air/oil separators. These systems and components allow the air compressor to perform its design function efficiently and safely. The following sections detail the purpose of these different components and systems, and their relationship to efficient air compression.

SAFETY DEVICES OF COMPRESSORS

Air compressors have automatic safety control devices that shut the unit down in the event of a mechanical malfunction.

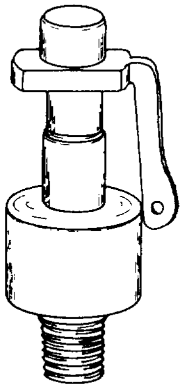


Figure 8-9.—Typical pressure release valve.

CAUTION

Safety devices on air compression systems are not to be bypassed FOR ANY REASON.

Engine overspeeding, overheating, low oil pressure, and low or high fuel pressure are all reasons for the prime mover to be shut down. These safety devices are placed on the power source to protect it.

On the compressor, a pressure release (safety relief) valve (fig. 8-9) releases excess air pressure to protect personnel, the compressor, tanks, and piping from damage if the air pressure exceeds the design limits. The safety valve is mounted in plain view on the air receiver and is normally set at 125 psi (special-duty air compressors may have different psi settings). The

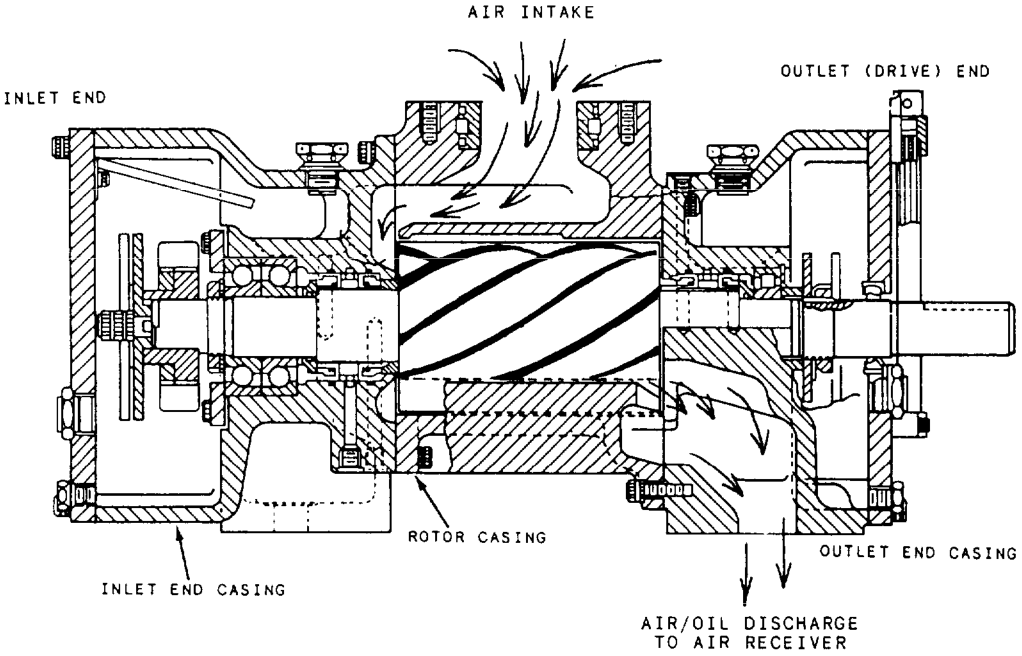


Figure 8-8.—Example of airflow through a screw type of air compressor.

pressure settings may be stamped on tags and wired to the valve. DO NOT REMOVE THE TAGS.

Air discharge temperatures of 220°F to 250°F (temperature ratings vary to manufacturer) will cause the engine to shut down. To activate this system, the operator is not required to act. Restart should not be attempted until the oil has cooled and the reason for the high oil temperature has been determined. This switch is located on the intercooler (two-stage units) or on the aftercooler (single-stage and two-stage units). Your repair manual will show the exact locations.

Check safety controls periodically to be sure they are functioning properly. Check them according to the manufacturer's specifications.

PRESSURE CONTROL SYSTEM

Air compressors are governed by a pressure control device. In a reciprocating compressor, the pressure control system causes the suction valves to remain open and the engine to idle when the air pressure reaches a set maximum. The discharge valve then acts as a check valve and air is trapped in the receiver at maximum required pressure. With the suction valve held open by receiver air pressure, the compressor cannot function (if it did, it would raise the receiver pressure above the design pressure and blow the safety valve). At the same time, receiver air pressure is fed to a speed control unit that returns the power source to idle (if the power source is an electric motor, the motor is shut off). As the air pressure in the receiver drops below the set minimum, the pressure control unit causes the engine to increase speed, the suction valves to close, and the compression cycle to resume.

The rotary type of air compressors control pressure by using a pneumatic, mechanical system (fig. 8-10) to select proper engine speed and air intake opening to suit demand. The air intake control assembly is modulated by receiver air pressure, depending on the need for air. When the engine slows to idle as a result of low demand, the air intake valve closes to lessen the amount of free air entering the compressor; first, by slowing, then by stopping the compression cycle. As the air pressure in the air receiver drops, it causes the control system to open the air intake valve and to apply the throttle at the same time, but only enough to return the receiver air pressure to its maximum limit.

The screw type of compressor uses a pressure control system similar to that of the rotary compressor

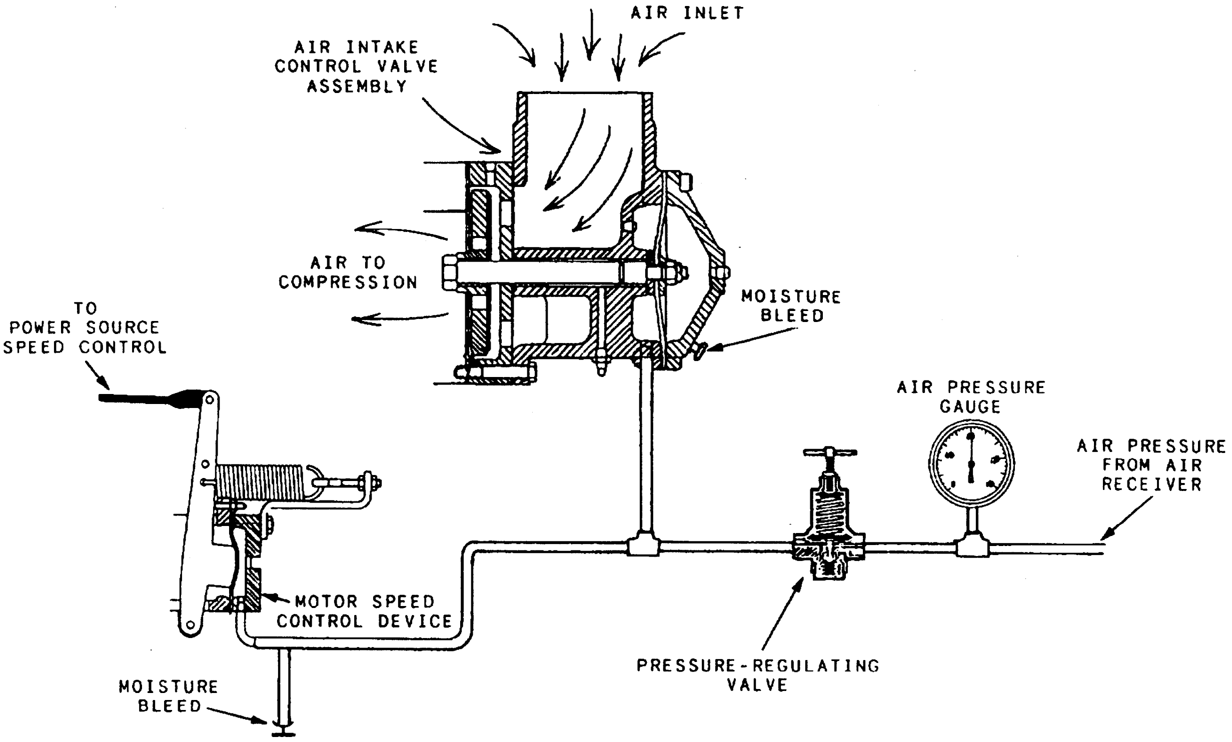


Figure 8-10.—Pressure control system for a rotary vane air compressor.

as it varies engine speed and air intake opening to meet the demand for compressed air.

Because of the great variety of throttle control and pressure-regulating devices used with compressors, detailed instructions on their adjustment and maintenance should be obtained from the manufacturer's maintenance and repair manual. When a control valve fails to work properly, disassembly and a thorough cleaning are necessary. Some control valves are fitted with filters filled with sponge or woolen yarn to prevent dust and grit from entering into the valve chamber and to remove gummy deposits that come from the oil used in the compressor cylinders. Replace the filter with the specified material each time a valve is serviced.

WARNING

Do NOT use cotton as a filter element as it will pack down and stop the airflow.

AIR INTAKE SYSTEM

Air compressors are protected against ingestion of dust and foreign particals by air cleaners. These maybe oil bath or dry-filter type. The filtration system maybe a single falter serving both the power source and the air compressor, or each unit may have an individual filter. Larger air compressors working in dirty conditions may use a two-stage system (fig. 8-11). In most cases, the falters are the same as those used on automotive and construction equipment engines, just larger.

Satisfactory operation of the compressor depends on a clean supply of air. Unless the filters are inspected and cleaned regularly they become clogged, lose their efficiency, become damaged, and compressor capacity is lost. Air filters can be replaced or cleaned. Oil bath air falter cleaning instructions can be found in the relevant maintenance and repair manual. This type of air filter is no longer common. The dry-type filter can be replaced or cleaned. Before cleaning, check the filter for damage

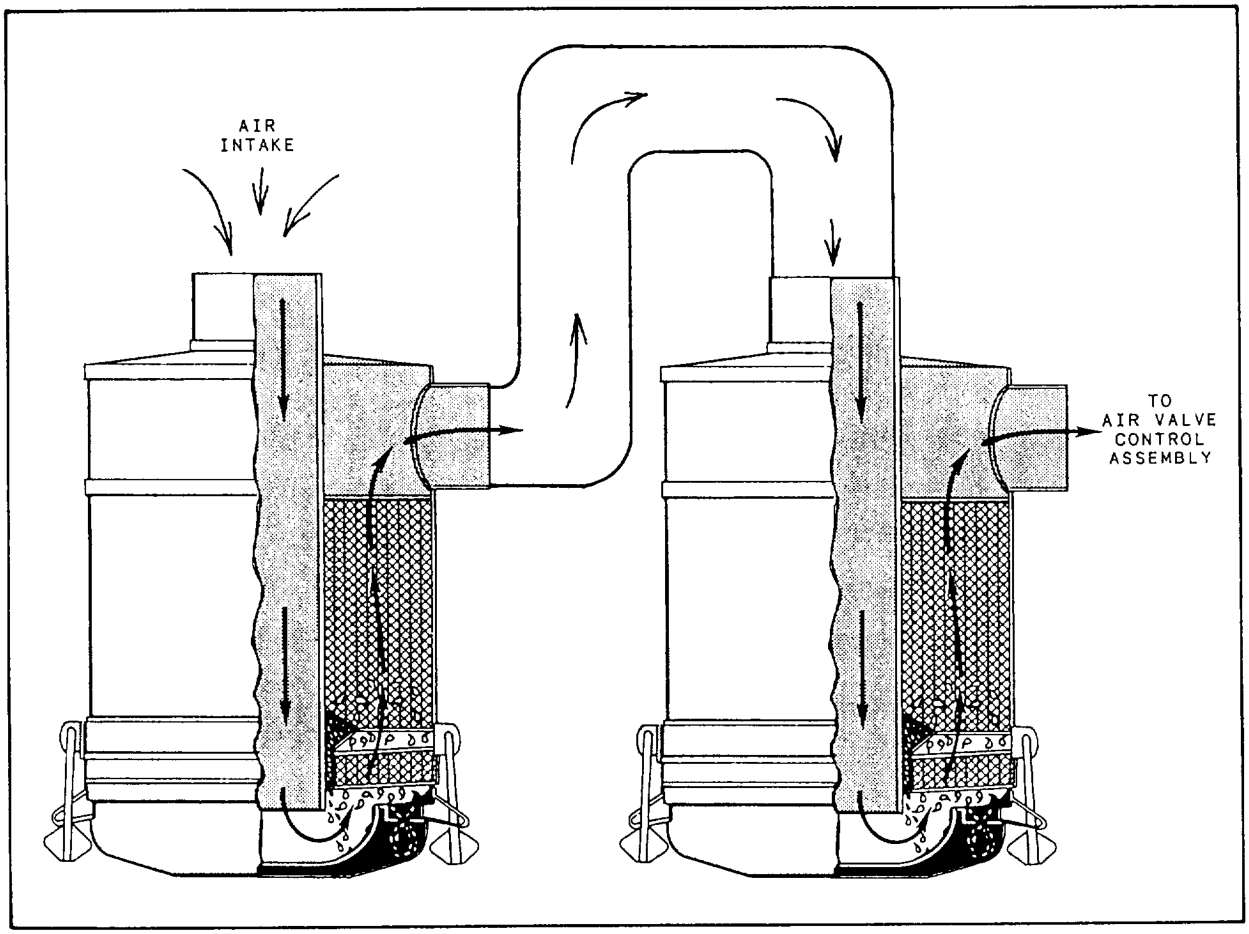


Figure 8-11.—Two-stage, oil bath, air filter system.

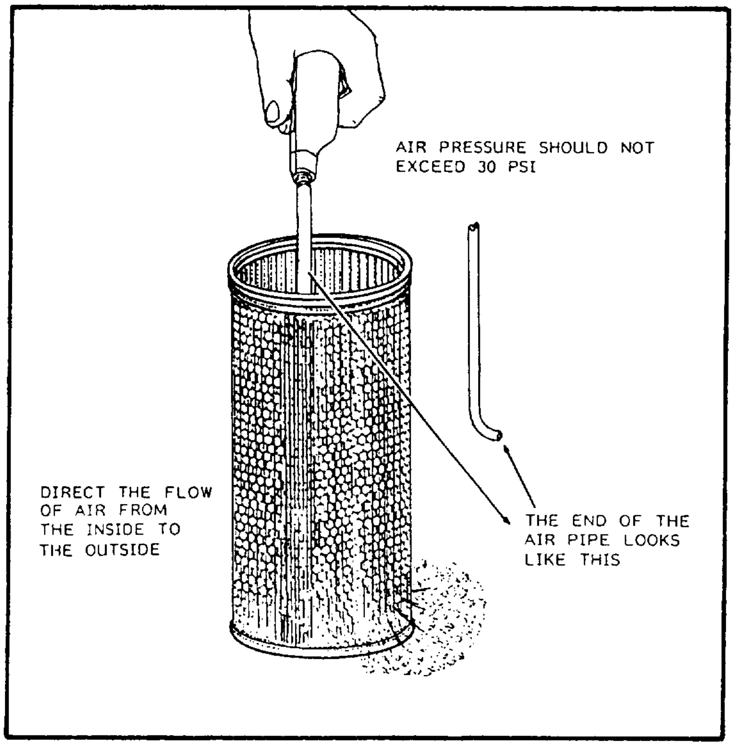


Figure 8-12.—Cleaning an air filter with low pressure air.

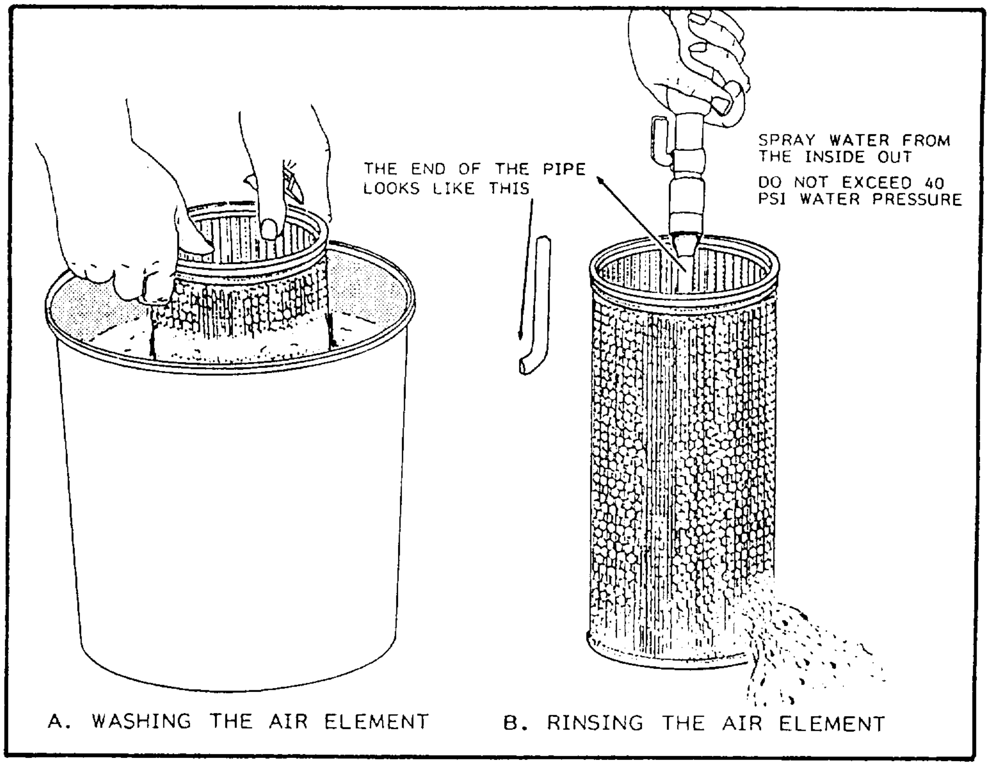


Figure 8-13.—Cleaning an air filter with soap and water.

that would require replacement, such as broken gaskets or dents that prevent sealing. One way to clean the filter is to use LOW-PRESSURE AIR, and blow the debris trapped in the filter against the direction of airflow from the inside to the outside (fig. 8-12). Never exceed pressures of 30 psi when using this method of cleaning, and never use this method of cleaning more than six times on the same filter. Another way you may clean the filter is to wash it with water and a mild detergent (fig. 8-13). This is useful if compressed air is unavailable or if the filter is clogged with grease or oily dirt. When you are using water, do not exceed water pressures of 40 psi.

WARNING

Gasoline or kerosene should never be used to clean air filter elements as it causes explosive fumes to collect in the air receiver.

Dry the filter and hold a bright light on the inside of it. Remember, concentrated light shining through the filter element indicates holes that require replacement of the filter. Following service to the air cleaning system, check and reset the air restriction indicator if required.

THE AIR RECEIVER

The air receiver is a welded steel tank installed on the discharge side of the compressor. It acts as an oil sump and a condensation chamber for the removal of oil and water vapors. It stores air during the operation to actuate the pressure control system. The oil separator element is in the tank; and on top, are the safety valve, automatic blow-down valve, and at least one outlet for a service valve. Figure 8-14 is an example of a typical air receiver-oil separator.

NOTE

Reciprocating air compressors do not require oil separators because oil is not circulated through the air system. NAVSEA approved reciprocating air compressors are the only systems used to compress air for diving operations.

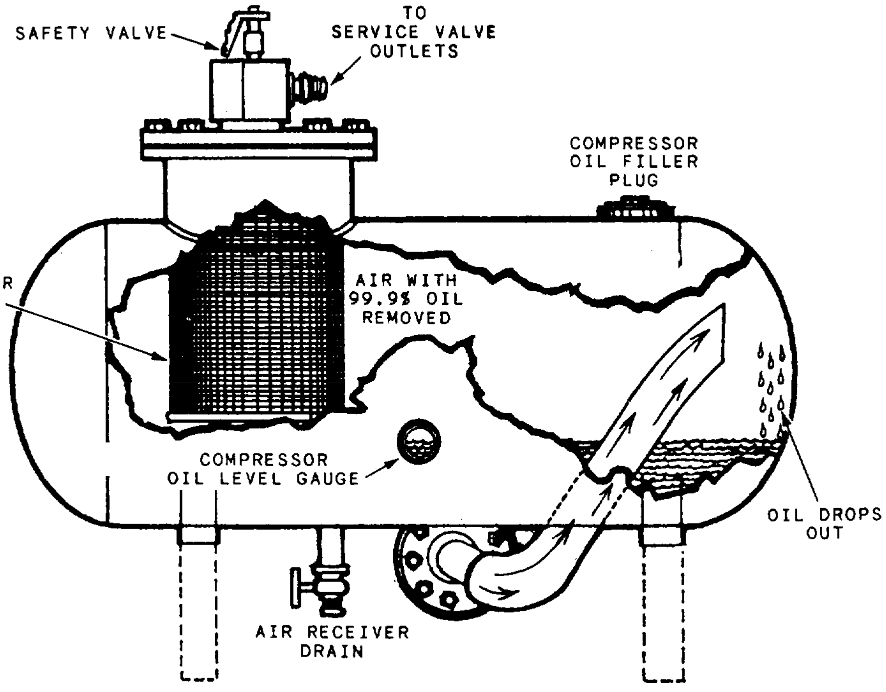


Figure 8-14.-Typical air receiver/oil separator.

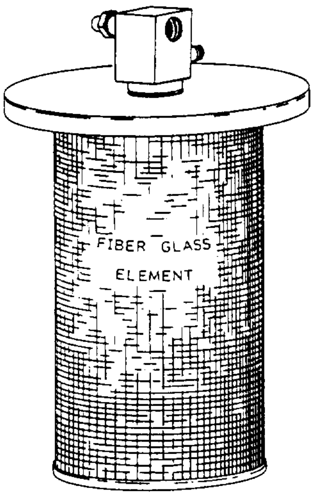


Figure 8-15-Oil separator element.

Maintenance for the air receiver is not complicated and is limited to visual inspection of flanges and threaded fittings. The demister (fig. 8-15), or oil separator, should be removed and replaced according to the manufacturer's recommendations for the unit you are working on.

INTERCOOLERS

As the air compressor compresses air, heat is generated which causes the air to expand requiring an increase of horsepower for further air compression. If you remove the heat generated by compressing air, the total horsepower required for additional air compression is reduced up to 15 percent. In multistage reciprocating compressors, heat is removed by the use of intercoolers (fig. 8-16) or heat exchangers placed between each stage of compression.

NOTE

In the rotary and screw types of air compressors, oil is injected into the compressor at the first stage-cooling the air. Thus, the intercooler is not required.

Some intercoolers have a condensation drain that should be serviced daily (at a minimum), and some have a safety relief. If the safety relief valve is opening due to overpressure, it is an indication of possible leakage in the high-pressure suction valves. You should keep the intercooler clean.

AFTERCOOLERS

Water or moisture is not desirable in the transmission lines of an air compression system. Water carried through the lines washes away lubricating oil from the tools the compressed air is running. This causes the tools to operate sluggishly and increases the need for maintenance. The effect is compounded in high-speed tools, where the wearing surfaces are limited in size and excessive wear reduces efficiency by creating air leakage. Further problems result from the decrease of temperature caused by the sudden expansion of air at the ted. This low temperature creates condensation which freezes around ports and valves and impairs efficiency. These conditions can be minimized by removing the moisture from the air directly after compression, before the air enters the distribution systems. Through the use of an aftercooler or air radiator, heat is transfered from

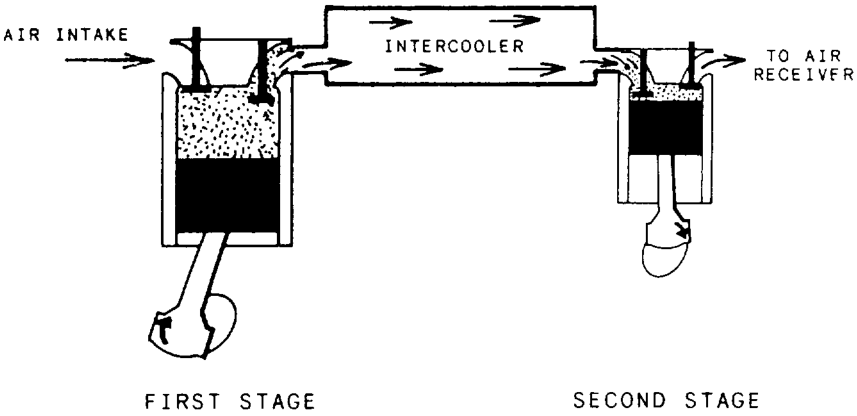


Figure 8-16.-Example of an intercooler on a two-stage reciprocating air compressor.

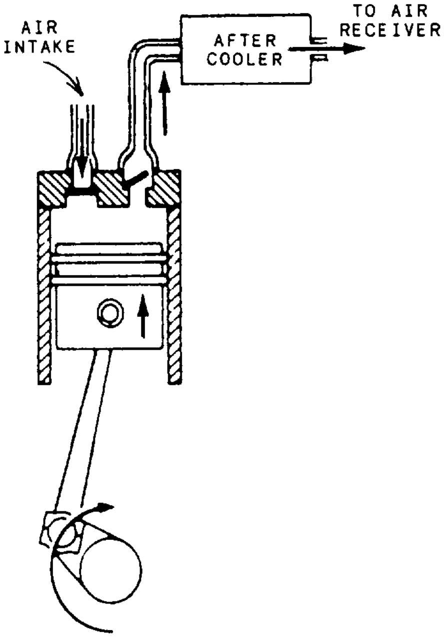


Figure 8-17.-Example of an aftercooler on a reciprocating type of air compressor.

the compressed air to the atmosphere reducing the temperature to a point where most of the moisture is removed. This eliminates the difficulties that moisture causes throughout the system and at the point where the air is used. Aftercoolers are normally found only on reciprocating units and are placed between the discharge valve and the air receiver (fig. 8-17).

LUBRICATION SYSTEM

The lubrication system in the reciprocating compressor is much like that of an automobile engine–a pressurized system force feeding oil to lubrication points (fig. 8-18). Oil assists the piston rings in forming a tight seal in the cylinders and performs a certain amount of cooling. Typical small compressors use a splash type of lubrication system.

As we have seen, vane and screw type of air compressors depend on oil for more than just lubrication. The oil lubricates the rotor bearings and internal working parts and adds to the efficiency of the compressor by forming a tight seal between each air compartment of the vanes or screws. Circulating oil also acts as a cooling medium absorbing the heat generated

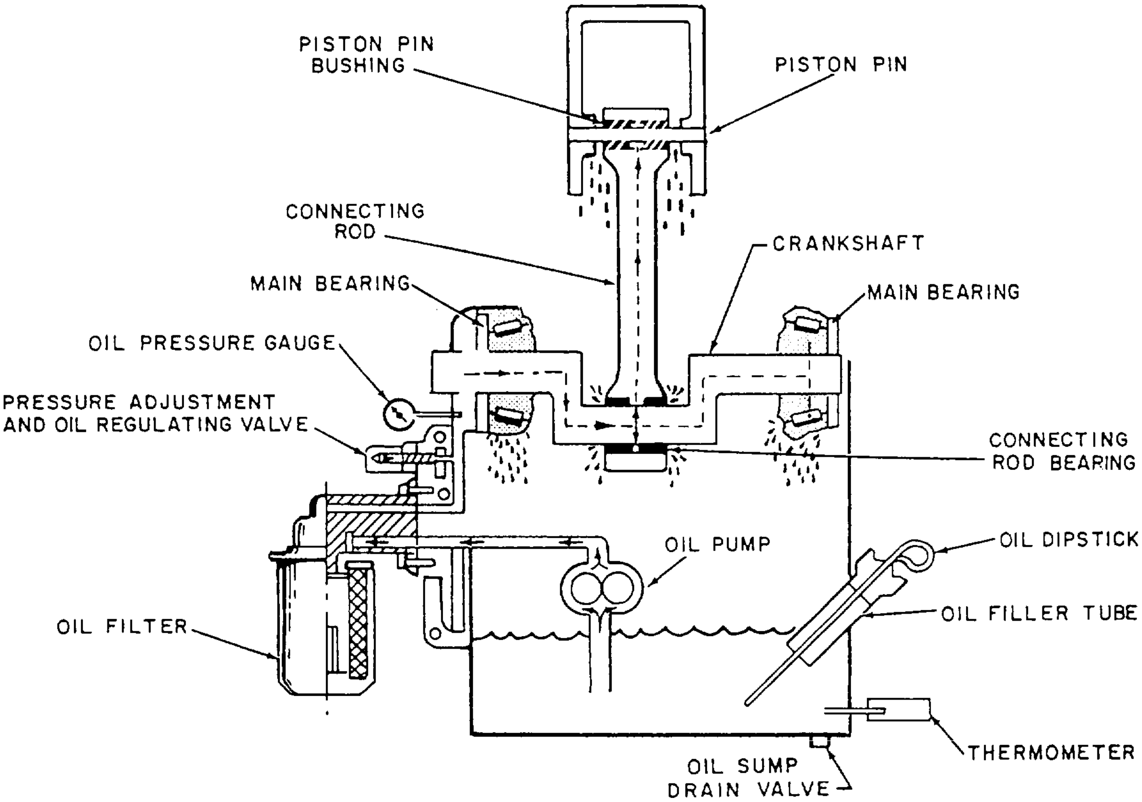


Figure 8-18.-Pressure type of lubricating system on a reciprocating type of air compressor.

by the air as it is being compressed. The lubricating oil is force fed to the required lubricating points by a means called a pressure differential system. Figure 8-19 shows the operation of this lubrication system, trace it as you follow the text. As the unit is started, air begins the compression cycle leaving the compressor and entering the air receiver. A factory-set minimum pressure valve, located on the air receiver, remains closed to allow rapid buildup of air pressure. The high pressure air in the air receiver is the force that moves the oil through the oil lines to the working parts of the compressor. An oil filter is placed in the system to remove impurities. After leaving the filter, a thermostatic control valve directs heated oil through an oil cooler to keep the oil temperature between 130°F and 180°F. Oil already cool bypasses this step. The oil is then directed to the intake side of the compressor where it is injected into the cylinder (vane type) or dual-bore cylinders (screw type) for sealing purposes and to cool the air as it is being compressed. Oil is also directed into the air intake control assembly and all bearings and other moving parts at the same time. The air-oil mix exits the compressor at the discharge end and re-enters the air receiver. The oil is removed from the air by means of an air-oil-labyrinth-separator which returns it to the sump where it starts the cycle again.

Some vane and screw type of air compressors use a mechanical type of oil pump in the lubrication system. You should check the level of the compressor oil daily, before operation. Refer to the manufacturer's maintenance manual for the correct type of oil and the proper procedure for checking and topping off.

CAUTION

> Because the system is under high pressure, the vane and screw types of air compressors must be shut down and unloaded before oil is added to the system.

Preventive maintenance procedures for all three types of air compressors are outlined in current manuals for the unit you are working on or operating. USE THEM!!! Oil should be changed according to these manuals, in most cases, at 500 hour intervals. The compressor oil filter and air separator should not be overlooked and the air filter, taking into account operating conditions, should be inspected daily. When you operate air compressors at any time, do not leave the unit unattended while it is running.

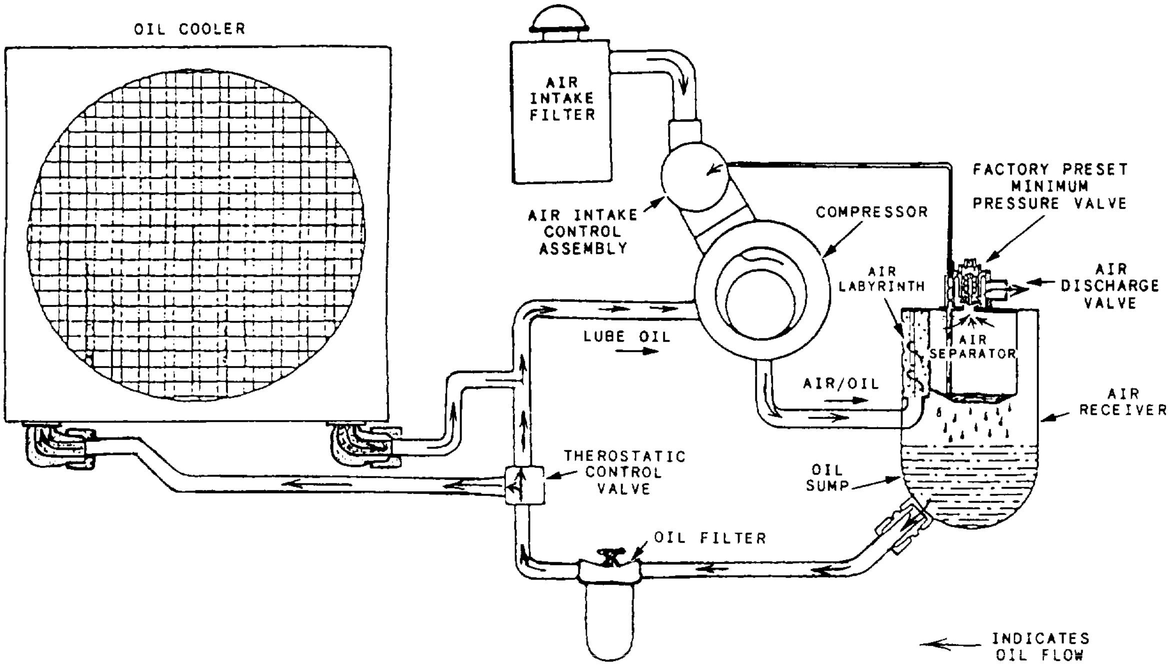


Figure 8-19.-Rotary vane air compressor lubrication system.

Table 8-1.-Air Compressor Troubleshooting Chart

PROBLEM	CAUSE
Overheating compressor	Oil cooler dirty Defective thermostatic bypass valve Insufficient oil in the unit Rotor blades sticking or broken Clogged oil filter Oil cooler is dirty
Air compressor is noisy during operation	Low oil level Worn or damaged internal parts
Compressor does not reach design pressure or capacity	Air pressure safety valve is leaking Receiver air valve is open Unloader valve is leaking Loose piping or fittings
Compressor will not load or unload	Unloader valve defective Air control valve is sticking or dirty Unloader pressure is improperly set (too high or too low) Water in the control lines Plugged control lines
Drive engine shuts down when idling	Idle speed is improperly set (too low) The equipment is not warmed up Check for proper operating procedures
The air compressor CFM is low	Dirty air compressor air filter Defective air intake control valve High idle on power source improperly set Damaged or worn rotor blades
Oil in the discharge lines	Saturated oil separator Damaged oil separator
Engine stalls during operation	Overheated compressor oil High discharge air pressure Low or no engine oil pressure High engine coolant temperature Engine overspeeding

WARNING

Reciprocating air compressors used to produce breathable air used in diving operations use special lubricating oil. Failure to observe these specific precautions set by NAVSEA maintenance instructions could lead to fatal injury of the diver.

AIR COMPRESSOR TROUBLESHOOTING

Years of development have made the air compressor a rugged and dependable machine. However, as with any machine, problems do arise. As a CM-1, it is your job to troubleshoot the air compressor once it has malfunctioned.

Now, the large reciprocating type of air compressor (used for construction purposes) is rarely found in the NCF. For this reason, the following troubleshooting procedures detailed in this chapter are for the vane and screw types of air compressors.

CAUTION

For exact information on the equipment you are working on, go to the manufacturer's maintenance and repair manual.

There are several ways to troubleshoot equipment to eliminate possible problems. The best way is to first ask the operator the following questions: Did it start at all? How did it shut down? What noises did it make? Was there any smoke or unusual smell? Next, get the book and do some reading! DO NOT JUST GET IN THERE AND REPLACE A FEW PARTS. Sure, you may correct the problem, but this type of "repair" work wastes government money, and you did not do your job as a troubleshooter. After your short study period, check the machine and be sure it is safe to start. Look for obvious damage, open discharge lines, broken air or oil lines, oil leaks, and clogged air filters. Prestart check the unit. If you determine the unit is safe to start, do so, but watch the engine oil pressure, and if it does not come up immediately, the power source is the problem. Shut the unit down quickly and take it to the shop for a detailed inspection by the mechanics. If the oil pressure is correct, watch the air pressure buildup next. If the air pressure buildup does not come up, stop the unit because the vane and screw types of air compressors depend on air pressure for lubrication. If the air pressure comes up slowly or if the compressor fails to unload, finally stalling the unit, check for a sticking air intake control valve. If the compressor does start and there is no apparent problem, do not leave the scene right away. The problem could be that the unit has tripped to shutdown due to overheating oil. Let the unit thoroughly cool down. Then simulate the conditions by starting and working the unit. Watch the gauges to see how fast the oil temperature rises. From the book (You did read it didn't you?), you know the limits for oil temperature. Return the unit to the shop if you see these limits exceeded Finally, noise. If the unit starts and the noise level exceeds that of a normal running unit, return the unit to the shop for inspection and repair. DO NOT JEOPARDIZE THE HEALTH OF THE CESE FOR THE SAKE OF THE PROJECT. See table 8-1 for a more detailed listing of troubleshooting the vane and screw types of air compressors.

AIR COMPRESSOR OVERHAUL

Because of the durability of the vane and screw types of air compressors, major overhaul is seldom required. A properly maintained unit will perform reliably for 10,000 hours or more. When a major overhaul is required, the following preparations apply to air compressors as to other components discussed in this TRAMAN; have a clean work area; obtain all special tools; get the manufacturer's repair manual; preclean the unit. Once you have done this-think SAFETY, use a hoist for the heavier parts. You are now ready to start your overhaul.

The primary wear point on the rotary type of air compressor is the rotor vanes. For this reason, the unit has been designed to allow for simplified inspection of the vanes by the removal of the rear cover of the compressor (fig. 8-20).

ATTENTION

Before the rotor vanes can be removed from most rotary compressors, the rotor must be positioned correctly (fig. 8-21).

The rotor vanes should slide out easily offering little or no resistance. Rotor vanes that resist removal indicate problems. Once you remove the rotor vanes, shine a light inside the rotor compartment and slots. Inspect the condition of the rotor slots. The slots should be clean and have straight edges. A worn-rotor slot would most likely have a slight saw-toothed effect on the trailing edge–a condition that can cause rapid rotor vane wear. Next, inspect the inside of the rotor compartment for

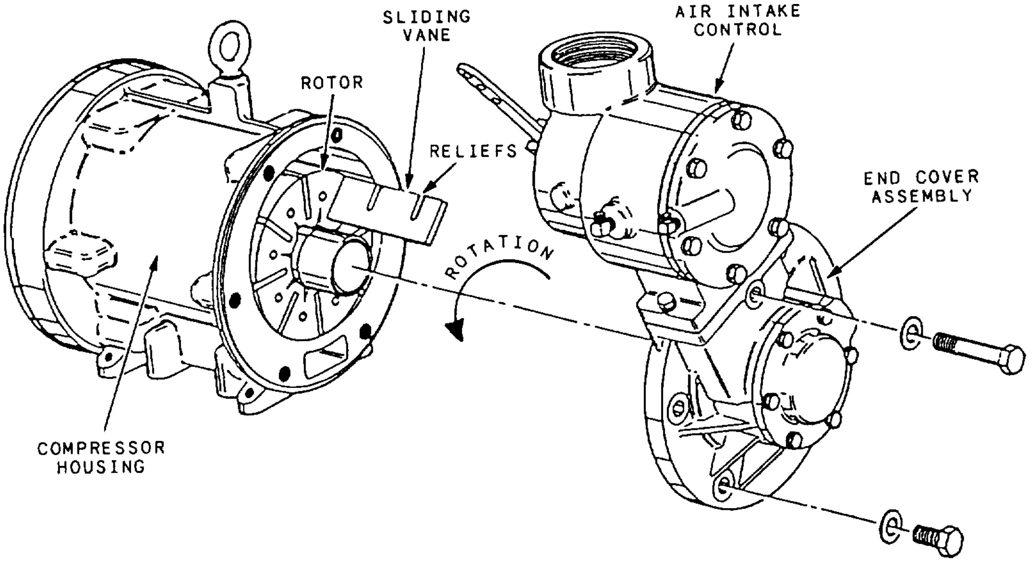


Figure 8-20.-Removing vanes for inspection and replacement.

irregularities, such as scoring, heat cracks, or gouging. Damage to the rotor compartment usually means the replacement of this part is necessary.

Inspect the individual rotor vanes, look for excessive wear, chipping, cracking, or breakage. Rotor vanes worn beyond specifications set by individual manufacturers should be replaced (fig. 8-21). If the rotor vanes have broken in the compressor, it is of extreme importance that ALL DEBRIS BE REMOVED. Chips and other foreign matter left in the compressor will be ingested into the lubrication system, causing further damage to the air control system and the compressor. Following rotor vane breakage, flush the cylinder and rotor with steam or high-pressure water. The oil tank or air receiver must be drained and flushed. Air and oil lines should be purged and entirely free of rotor vane chips.

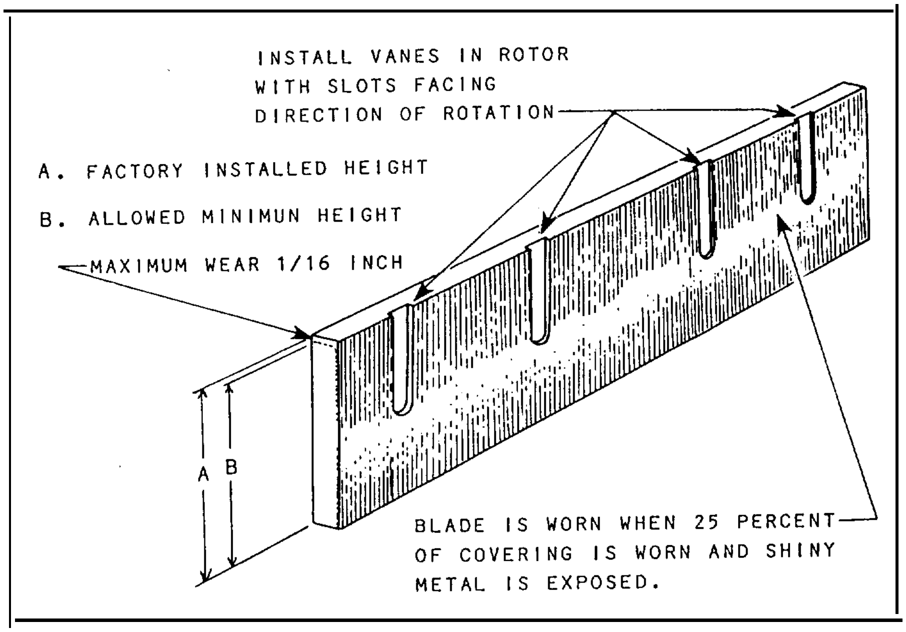


Figure 8-21.-Rotor vane inspection.

Dry all parts with compressed air and relubricate them with compressor oil.

If you must change the rotor bearings and races, you should do so with suitable pullers and installers. In extreme circumstances, some manufacturers recommend heating the inner races to ease removal. Disgard bearing races that have been heated in this type of removal process.

Some rotary and screw types of air compressors have an oil pump in the lubrication system. Disassemble, inspect, and overhaul the oil pump according to the manufacturer's specifications.

Before you reassemble the air compressor, make sure all the air and oil passages are clean. All parts should be lightly oiled and ready for use. The reassembly process of air compressors is not complicated, but stick to the instructions in the manufacturer's repair and maintenance manual.

The manufacturers of the screw type of air compressors do not recommend that overhaul be done in the field.

As a parting shot, you can get the most out of this machinery by PERFORMING PREVENTIVE MAINTENANCE AS REQUIRED. The importance of timely oil, oil filter, and air filter changes cannot be overstressed. Do your job and this unit will do its job.

CHAPTER 9

THE SHOP INSPECTOR

Preventive maintenance (PM) and the safety inspection of a vehicle go hand in hand. Besides keeping a vehicle in good operating condition, preventive maintenance ensures that a vehicle is safe to operate. The proper inspection of the devices or parts of a vehicle that make for safe operation can be done at scheduled preventive maintenance times.

As a CM-1, you maybe assigned the job of vehicle inspector. Besides making scheduled CESE inspections, you should be looking for inoperative devices that make a vehicle unsafe, and for damage that may have been caused by improper or dangerous operating procedures. You will need to be familiar with instructions and regulations pertaining to safety as well as regular scheduled maintenance inspections. Using the COMCBPAC/COMCBLANTINST 5100 (series), NAVFAC P-300, *Management of Transportation Equipment Manual* and chapter 19 of the U.S. Army Corps of Engineers, *Safety and Health Requirements Manual*, 385-1-1, will provide you with guidance in vehicle safety and reliability inspections. Be sure the mechanics working under your supervision are aware of these instructions and the proper procedures of making a thorough vehicle inspection. The job of vehicle inspector should not be assigned to an inexperienced mechanic.

WARNING

CUTTING SAFETY SHORT MAY CUT SOMEONE'S LIFE SHORT.

THE VEHICLE INSPECTOR

The vehicle inspector is assigned to a maintenance shop in either a public works department, a battalion, or a special operating unit to assist the transportation shops supervisor (public works) or maintenance supervisor (battalion) in inspecting the equipment to be serviced. The inspector should be a senior mechanic, proficient in his rating, and capable of readily determining the nature of necessary repairs. He should be able to exercise independent judgment as to whether the equipment requires immediate attention or can be delayed until the next regular scheduled preventive maintenance inspection. The scheduled preventive maintenance system is designed to ensure optimum life out of the equipment of a unit or station. Figure 9-1 defines the level of inspection and the intervals required for each of

	TYPE "A" PM	TYPE "B" PM	TYPE "C" PM
Equipment Type	**Minimum Service**	**Detailed Service & Inspection**	**Annual Safety Inspection**
Automotive	Every 40 working days	After every two "A" PMs	As directed by COMCBPAC/ COMCBLANT & COM-FIRSTNCB representatives. (50% of CESE on site per deployment)
Construction	Every 40 working days	After every two "A" PMs	
Material Handling	Same as for Construction Equipment	Same as for Construction Equipment	

NOTE 1: **The above are minimum inspection and service intervals under normal conditions and should be decreased for double shift operations and extreme terrain conditions or as directed by the maintenance supervisor.**

NOTE 2: **PM scheduling for CESE attached to COMFIRSTNCB (Reserves) will be serviced as follows: an "A" type PM will be performed every 90 working days, and a "B" type PM will be performed after three consecutive "A" type PMs. Reserve units will use a standard 40 day PM cycle when the unit is recalled to active status.**

Figure 9-1.-Preventive maintenance interval schedule.

the three categories of equipment. The inspector is responsible for the following:

1. Performing the scheduled inspection, completing the appropriate record forms, and noting deficiencies clearly on the Equipment Repair Order or Shop Repair Order

2. Checking the file of operator trouble reports before equipment inspection

3. Using the latest testing equipment and methods available to the unit or public works department

4. Performing minor adjustments incidental to the inspection

5. Delivering the initialed Equipment Repair Order or Shop Repair Order to the maintenance supervisor or shops supervisor

6. Road testing or field testing the equipment before and following the PM, repair, or overhaul

7. Releasing the equipment to full service "ONLY" after final inspection is completed

Inspectors will immediately notify the maintenance supervisor or shops supervisor whenever suspected vehicle abuse or reoccurring mechanical failures occur.

THE PUBLIC WORKS SHOP INSPECTOR

The three types of inspections performed at an equipment maintenance shop on a public works station are reliability, acceptance, and safety.

The safety inspection is done once a year or every 12,000 miles, whichever occurs first. All deficiencies found should be corrected before the vehicle is returned to service. Automotive safety inspections include the following:

1. Brake system. Road test to determine if the brakes are functioning properly. Check brake pedal free travel, Remove the wheels and inspect drums and rotors for wear or cracking. Inspect the pads and lining for excessive wear. Check all brake calipers and wheel cylinders for damage or leaks. Inspect all hydraulic broke lines for leaks, and check the brake fluid level. On air-brake systems, inspect air-brake accessories, air lines, and air tanks for leaks and deterioration. Check air-broke instruments, air control valves, trailer hoses, and glad hands.

2. Steering and suspension system. Check all steering devices and linkage for wear or damage. Inspect all suspension bushings and pivot points. Check all suspension parts for wear or damage.

3. Shock absorbers. Check for leakage and proper operation.

4. Tires and wheels. Check tires for damage or excessive wear. Front tires of buses, trucks, and truck tractors will be replaced when less than 4/32-inch tread remains. All tires will be replaced when less than 2/32-inch tread remains.

5. Fuel system. Check all fuel lines and fuel line connections for signs of leakage. Inspect fuel filter housings for signs of leakage or damage.

6. Exhaust system. Check the muffler, exhaust pipe, tailpipe, and all connections for serviceability and leakage.

7. Seat belts. Inspect seat belts for wear and for proper mounting.

8. Lights. Check all lights, signals, and reflectors. Inspect the condition of the trailer jumper cable. Check the headlights for proper alignment. Lighting requirements are found in the *Federal Motor Carrier Regulations Pocketbook*, U.S. Department of Transportation, Federal Highway Administration, Parts 393.9 through 393.33.

9. Instruments, controls, and warning devices. Inspect all instruments, gauges, mirrors, switches, and warning devices for proper functioning and damage.

10. Windshield wipers, glass, defrosters. Check wipers, glass, and defrosters for proper operation, wear, damage, or deterioration.

11. Fifth wheel and trailer. Inspect trailer kingpin for wear and damage. Check tow bars, tongue sockets, and safety chains.

12. Special markings. Inspect all special identification markings, such as NONPOTABLE WATER, FLAMMABLE, U.S. NAVY, and so forth.

13. Other items. Check all other components required by the states in which the vehicle is being operated.

For the annual safety inspection on construction and allied equipment, use the correct manufacturer's maintenance and repair manual for guidance.

To avoid unnecessary downtime, coordinate and perform the safety and reliability inspections at the same time. Figure 9-2 is one example of a standard inspection sheet used at some public works stations. The inspection, lubrication, and adjustment functions and

SPECIFICATION FOR SCHEDULED MAINTENANCE INSPECTIONS AND SERVICES

VEHICLE MAKE **MODEL(S)** **YEAR(S)**

OPERATION	SERVICE INTERVAL								See Manual Page
1000 MILES →	6	12	18	24	30	36	42	48	
ENGINE									
Change engine oil and filter	X	X	X	X	X	X	X	X	
Clean and refill oil bath air cleaner (if so equipped)	X	X	X	X	X	X	X	X	
Replace dry type of air cleaner filter (6 cyl.)		X		X		X		X	
Replace dry type of air cleaner filter (8 cyl.)				X				X	
Test crankcase emission system. Clean system and replace emission control valve if required.	X	X	X	X	X	X	X	X	
Clean crankcase emission system hoses, tubes, fittings, carburetor spacer and replace if necessary. Replace emission control valve.		X		X		X		X	
Clean crankcase filler breather cap.	X	X	X	X	X	X	X	X	
Replace fuel system filter (gas engine)				X				X	
Inspect thermactor exhaust emission control system hoses and replace if required		X		X		X		X	
Drain, flush, and refill cooling system	EACH 24 MONTHS								
Check and lubricate exhaust control valve. Free up if necessary (if so equipped).	X	X	X	X	X	X	X	X	
Clean and adjust distributor points–replace as required (Clean distributor cap)		X		X		X		X	
Check and adjust carburetor–idle speed and fuel mixture		X		X		X		X	
Check and clean external choke mechanism		X		X		X		X	
Check and adjust ignition timing–initial timing, mechanical and vacuum advances, and vacuum retard (if so equipped).		X		X		X		X	

Figure 9-2.-Example of public works equipment inspection sheet.

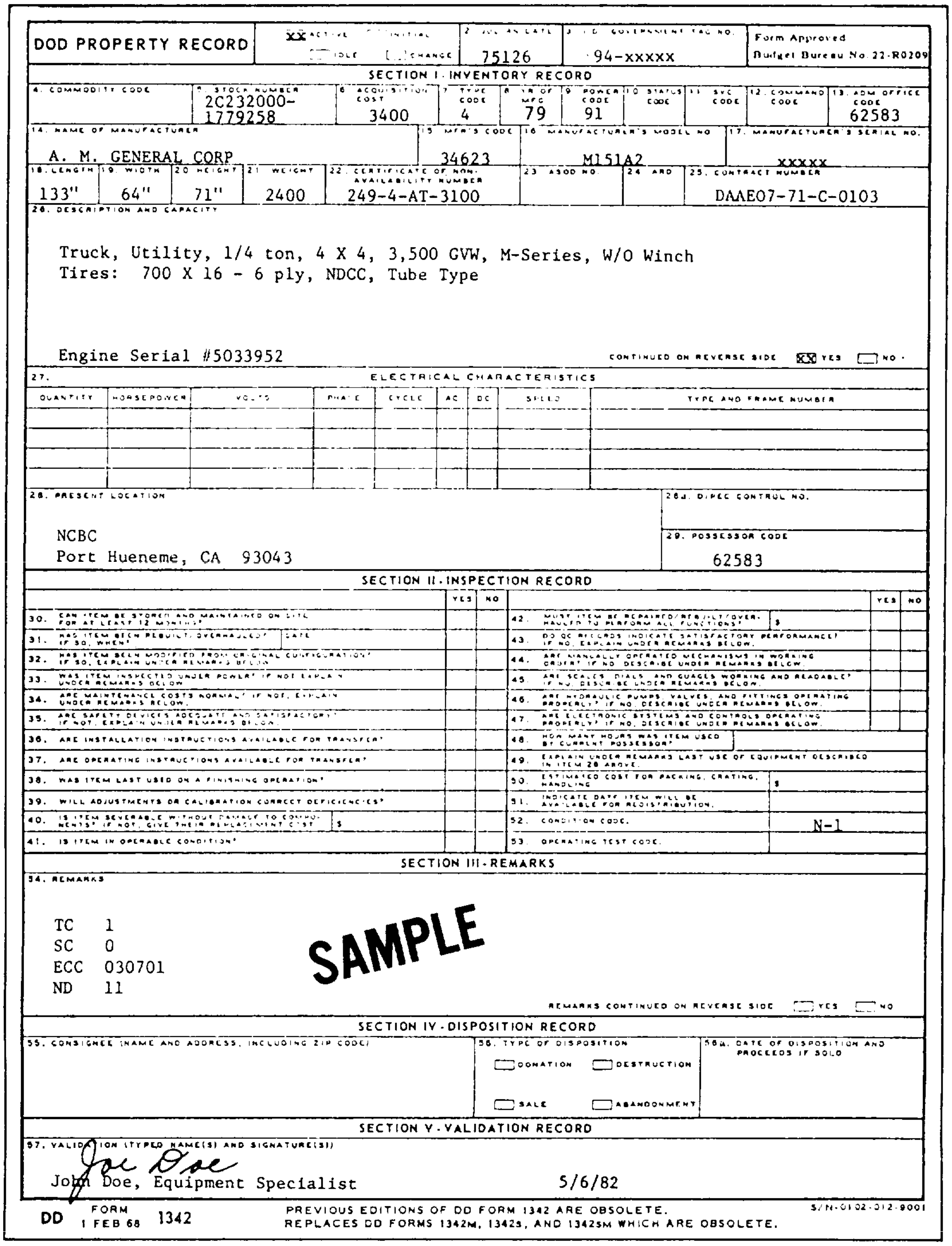
frequencies are to be determined by the maintenance and repair manual supplied with the vehicle. When these specifications are not available, they shall be developed under the direction of the transportation director and approved in writing.

ACCEPTANCE INSPECTIONS

Equipment inspectors will inspect all CESE arriving at an activity. Predelivery inspection is similar to that performed by a dealership and is required to ensure safe, serviceable operation. The inspector should pay particular attention to the detection of deficiencies eligible for correction under the warranty program, and for damage caused by the shipper (see chap. 1). Report these problems to the transportation shops supervisor for appropriate action.

PROPERTY RECORD CARD, DD FORM 1342

The inspector is the primary source for gathering information used to complete the Property Record Card,



DOD PROPERTY RECORD	1. ☒ ACTIVE ☐ INITIAL ☐ IDLE ☐ CHANGE	2. JULIAN DATE 75126	3. I.D. GOVERNMENT TAG NO. 94-xxxxx	Form Approved Budget Bureau No. 22-R0209

SECTION I - INVENTORY RECORD

4. COMMODITY CODE	5. STOCK NUMBER 2C232000-1779258	6. ACQUISITION COST 3400	7. TYPE CODE 4	8. YR OF MFG 79	9. POWER CODE 91	10. STATUS CODE	11. SVC CODE	12. COMMAND CODE	13. ADM OFFICE CODE 62583

14. NAME OF MANUFACTURER A. M. GENERAL CORP	15. MFR'S CODE 34623	16. MANUFACTURER'S MODEL NO. M151A2	17. MANUFACTURER'S SERIAL NO. xxxxx

18. LENGTH 133"	19. WIDTH 64"	20. HEIGHT 71"	21. WEIGHT 2400	22. CERTIFICATE OF NON-AVAILABILITY NUMBER 249-4-AT-3100	23. ASOD NO.	24. ARD	25. CONTRACT NUMBER DAAE07-71-C-0103

26. DESCRIPTION AND CAPACITY

Truck, Utility, 1/4 ton, 4 X 4, 3,500 GVW, M-Series, W/O Winch
Tires: 700 X 16 - 6 ply, NDCC, Tube Type

Engine Serial #5033952

CONTINUED ON REVERSE SIDE ☒ YES ☐ NO

27. ELECTRICAL CHARACTERISTICS

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

28. PRESENT LOCATION NCBC Port Hueneme, CA 93043	28a. DIPEC CONTROL NO. 29. POSSESSOR CODE 62583

SECTION II - INSPECTION RECORD

	YES	NO		YES	NO
30. CAN ITEM BE STORED AND MAINTAINED ON SITE FOR AT LEAST 12 MONTHS?			42. MUST ITEM BE REPAIRED/REBUILT/OVERHAULED TO PERFORM ALL FUNCTIONS? $		
31. HAS ITEM BEEN REBUILT/OVERHAULED? IF SO, WHEN? DATE			43. DO QC RECORDS INDICATE SATISFACTORY PERFORMANCE? IF NO, EXPLAIN UNDER REMARKS BELOW.		
32. HAS ITEM BEEN MODIFIED FROM ORIGINAL CONFIGURATION? IF SO, EXPLAIN UNDER REMARKS BELOW.			44. ARE MANUALLY OPERATED MECHANISMS IN WORKING ORDER? IF NO, DESCRIBE UNDER REMARKS BELOW.		
33. WAS ITEM INSPECTED UNDER POWER? IF NOT EXPLAIN UNDER REMARKS BELOW.			45. ARE SCALES, DIALS, AND GUAGES WORKING AND READABLE? IF NO, DESCRIBE UNDER REMARKS BELOW.		
34. ARE MAINTENANCE COSTS NORMAL? IF NOT, EXPLAIN UNDER REMARKS BELOW.			46. ARE HYDRAULIC PUMPS, VALVES, AND FITTINGS OPERATING PROPERLY? IF NO, DESCRIBE UNDER REMARKS BELOW.		
35. ARE SAFETY DEVICES ADEQUATE AND SATISFACTORY? IF NOT, EXPLAIN UNDER REMARKS BELOW.			47. ARE ELECTRONIC SYSTEMS AND CONTROLS OPERATING PROPERLY? IF NO, DESCRIBE UNDER REMARKS BELOW.		
36. ARE INSTALLATION INSTRUCTIONS AVAILABLE FOR TRANSFER?			48. HOW MANY HOURS WAS ITEM USED BY CURRENT POSSESSOR?		
37. ARE OPERATING INSTRUCTIONS AVAILABLE FOR TRANSFER?			49. EXPLAIN UNDER REMARKS LAST USE OF EQUIPMENT DESCRIBED IN ITEM 26 ABOVE.		
38. WAS ITEM LAST USED ON A FINISHING OPERATION?			50. ESTIMATED COST FOR PACKING, CRATING, HANDLING $		
39. WILL ADJUSTMENTS OR CALIBRATION CORRECT DEFICIENCIES?			51. INDICATE DATE ITEM WILL BE AVAILABLE FOR REDISTRIBUTION.		
40. IS ITEM SEVERABLE WITHOUT DAMAGE TO COMPONENTS? IF NOT, GIVE THEIR REPLACEMENT COST $			52. CONDITION CODE. N-1		
41. IS ITEM IN OPERABLE CONDITION?			53. OPERATING TEST CODE.		

SECTION III - REMARKS

54. REMARKS

TC 1
SC 0
ECC 030701
ND 11

SAMPLE

REMARKS CONTINUED ON REVERSE SIDE ☐ YES ☐ NO

SECTION IV - DISPOSITION RECORD

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

SECTION V - VALIDATION RECORD

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

Joe Doe

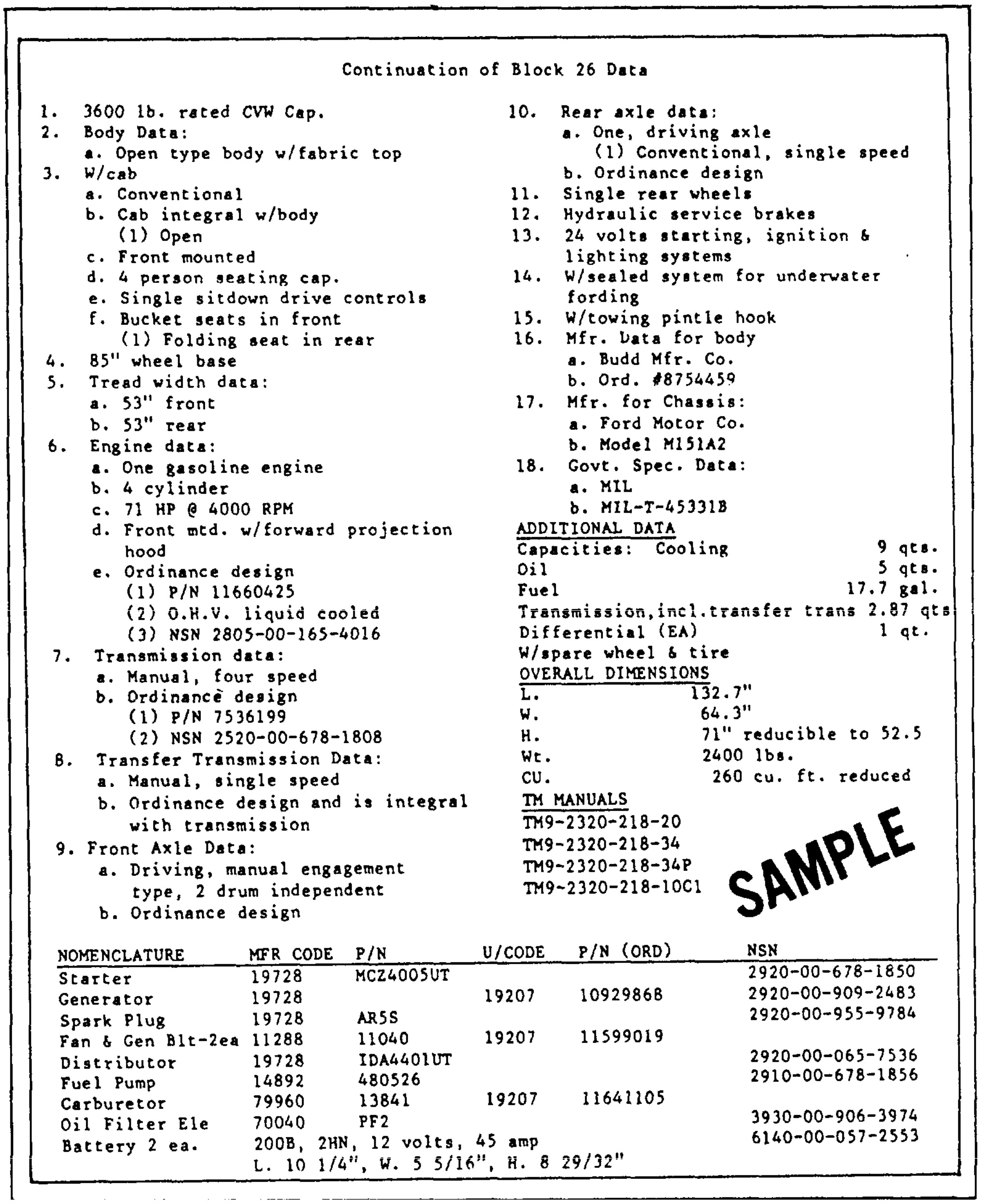
John Doe, Equipment Specialist 5/6/82

DD FORM 1 FEB 68 1342 PREVIOUS EDITIONS OF DD FORM 1342 ARE OBSOLETE. REPLACES DD FORMS 1342M, 1342S, AND 1342SM WHICH ARE OBSOLETE. S/N-0102-012-9001

Figure 9-3.-DoD Property Record Card, DD Form 1342 (front).

DD Form 1342 (fig. 9-3 and fig. 9-4). This form is used to report acquisitions and transfers of Navy equipment in support of the Navy equipment registration system. It is also used to assist the mechanics, shop supervisor, and technical librarian with information needed in the research of repair parts. Property Record Cards are updated each time a serialized component is changed on the unit (engine, transmission, etc.). The need for accurate preparation of this form cannot be overemphasized as this document is the sole source for recording all pertinent data relative to the equipment at the Civil Engineer Support Office, Port Hueneme, California.

Since he is the one performing the final inspection, the inspector is responsible for accuracy in obtaining correct information.



Continuation of Block 26 Data

1. 3600 lb. rated CVW Cap.
2. Body Data:
   a. Open type body w/fabric top
3. W/cab
   a. Conventional
   b. Cab integral w/body
      (1) Open
   c. Front mounted
   d. 4 person seating cap.
   e. Single sitdown drive controls
   f. Bucket seats in front
      (1) Folding seat in rear
4. 85" wheel base
5. Tread width data:
   a. 53" front
   b. 53" rear
6. Engine data:
   a. One gasoline engine
   b. 4 cylinder
   c. 71 HP @ 4000 RPM
   d. Front mtd. w/forward projection hood
   e. Ordinance design
      (1) P/N 11660425
      (2) O.H.V. liquid cooled
      (3) NSN 2805-00-165-4016
7. Transmission data:
   a. Manual, four speed
   b. Ordinance design
      (1) P/N 7536199
      (2) NSN 2520-00-678-1808
8. Transfer Transmission Data:
   a. Manual, single speed
   b. Ordinance design and is integral with transmission
9. Front Axle Data:
   a. Driving, manual engagement type, 2 drum independent
   b. Ordinance design
10. Rear axle data:
    a. One, driving axle
       (1) Conventional, single speed
    b. Ordinance design
11. Single rear wheels
12. Hydraulic service brakes
13. 24 volts starting, ignition & lighting systems
14. W/sealed system for underwater fording
15. W/towing pintle hook
16. Mfr. Data for body
    a. Budd Mfr. Co.
    b. Ord. #8754459
17. Mfr. for Chassis:
    a. Ford Motor Co.
    b. Model M151A2
18. Govt. Spec. Data:
    a. MIL
    b. MIL-T-45331B

ADDITIONAL DATA

Capacities: Cooling 9 qts.
Oil 5 qts.
Fuel 17.7 gal.
Transmission, incl. transfer trans 2.87 qts
Differential (EA) 1 qt.
W/spare wheel & tire

OVERALL DIMENSIONS

L. 132.7"
W. 64.3"
H. 71" reducible to 52.5
Wt. 2400 lbs.
CU. 260 cu. ft. reduced

TM MANUALS

TM9-2320-218-20
TM9-2320-218-34
TM9-2320-218-34P
TM9-2320-218-10C1

SAMPLE

NOMENCLATURE	MFR CODE	P/N	U/CODE	P/N (ORD)	NSN
Starter	19728	MCZ4005UT			2920-00-678-1850
Generator	19728		19207	10929868	2920-00-909-2483
Spark Plug	19728	AR5S			2920-00-955-9784
Fan & Gen Blt-2ea	11288	11040	19207	11599019	
Distributor	19728	IDA4401UT			2920-00-065-7536
Fuel Pump	14892	480526			2910-00-678-1856
Carburetor	79960	13841	19207	11641105	
Oil Filter Ele	70040	PF2			3930-00-906-3974
Battery 2 ea.	200B, 2HN, 12 volts, 45 amp L. 10 1/4", W. 5 5/16", H. 8 29/32"				6140-00-057-2553

Figure 9-4.-DoD Property Record Card, DD Form 1342 (Block 26).

For guidance in completing the DD Form 1342, Property Record Card, use the NAVFAC P-300, *Management of Transportation Equipment Manual;* NAVFAC P-404, *Naval Construction Force Equipment Management Manual;* or the COMCBPAC/COMCBLANTINST 11200.1 (series).

THE BATTALION MAINTENANCE SHOP INSPECTOR

The battalion maintenance shop inspector works directly for and is responsible to the maintenance supervisor. The inspector in a battalion or a special operating unit will use the COMCBPAC/COMCBLANTINST 11200.1 (series) or the NAVFAC P-404, *Naval Construction Force Equipment Management Manual,* as guides. The inspector requirements are similar if not identical to those of the public works shop inspector.

BEEP INSPECTIONS

As discussed in chapter 2, a Battalion Equipment Evaluation Program, or "BEEP," inspection is conducted under COMCBPAC/COMCBLANTINST 11200.1 (series) each time a battalion is relieved on site.

LIVE STORAGE CYCLE LOG			Weekly Start-Up and Inspection Procedures (COMCBLANTINST 11200.9E enclosure (3))	20-, 40- & 60-Day Dry Operational Test Procedures (COMCBLANTINST 11200.9E enclosure (4))			80-Day Fully Operational Test Procedures (COMCBLANTINST 11200.9E enclosure (5))	DATE:__________	
ECC	USN	DESCRIPTION	WEEKLY	20-	40-	60-	80-DAY	REMARKS	INSP SIGNATURE

Maintenance Supervisor ________________
Signature

Figure 9-5.-Example of live storage cycle log.

This inspection evaluates the condition of the equipment to establish replacement priorities. If conducted properly, it also provides the maintenance supervisor of the relieving battalion with a means of establishing a shop workload plan for the deployment.

At the time the "BEEP" inspection is conducted, all discrepancies, including rust, body damage, and paint requirements, are written on the Equipment Repair Order. The repairs needed during the "BEEP" vary with each situation. As a rule, all needed safety repairs will be corrected and repairs of less than 4 hours time completed if parts are available. Major repairs, component overhaul, and body work are generally deferred until after the completion of the "BEEP" and the scheduled maintenance cycle has begun. Examples of equipment evaluation inspection and attachment evaluation inspection guides are in chapter 2, figures 2-17, 2-18, and 2-19.

EMBARKATION INSPECTIONS

Clean vehicles, a critical part of embarkation inspections, allow for closer inspections and speed up clearance of customs where vehicles must be certified free of dirt and bugs. Vehicles leaving foreign countries normally will be inspected leaving that area and again upon arrival at their destination.

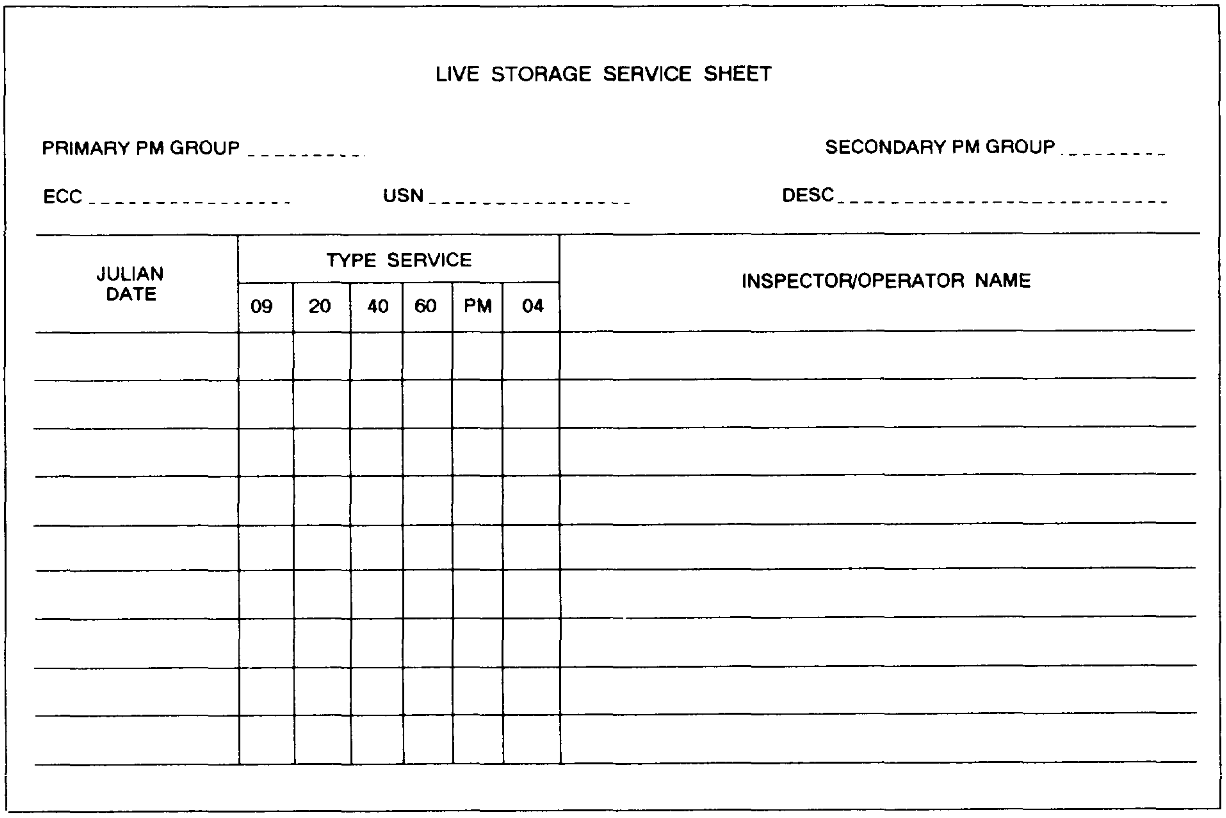
In addition to safety and operational checks, vehicles inspected for embarkation require an emphasis on oil, fuel, and water seepage. An occasional drip may not adversely affect the normal operation of the vehicle, but it could become hazardous while being transported. You should make sure the spare tire and all collateral equipage are loaded with the vehicle, especially under tactical conditions.

In the shop area, it is easy to accomplish the configuration of the vehicle for loading, to put down the roll over protective structure (ROPS), and to remove the counterweights, and so forth. Itemizing these and related tasks on the Equipment Repair Order will ensure that the work will be completed, and in addition, provide a record of work required at the destination.

PRESERVATION INSPECTIONS

Different units you may be attached to, usually NMCBs, will have a certain amount of their equipment in a storage program. This program is used to reduce maintenance hours by removing selected CESE from service for extended periods of time. The criteria for storage programs is listed in the COMCBLANTINST 11200.9 (series) for live storage and COMCBPACINST 11200.22 (series) for inactive storage. The maintenance supervisor should be certain that equipment shop inspectors are thoroughly familiar with these instructions. Samples of live storage cycle logs and live storage service sheets are shown in figures 9-5 and 9-6.

In the NCF (battalion), according to both instructions listed in the preceding paragraph, cranes will not be placed in active or inactive storage. Cranes will be under the control of the crane crew and will be cycled at a minimum of once every 5 days to make sure that all moving parts are mechanically sound and fully operational.



LIVE STORAGE SERVICE SHEET

PRIMARY PM GROUP _________

SECONDARY PM GROUP _________

ECC _______________

USN _______________

DESC _________________________

JULIAN DATE	TYPE SERVICE						INSPECTOR/OPERATOR NAME
	09	20	40	60	PM	04	

Figure 9-6.-Example of live storage service sheet.

Public works stations have equipment utilized on a seasonal basis (snow removal equipment, grounds maintenance equipment, etc.) and is unused, in some cases, most of the year. Since specific equipment preservation and storage instructions are not available to public works commands, the transportation supervisor and the equipment inspector should develop a system to preserve, store, and monitor CESE in its preserved condition.

Appendix E of the NAVFAC P-434, *Construction Equipment Department Management and Operations Manual,* provides operational testing instructions for CESE. It is also a good source of information on preservatives and their specific uses.

DEADLINE INSPECTIONS

Deadlined equipment is inspected on its scheduled PM due date, or sooner if the maintenance supervisor determines it is needed. When a unit is placed on deadline, an 01 level PM will be performed. The equipment inspector ensures the following:

1. All openings are covered and weathertight

2. All machine surfaces are preserved.

3. All disassembled components are tagged, covered, and stored.

4. No cannibalization has taken place since the last inspection. Controlled parts interchange is not approved as a normal procedure, although the maintenance supervisor may authorize it to meet operational commitment.

5. Any parts removed from the deadlined equipment we replaced with the nonserviceable item, and the maintenance supervisor makes sure that the replacement parts are ordered NORS (not operational ready supply).

6. All replacement parts, cost, and labor hours related to the interchange are charged against the piece of equipment on which the part failed. When the replacement parts are received and installed, only the labor involved is to be charged to the piece of equipment from which the interchange part was taken. As a part of the 01 type PM, the equipment will be cycled to prevent further deterioration.

VEHICLE INSPECTIONS INVOLVING ACCIDENTS

For Naval Construction Force (NCF) units, when a vehicle that has been involved in an accident is inspected, a type 12 Equipment Repair Order will be initiated regardless of the damage.

EXHAUST EMISSION CONTROL INSPECTIONS

Under the clean air act, DoD is required to comply with all state and local programs to improve air quality. With this in mind, check the following emissions control components on all vehicles you are inspecting for damage and tampering:

1. Catalytic converter.

2. Fuel tiller inlet restrictor.

3. Exhaust gas recirculation valve.

4. Air pump and air pump drive belt.

5. Verify the proper hookup of all vacuum lines and be sure no vacuum lines are plugged.

6. Check all other pollution control devices attached to the vehicle.

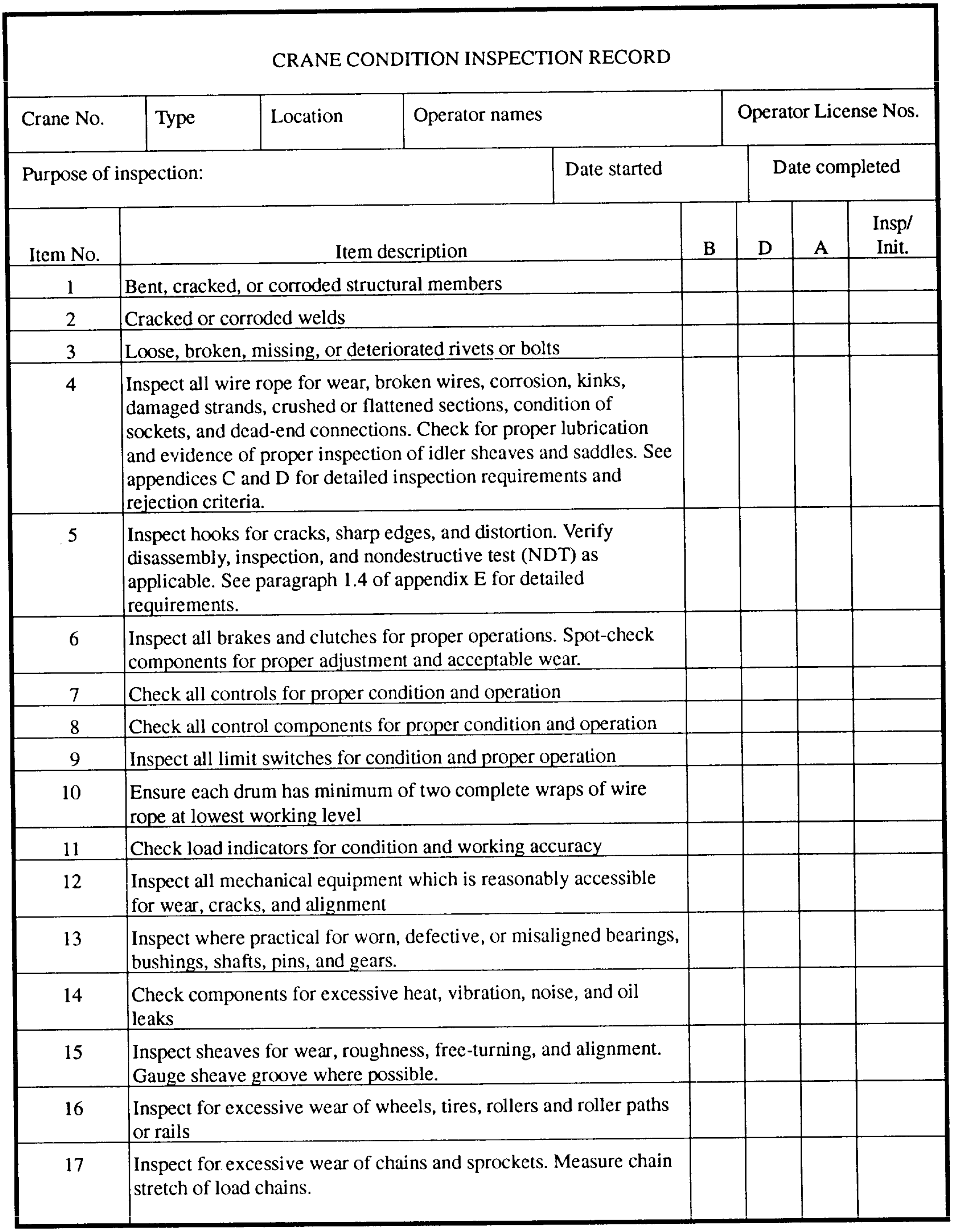
As you already know, emission control design varies between different manufacturers. Go to the proper repair and maintenance publications for correct information on these devices.

State and federal law forbid your removing or tampering with emission control devices. If the unit or station that you are assigned to does not have the equipment needed to analyze and adjust CESE equipped with these devices, the vehicle should be sent to a local dealer for repairs and proper adjustment.

CRANE INSPECTIONS

The crane inspector should be the most knowledgeable and conscientious mechanic available. In addition to the regular CESE inspection, the weight-handling equipment inspection will place primary emphasis on safety of all load bearing, load controlling parts, and safety devices for safe and sound working conditions. Examination will be made by sight, sound, touch, and as necessary, by instrumentation, nondestructive testing, and disassembly. Figure 9-7 shows the type of format used in crane condition inspection. Disassembly should be limited to suspected or abnormal conditions.

It is strongly recommended that the person selected for the job of crane inspector attend special construction battalion training-540.1, Crane and Attachments I and 540.2, Cranes and Attachments II. Both courses are



CRANE CONDITION INSPECTION RECORD

Crane No.	Type	Location	Operator names	Operator License Nos.

Purpose of inspection:	Date started	Date completed

Item No.	Item description	B	D	A	Insp/ Init.
1	Bent, cracked, or corroded structural members				
2	Cracked or corroded welds				
3	Loose, broken, missing, or deteriorated rivets or bolts				
4	Inspect all wire rope for wear, broken wires, corrosion, kinks, damaged strands, crushed or flattened sections, condition of sockets, and dead-end connections. Check for proper lubrication and evidence of proper inspection of idler sheaves and saddles. See appendices C and D for detailed inspection requirements and rejection criteria.				
5	Inspect hooks for cracks, sharp edges, and distortion. Verify disassembly, inspection, and nondestructive test (NDT) as applicable. See paragraph 1.4 of appendix E for detailed requirements.				
6	Inspect all brakes and clutches for proper operations. Spot-check components for proper adjustment and acceptable wear.				
7	Check all controls for proper condition and operation				
8	Check all control components for proper condition and operation				
9	Inspect all limit switches for condition and proper operation				
10	Ensure each drum has minimum of two complete wraps of wire rope at lowest working level				
11	Check load indicators for condition and working accuracy				
12	Inspect all mechanical equipment which is reasonably accessible for wear, cracks, and alignment				
13	Inspect where practical for worn, defective, or misaligned bearings, bushings, shafts, pins, and gears.				
14	Check components for excessive heat, vibration, noise, and oil leaks				
15	Inspect sheaves for wear, roughness, free-turning, and alignment. Gauge sheave groove where possible.				
16	Inspect for excessive wear of wheels, tires, rollers and roller paths or rails				
17	Inspect for excessive wear of chains and sprockets. Measure chain stretch of load chains.				

Figure 9-7.-Crane condition inspection record.

Item No.	Item description	B	D	A	Insp/ Init.
18	Verify that correct certified capacity charts or hook load rating data is in view of operator and/or rigging personnel				
19	Inspect operators cab for cleanliness and operation of all equipment				
20	Check machinery house for cleanliness, proper safety guards, warning signs, and storage of tools and equipment				
21	Check operation of all indicators, warning devices, and lights				
22	Check for proper type and condition of all fire protection equipment				
23	Verify that pressure vessel inspection certificates are posted and current (see NAVFAC M0-324 or appropriate document for test procedures)				
24	Check condition and function of outriggers, pads, boxes, wedges, and cylinder mountings. Check level indicators				
25	Check center pin nut and steadiment by observing operational behavior during load test (see paragraph 2.2.2, appendix E)				
26	Check travel, steering, braking, and locking devices for condition and proper operation				
27	Check radius indicator for accuracy by measuring actual radius in at least two boom positions				
28	Check pawls, ratchets, and spuds for proper engagement and operation of interlocks				
29	Inspect tanks, lines, valves, drains, filters, and other components of air systems for leakage and proper operation				
30	Inspect reservoirs, pumps, motors, valves, lines cylinders, and other components of hydraulic systems for leakage and proper operation				
31	Check engines and engine-generator sets for proper performance, safety and system leakage				
32	Inspeck for bent, cracked, corroded, or dented boom members				
33	Check condition of counterweights, ballast, and securing fasteners				
34	Check all compartments (voids) for water tightness				
35	Check accuracy of list and trim indicators against design data or previous test data				

Remarks:

Legend: B–before; D–during; A–after

Inspector Signature/Date	Test Director Signature/Date

Figure 9-7.-Crane condition inspection record–Continued.

offered at NCTC, Port Hueneme, California, and NCTC, Gulfport, Mississippi.

The crane certifying officer is designated by the commanding officer in writing. The crane certifying officer, according to the COMCBPAC/COMCBLANTINST 11200.1 (series), designates the crane inspector in writing.

The inspector should use the NAVFAC P-307, *Management of Weight-Handling Equipment Manual,* as a guide to perform inspections on cranes.

For the correct procedures and precautions for the towing of mobile cranes, see CESO maintenance bulletin No. 82.

FINAL INSPECTIONS

The shop inspector performs final inspections on all CESE leaving the maintenance shop. The inspector makes sure that all repairs have been satisfactorily completed, readying the unit for return to service. After operational testing, the unit is turned over to dispatch. The inspector then returns the ERO or SRO package to cost control for closing out.

Occasional y a piece of equipment is returned to the shop for re-work. Keep in mind the quality of work leaving the maintenance shop is a direct reflection of how well you, as the inspector, are doing your job. If you do not feel the quality of work coming out of individual shops (automotive, 5000, heavy, etc.) is satisfactory, return the ERO or SRO to the shop supervisor. Inform the maintenance supervisor of the problem. He will discuss the situation with the shop supervisors and correct the problem.

Re-work is double work!!! Get the job done right the first time and you will not have to do it the second time. Quality assurance through thorough final inspection is the only way to achieve the goal of ZERO re-work. Ask the following questions in looking for common problems:

1. Was the maintenance or repair completed in a realistic time frame? Is it noted on the ERO?
2. Was all of the work completed?
3. Were all of the DTO parts installed?
4. Are parts being left off the completed unit (nuts, bolts, covers, etc., missing)?
5. Was the vehicle cleaned after the work was performed (important if it was the COs sedan)?
6. Were any lubrication fittings missed? (Do your homework first; get the technical manual.)
7. WAS QUALITY PREVENTIVE MAINTENANCE AND REPAIRS PERFORMED? You are the inspector. Only you can answer this question.

One last item. As an inspector, your direct supervisor is the maintenance supervisor. Do not cut him short by not keeping him informed of what is happening in your world of vehicle inspection

ASSIGNMENT 8

Textbook Assignment: “Air Compressor Overhaul,” and “The Shop Inspector,” pages 8-1 through 9-11.

8-1. Operating an air compressor can be hazardous to your health for which of the following reasons?

1. Excessive smoke from high rpms
2. It can cause permanent hearing loss
3. The high-pressure air can cut through the skin and cause death through air embolism
4. Both 2 and 3 above

8-2. What are the three types of air compressors used in the NCF?

1. Piston, reciprocating, and sliding vane
2. Reciprocating, screw, and sliding vane
3. Screw, rotary piston, and sliding vane

8-3. Air compressors used by the NCF are different from those used in private industry.

1. True
2. False

8-4. Some air compressors may be specially mounted on modified trailers for which of the following reasons?

1. To lower the profile of the unit
2. To make the unit more maneuverable
3. To make preventative maintenance less of a problem
4. To allow the unit to be loaded on a C130 type of aircraft

8-5. A reciprocating air compressor is likely to be found in all except which of the following locations?

1. At a public works station
2. In a construction battalion on a project site
3. Under the hood of a unit of CESE
4. In a maintenance shop

8-6. The rotary vane type of air compressor is less of a maintenance problem than a reciprocating unit for which of the following reasons?

1. It has fewer moving parts
2. The internal parts are more finely machined
3. It is a more complex design

8-7. The vanes are farthest from the center of the rotor in what phase of the rotary compressor operation?

1. Intake
2. Discharge
3. Compression

8-8. In a rotary vane type of air compressor, the vanes are kept extended maintaining a wiping contact between the compressor casing and the edge of the vanes. This function is done by what means?

1. Oil pressure
2. Air pressure
3. Spring pressure
4. Centrifugal force

8-9. The vanes of a rotary compressor are sealed against the compressor casing wall by what means?

1. High-pressure air
2. Oil that is circulated through the air compressor
3. O-rings

8-10. At what point does compression take place in the rotary-screw air compressor?

1. When the volume decreases between the turning rotor blades
2. At the discharge end of the compression cycle
3. When it reaches the grooved rotor

8-11. The rotary-screw air compressor produces an extremely smooth operation for which of the following reasons?

1. Compression is completed before the air leaves the twin bore cylinder
2. It is a dual stage unit
3. The compression process is continuous

8-12. Oil is injected into the rotors of a screw-type air compressor for which of the following reasons?

1. To seal the rotor surfaces
2. To lubricate the working parts of the compressor
3. To cool the compressing air
4. Each of the above

8-13. When, if ever, may safety control devices be bypassed on a piece of air compression equipment?

1. When assigned projects need to be completed
2. When it is a piece of shop equipment and not rolling stock
3. Never

8–14. A compressor safety valve is normally set at what pressure?

1. 90 psi
2. 100 psi
3. 110 psi
4. 125 psi

8-15. An air compressor has shut down due to high discharge air temperature. It may be restarted after which of the following conditions is/are met?

1. The battery has been recharged
2. The oil has cooled
3. The reason for the shutdown has been determined
4. Both 2 and 3 above

8-16. When the air pressure reaches a set maximum in a reciprocating type of air compressor, the pressure control system causes which of the following events to happen?

1. The discharge valve to remain open
2. The suction valve to remain open
3. The discharge valve to remain closed
4. The check valve to open

8-17. In a reciprocating air compressor system with an electric motor as the power source, the motor runs only when the compressor cycle is operational.

1. True
2. False

8-18. In a rotary type of air compressor, air demand is controlled by what means?

1. Engine speed
2. Air intake opening
3. Both 1 and 2 above
4. Discharge valve opening

8-19. In a rotary type of air compressor, as air pressure drops, the air control system reacts in what way?

1. It opens the throttle
2. It opens the air valve
3. It opens the air valve and the throttle
4. It slows the compression cycle

8-20. The screw type of air compressor uses an air pressure control system much different from the rotary–type air compressor.

1. True
2. False

8-21. Which of the following materials must NOT be used as an air filter element in an air compressor?

1. Paper
2. Wire Mesh
3. Cotton

8-22. If the air filters become clogged in an air compressor, which of the following problems will occur?

1. Air compressor capacity will be lost
2. Engine performance will be lost
3. The air compressor will not unload

8-23. When using air pressure to clean dry type air filters, you should not exceed what maximum air pressure?

1. 10 psi
2. 30 psi
3. 50 psi
4. 75 psi

8-24. Gasoline should not be used to clean the air filter elements of air compressors for which of the following reasons?

1. It can cause explosive fumes to collect in the air receiver
2. It can cause hard starting
3. It can cause the engine to over speed
4. It can damage the rotor bearings

8-25. You are testing a dry type of air filter. When a concentrated light shines through the filter, you should take which of the following actions?

1. Reuse the filter as is
2. Reclean the filter and retest it
3. Replace the filter
4. Retain the filter for emergency use only

8-26. Oil separators are not required on reciprocating-type air compressors for which of the following reasons?

1. An aftercooler is used
2. An intercooler is used
3. The air system does not require lubrication
4. Oil is not circulated through the air system

8-27. If you remove the heat generated by compressing air, the total horsepower required for additional air compression is reduced up to what approximate percentage?

1. 5%
2. 10%
3. 15%
4. 25%

8-28. At what stage is oil injected into the compressor cycle in rotary- and screw-type air compressors?

1. The first stage
2. The second stage
3. The third stage
4. The cooling stage

8-29. The condensation drain on an air compressor in the cooler should be serviced at least how often?

1. Every 4 hours
2. Daily
3. Every 3 days
4. Weekly

8-30. Condensation is not desirable in an air system for which of the following reasons?

1. It causes air tools to operate sluggishly
2. It washes lubricants away from weak surfaces
3. It increases the need for maintenance
4. All of the above

8-31. Aftercoolers are normally found on what type of air compressor system?

1. Sliding vane
2. Reciprocating
3. Rotary
4. Screw

8-32. Small reciprocating air compressors normally use what type of lubrication system?

1. Splash
2. Power feed
3. Pressurized
4. Closed

8-33. A tight seal between each compartment of a rotary type of air compressor adds to its efficiency. This seal is formed by what means?

1. Gaskets
2. Moisture
3. Oil
4. Close contact of the rotating components

8-34. In most rotary- and screw-type air compressors, the oil is moved through the oil lines to the working parts of the air compressor by what device or force?

1. A gear type of oil pump
2. A piston type of oil pump
3. Air pressure
4. Vacuum

8-35. The thermostatic control valve directs heated oil through an oil cooler to keep the oil temperature in what range?

1. 110°F to 150°F
2. 130°F to 180°F
3. 150°F to 200°F
4. 180°F to 220°F

8-36. In a rotary type of air compressor, as the air/oil mix exits the last compressor stage, it enters what compartment?

1. The aftercooler
2. The thermostatic control unit
3. The air control unit
4. The air receiver

8-37. Before oil is added to a rotary or a screw type of air compressor, the unit must be shut down for what reason?

1. To allow it to cool down
2. To unload the air pressure
3. To allow the oil foam to subside

8-38. In most cases, the oil in the rotary- and screw-type air compressors should be changed at what hourly interval?

1. Every 200 hours
2. Every 300 hours
3. Every 500 hours
4. Every 750 hours

8-39. Which of the following types of air compressors produces breathable air for diving operations?

1. Reciprocating
2. Rotary
3. Screw
4. Diaphragm

8-40. You should start the equipment troubleshooting evolution by first taking which of the following actions?

1. Visually checking the unit
2. Questioning the operator
3. Running the unit and observing the operations

8-41. Which of the following conditions is most likely to cause an air compressor to overheat?

1. A clogged air filter
2. Worn rotor blades
3. A low oil level
4. A damaged oil separator

8-42. Noisy air compressor operation may be caused by which of the following problems?

1. Damaged internal parts
2. Low oil level
3. Both 1 and 2 above
4. Sticking rotor blades

8-43. If the drive engine shuts down while the air compressor is idling, what is the probable cause?

1. The unit is still cold
2. The air intake control valve is defective
3. The control lines are plugged
4. The unloader valve is leaking

8-44. A defective air intake control valve can cause an air compressor to malfunction in which of the following ways?

1. It will not unload
2. The compressor will overheat
3. The engine will stall during operation
4. The compressor will not reach design capacity

8-45. Which of the following actions should you take if the oil temperature limits of a unit are exceeded?

1. Change the oil
2. Return the unit to the shop for repair
3. Change the filter
4. Run the unit at a lighter load

8-46. The engine of an air compressor stalls during operation. Which of the following factors could cause this problem?

1. High discharge air pressure
2. A dirty compressor air filter
3. A dirty engine air filter
4. Worn rotor blades

8-47. Which of the following problems could be the cause of oil in the air discharge lines?

1. Worn rotor blades
2. Overheated compressor oil
3. Damaged oil separator
4. Leaking unloader valve

8-48. A properly maintained rotary or screw type of compressor operates reliably for approximately how many hours?

1. 5,000
2. 7,500
3. 10,000
4. 15,000

8-49. What is the primary wear point on a rotary vane type of air compressor?

1. The rotors
2. The rotor vanes
3. The bearings
4. The end plates

8-50. In a rotary vane type of compressor, the rotor vanes may be removed with the rotor in any position.

1. True
2. False

8-51. A rotor slot with a slight saw-toothed trailing edge will have what effect, if any, on the rotor vanes?

1. Cause breaking
2. Cause shifting
3. Cause rapid wear
4. None

8-52. What should you do with bearing races that have been removed by heating?

1. Discard them
2. Refinish them and reuse them
3. Reuse them after they cool

8-53. Before you reassemble a rotary- or screw-type air compressor, you should treat the parts in what way?

1. Lightly coat the bearing surface only
2. Dry them all completely
3. Coat them all with a light coat of grease
4. Lightly oil all of them

8-54. As a CM1 assigned to a shop, your job will consist of which of the following responsibilities?

1. Making regular CESE inspections
2. Looking for inoperative devices that make a vehicle unsafe
3. Looking for damage caused by dangerous or improper operating procedures
4. Each of the above

8-55. The individual assigned as a vehicle inspector should be a senior mechanic capable of performing which of the following functions?

1. Operating the equipment he is inspecting
2. Readily determining necessary repairs of equipment
3. Handling shop personnel contacts in a mature and tactful manner
4. All of the above

8-56. When a reserve Naval Mobile Construction Battalion is recalled to active duty what pm cycle does that unit use?

1. It retains the same pm cycle
2. A standard 40-day cycle
3. A 60–day pm cycle
4. An 80-day pm cycle

8-57. When you are performing repairs or maintenance, at what time should the unit be operationally tested?

1. Before the work is performed
2. After the work is performed
3. Before and after the work is performed
4. In the field

8-58. If vehicle abuse is suspected, the inspector should notify which of the following persons?

1. The dispatcher
2. The yard boss
3. The maintenance supervisor
4. The Alfa company commander

8-59. What action should be taken if the front tires of a bus, truck, or tractor-trailer are worn to less than 4/32 of an inch?

1. They should be replaced immediately
2. The frequency of inspections should be increased
3. They should be replaced at the next pm cycle

8-60. Vehicle lighting requirements are found in which of the following publications?

1. Federal motor carrier regulations pocketbook
2. NAVFAC P-404
3. NAVFAC P-405
4. NAVFAC p-437

8-61. When repair, adjustment, and preventive maintenance frequency specifications are not available, they should be developed under the direction of what person?

1. The shop supervisor
2. The transportation supervisor
3. The transportation director
4. The department head

8-62. While working in a construction battalion, the shop inspector is directly responsible to what person?

1. The shop supervisor
2. The maintenance supervisor
3. The cost control supervisor
4. The heavy shop supervisor

8-63. A series of properly conducted BEEP inspections provide the maintenance supervisor with a means for establishing which of the following items?

1. A pm schedule
2. A shop work load plan for the deployment
3. A vehicle safety inspection plan

8-64. Repairs of more than how many hours are normally deferred until after the completion of the BEEP?

1. 1 hour
2. 2 hours
3. 3 hours
4. 4 hours

8-65. When inspecting equipment for embarkation, you should make sure the collateral equipment is handled in what way?

1. Loaded with the vehicle
2. Placed in storage until the unit returns
3. Boxed and shipped separately
4. Stored at the maintenance shop

8-66. When accomplishing the vehicle loading configurations during embarkation, you should itemize the tasks on what form?

1. The hard card
2. The Shop Repair Order
3. The Equipment Repair Order

8-67. To make sure all parts work, you should have the crane crew personnel cycle the cranes at least how often?

1. Every 3 days
2. Every 5 days
3. Every 10 days
4. Every 25 days

8-68. What NAVFAC publication is an excellent source of information on preservatives and their uses?

1. P-405
2. P-433
3. P-434
4. P-437

8-69. Deadlined equipment is inspected at least how often?

1. Daily
2. Weekly
3. Monthly
4. At its scheduled pm date

8-70. The interchanging of controlled parts may be authorized by what person?

1. The maintenance supervisor
2. The shop supervisor
3. The inspector
4. The company commander

8-71. What type of equipment repair order is initiated for a vehicle that has been involved in an accident?

1. Type 01
2. Type 04
3. Type 06
4. Type 12

8-72. The crane certifying officer is designated by what person?

1. The Alfa company commander
2. The operations officer
3. The commanding officer
4. COMCBPAC/COMCBLANT DET OIC

8-73. When you are inspecting cranes, which of the following NAVFAC publications should you use as a guide?

1. P–306
2. P-307
3. P-405
4. P-437

8-74. As an inspector, if you do not think the quality of work leaving the shop is satisfactory, which of the following actions should you take?

1. Inform the maintenance supervisor
2. Return the ERO to the shop supervisor
3. Both 1 and 2 above
4. Return the ERO to the mechanic

CHAPTER 10

HYDRAULIC SYSTEMS

As a CM1, you will be responsible for the maintenance, repair, and troubleshooting of hydraulic systems. You must be able to analyze the malfunctions of these systems and supervise your personnel in the required corrective action. To be able to do this, you must thoroughly understand the basic system, the operational principles, and the components of the system.

NOTE: Before you continue with this chapter, you should review the appropriate chapters of the *CM 3&2,* NAVEDTRA 10645-G1.

The first part of this chapter briefly covers some of the basic principles associated with hydraulics, followed by coverage of various system components. The purpose of this information is to give you an analytical understanding of the interrelationships of principles and components in an operating system. When you understand the operation of a system, it is much easier to analyze a malfunction.

BASIC PRINCIPLES OF HYDRAULICS AND PNEUMATICS

In automotive and construction equipment, the terms *hydraulic* or *pneumatic* describe a method of transmitting power from one place to another through the use of a liquid or a gas. Several kinds of gases are used in the various hydraulic systems; however, certain physical laws or principles apply to all liquids and gases. As a CM, you should be aware of this. You should also be familiar with the following terms as they are associated with hydraulic and pneumatic systems.

- HYDRAULICS is that branch of science that deals with the study and use of liquids, as related to the mechanical aspects of physics.

- PNEUMATICS is that branch of science that deals with the study and use of air and other gases, as related to the mechanical aspects of physics.

- FORCE is the push or pull on an object. In hydraulics and pneumatics, force is usually expressed in pounds.

- PRESSURE is the amount of force distributed over each unit on the area of an object. In hydraulics/pneumatics, pressure is expressed in pounds per square inch (psi).

A FLUID is defined as any substance made up of small particles or molecules that have the ability to flow or move easily (conforms to the outline of its container); this includes both liquid and gas. The terms *liquids* and *fluids* are often used interchangeably; however, fluids have a much broader meaning. All liquids are fluids, but not all fluids are liquid; fluids can be liquid, but they can also be air and other gases that are not liquid. In support equipment, hydraulics mean liquid and pneumatics mean air or other gases.

INCOMPRESSIBILITY AND EXPANSION OF LIQUIDS

For all practical purposes, fluids are incompressible. Under extremely high pressures, the volume of a fluid can be decreased somewhat, though the decrease is so slight that it is considered to be negligible except by design engineers.

Liquids expand and contract because of temperature changes. When liquid in a closed container is subjected to high temperatures, it expands; this exerts a pressure on the walls of the container; therefore, it is necessary that pressure-relief mechanisms and expansion chambers be incorporated into hydraulic systems. Without these precautionary measures, the expanding fluid might exert enough pressure to rupture the system.

COMPRESSIBILITY AND EXPANSION OF GASES

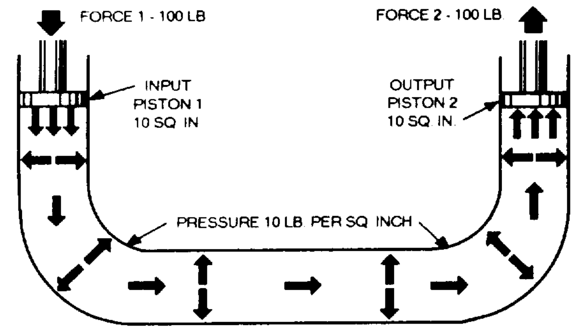
A gas is a substance in which the molecules are separated by relatively large spaces. The two major differences between liquids and gases are their compressibility and expansion. While liquids are incompressible, gases are highly compressible because of these large spaces between the molecules.

Gases, like liquids, expand and contract because of temperature change; but unlike liquids, a gas expands to till completely any closed container in which it is contained; a liquid tills the container only to the extent of its normal volume.

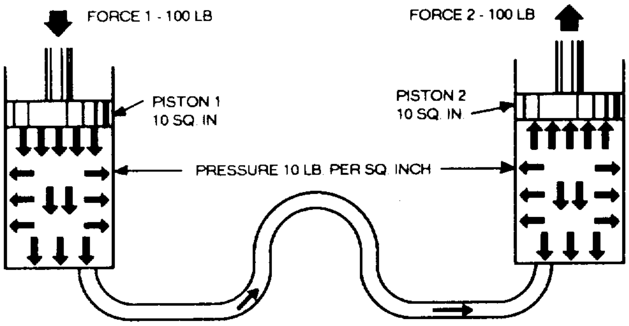
PASCAL'S LAW

Pascal was a noted French physicist who discovered that a closed container of fluid could be used to transfer force from one place to another or to multiply forces by its transmission through a fluid. Pascal's law may be stated as follows: PRESSURE APPLIED ANYWHERE ON A CONFINED FLUID IS TRANSMITTED UNDIMINISHED IN EVERY DIRECTION. THE FORCE THUS EXERTED BY THE CONFINED FLUID ACTS AT RIGHT ANGLES TO EVERY PORTION OF THE SURFACE OF THE CONTAINER AND IS EQUAL UPON EQUAL AREAS. It should be noted that Pascal's law applies to fluids-both gas and liquid. It is the use of Pascal's law that makes possible today's hydraulic and pneumatic systems.

According to Pascal's law, any force applied to a confined fluid is transmitted in all directions throughout the fluid regardless of the shape of the container. Consider the effect of this in the systems shown in views A and B of figure 10-1. If there is a resistance on the output piston (view A, piston 2) and the input piston is pushed downward, a pressure is created through the fluid, which acts equally at right angles to surfaces in all parts of the container.



A. TRANSMITTED FORCE THROUGH FLUID



B. TRANSMITTED FORCE THROUGH SMALL PIPE

Figure 10-1.-Force transmitted from piston to piston.

If the force 1 is 100 pounds and the area of input piston 1 is 10 square inches, then the pressure in the fluid is 10 psi (100 ÷ 10). It must be emphasized that this fluid pressure cannot be created without resistance to flow, which, in this case, is provided by the 100 pound force acting against the top of the output piston 2. This pressure acts on piston 2 so that for each square inch of its area it is pushed upward with a force of 10 pounds. In this case, a fluid column of uniform cross section is considered so that the area of the output piston 2 is the same as the input piston 1, or 10 square inches; therefore, the upward force on the output piston 2 is 100 pounds-the same as was applied to the input piston 1. All that has been accomplished in this system was to transmit the 100-pound force around a bend; however, this principle underlies practically all mechanical applications of fluid power.

At this point, it should be noted that since Pascal's law is independent of the shape of the container, it is not necessary that the tube connecting the two pistons should be the full area of the pistons. A connection of any size, shape, or length will do so long as an unobstructed passage is provided. Therefore, the system shown in view B of figure 10-1 (a relatively small, bent pipe connects two cylinders) will act exactly the same as that shown in view A.

Multiplication of Forces

In figure 10-1, views A and B, the systems contain pistons of equal area wherein the output force is equal to the input force. Consider the situation in figure 10-2 where the input piston is much smaller than the output piston. Assume that the area of the input piston 1 is 2

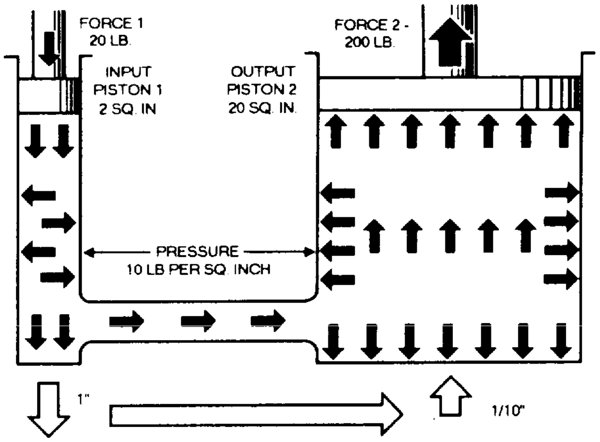


Figure 10-2.-Multiplication of force.

square inches. With a resistant force on piston 2, a downward force of 20 pounds acting on piston 1 creates 10 psi (20÷2) in the fluid. Although this force is much smaller than the applied forces in figure 10-1, the pressure is the same because the force is concentrated on a relatively small area.

This pressure of 10 psi acts on all parts of the fluid container, including the bottom of the output piston 2; therefore, the upward force on the output piston 2 is 10 pounds for each of its 20 square inches of area, or 200 pounds (10 x 20). In this case, the original force has been multiplied tenfold while using the same pressure in the fluid as before. In any system with these dimensions, the ratio of output force to input force is always 10 to 1 regardless of the applied force; for example, if the applied force of the input piston 1 is 50 pounds, the pressure in the system is increased to 25 psi. This will support a resistant force of 500 pounds on the output piston 2.

The system works the same in reverse. Consider piston 2 as the input and piston 1 as the output; then the output force will always be one-tenth the input force. Sometimes such results are desired.

Therefore, the first basic rule for two pistons used in a fluid power system is *the force acting on each is directly proportional to its area and the magnitude of each force is the product of the pressure and its area,* is totally applicable.

Volume and Distance Factors

In the systems shown in views A and B of figure 10-1, the pistons have areas of 10 square inches. Since the areas of the input and output pistons are equal, a force of 100 pounds on the input piston will support a resistant force of 100 pounds on the output piston. At this point, the pressure of the fluid is 10 psi. A slight force, in excess of 100 pounds, on the input piston will increase the pressure of the fluid, which will, in turn, overcome the resistance force. Assume that the input piston is forced downward 1 inch. This displaces 10 cubic inches of fluid. Since liquid is practically incompressible, this volume must go some place. In the case of a gas, it will compress momentarily but will eventually expand to its original volume at 10 psi. This is provided, of course, that the 100 pounds of force is still acting on the input piston. Thus this volume of fluid moves the output piston. Since the area of the output piston is likewise 10 square inches, it moves 1 inch upward to accommodate the 10 cubic inches of fluid. The pistons are of equal areas; therefore, they will move equal distances, though in opposite directions.

Applying this reasoning to the system in figure 10-2, it is obvious that if the input piston 1 is pushed down 1 inch, only 2 cubic inches of fluid is displaced. The output piston 2 will have to move only one-tenth of an inch to accommodate these 2 cubic inches of fluid, because its area is 10 times that of the input piston 1. This leads to the second basic rule for two pistons in the same fluid power system, which is *the distances moved are inversely proportional to their areas.*

While the terms and principles mentioned above are not all that apply to the physics of fluids, they are sufficient to allow further discussion in this training manual. It is recommended that *Fluid Power,* NAVEDTRA 12964 (latest edition), be studied for a more detailed and knowledgeable coverage of the physics of fluids and basic hydraulic/pneumatic systems.

COMPONENTS

Since fluids are capable of transmitting force and at the same time flow easily, the force applied to the fluid atone point is transmitted to any point the fluid reaches. Hydraulic and pneumatic systems are assemblies of units capable of doing this. They contain a unit for generating force (pumps), suitable tubing and hoses for containing and transmitting the fluid under pressure, and units in which the energy in the fluid is converted to mechanical work (cylinders and fluid motors). In addition, all operative systems contain valves and restrictors to control and direct the flow of fluid and limit the maximum pressure in the system.

Because of the similarities of hydraulic and pneumatic systems (that is, from a training point of view), only the components of hydraulic systems are covered in this section. Remember that most of the information is also applicable to pneumatic systems and their components.

PUMPS

The heart of any hydraulic system is its pumps; it is the pump that generates the force required by the actuating mechanisms. The pump causes a flow of fluid; thus, the amount of pressure created in a system is not controlled by the pump but by the workload imposed on the system and the pressure-regulating valves.

Basically, pumps may be classified into two groups based on performance: (1) fixed delivery when running at a given speed and (2) variable delivery when running at a given speed.

Pumps may further be divided into types, based upon the design used to create force (fluid flow). Practically all hydraulic pumps fall within three classifications of design–rotary, reciprocating, and centrifugal. The centrifugal style pumps find little use in CESE hydraulic systems used in the Naval Construction Force and will not be covered here. Pumps may be driven by air pressure, electric motors, gas turbine engines, or the conventional internal combustion engines (gasoline and diesel).

Rotary Pumps

All rotary pumps operate by means of rotating parts, that trap the fluid at the inlet (suction) port and force it through the discharge port into the hydraulic system. Gears, lobes, and vanes are commonly used as elements in rotary pumps. Rotary pumps operate on the positive displacement principle and are of the fixed displacement type.

There are numerous types of rotary pumps and various methods of classification. They may be classified as to shaft position—either vertically or horizontally mounted; the type of drive-electric motor, internal combustion engine, and so forth; manufacturer's name; or service application; however, classification of rotary pumps is generally made according to the type of rotating element. A few of the most common types of rotary pumps are covered in the paragraphs below.

GEAR PUMP.— Gear pumps are classified by their method of meshing together. This style pump is simple in design and finds wide use in low-pressure hydraulic systems. A gear pump delivers a constant volume of fluid at any given rpm (fig. 10-3).

The pump shown is known as a spur tooth and consists of two meshed gears that revolve alongside each other in one housing. The drive gear in the illustration is turned by a drive shaft that engages the power source. The clearances between the gear teeth, as they mesh, and the pump housing are very small.

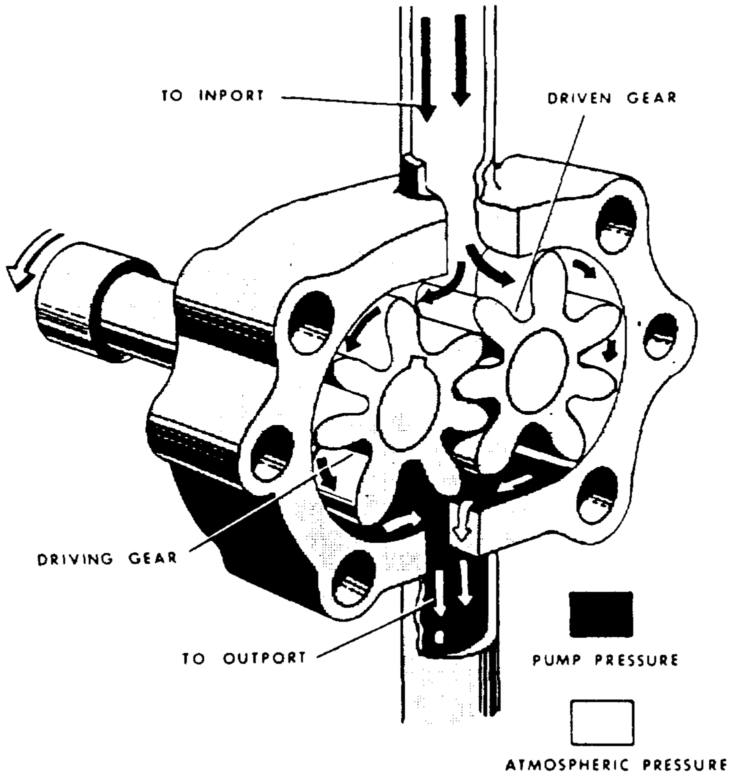


Figure 10-3.-Typical gear type of hydraulic pump.

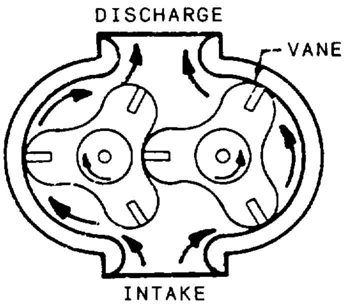


Figure 10-4.-Lobe type of pump.

The inlet port is connected to the fluid supply line, and the outlet port is connected to the pressure line. Referring to the figure, the drive gear is rotating in a counterclockwise direction, and the driven gear (idler gear) is rotating in a clockwise direction. As the teeth pass the inlet port, fluid is trapped between the teeth and the housing; this liquid is carried around the housing to the outlet port. As the teeth mesh again, the liquid between the teeth is displaced into the outlet port. This action produces a positive flow of liquid into the system. A shear pin or shear section is incorporated in the drive shaft to protect the power source or reduction gears if the pump fails because of excessive load or binding of parts.

A variation of the spur tooth pump is the lobe pump (fig. 10-4), which is also used on many diesel-powered equipments for an intake blower as well as in a variety of hydraulic systems. The principle of operation of this pump is exactly the same as the spur tooth. The lobes are so constructed that there is a continuous seal (vane) at the point of juncture at the center of the pump and also on the housing.

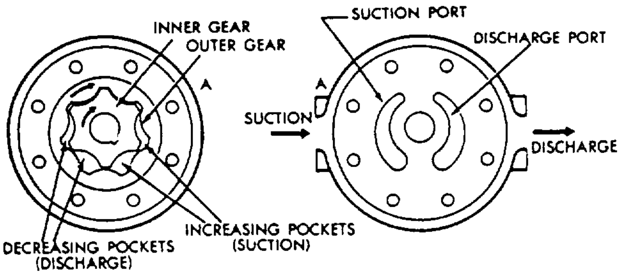


Figure 10-5.-Internal gear type of pump.

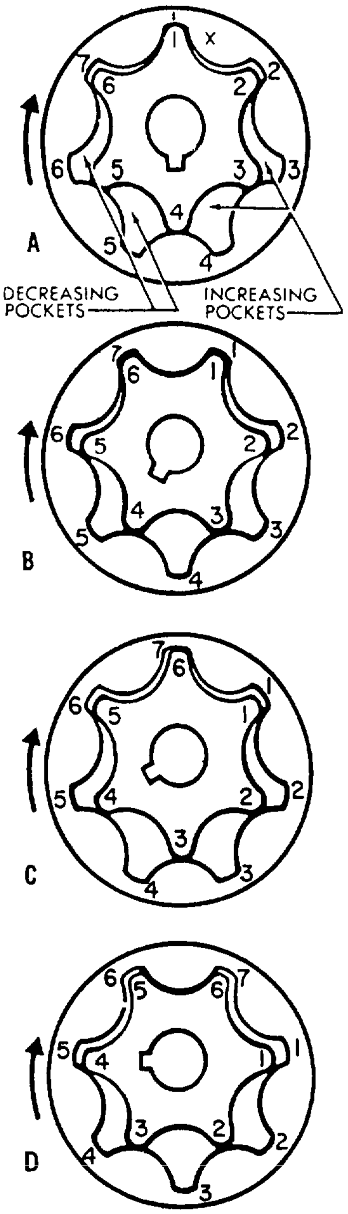


Figure 10-6.-Principles of operation of the internal gear type of pump.

Another popular style of gear pump is the internal gear (fig. 10-5). This pump consists of a pair of gear-shaped elements (one within the other) located in the pump chamber. The inner gear is connected to the drive shaft of the source of power.

For an explanation of the operation of this type of pump, refer to figure 10-6. The teeth of the inner gear and the spaces between the teeth of the outer gear are numbered. Note that the inner gear has one less tooth than the outer gear has spaces. The tooth force of each gear is related to that of the other in such away that each tooth of the inner gear is always in sliding contact with the surface of the outer gear. Each tooth of the inner gear meshes with the outer gear at just one point during each revolution. In the illustration, this point is at the top (X). In view A, tooth 1 of the inner gear is in mesh with space 1 of the outer gear. As the gears continue to rotate in clockwise direction and the teeth approach point (X), tooth 6 of the inner gear will mesh with space 7 of the outer gear, tooth 5 with space 6, and so forth. During this revolution, tooth I will mesh with space 3. As a result, the outer gear rotates at 1,400 rpm, and the outer gear will rotate at 1,200 rpm.

At one side of the point of mesh, pockets of increasing size are formed as the gears rotate, while on the other side the pockets decrease in size. The pockets on the right-hand side of the drawings are increasing in size as one moves down the illustration, while those on the left-hand side are decreasing in size. The intake side of the pump would therefore be to the right and the discharge to the left. Since the right-hand side of the drawing in figure 10-5 was turned over to show the ports, the intake and discharge appear reversed. Actually, A in one drawing covers A in the other.

VANE PUMP.— Figure 10-7 illustrates a vane pump of the unbalanced design. The rotor is attached to the drive shaft and is rotated by an outside power source, such as an electric motor or gasoline engine. The rotor is slotted, and each slot is fitted with a rectangular vane. These vanes, to some extent, are free to move outward in their respective slots. The rotor and vanes are enclosed in a housing, the inner surface of which is offset with the drive axis.

As the rotor turns, centrifugal force keeps the vanes snug against the wall of the housing. The vanes divide the area between the rotor and housing into a series of chambers. The chambers vary in size according to their respective positions around the shaft. The inlet port is located in that part of the pump where the chambers are expanding in size so that the partial vacuum (low-pressure area) formed by this expansion allows liquid to flow into the pump. The liquid is trapped between the vanes and carried to the outlet side of the pump. The chambers contract in size on the outlet side, and this action forces the liquid through the outlet port and into the system.

The pump is referred to as unbalanced because all of the pumping action takes place on one side of the shaft and rotor. This causes a side load on the shaft and rotor. Some vane pumps are constructed with an elliptical-shaped housing that forms two separate pumping areas on opposite sides of the rotor. This cancels out the side loads; therefore, such pumps are used quite extensively in power steering units in CESE to provide the flow.

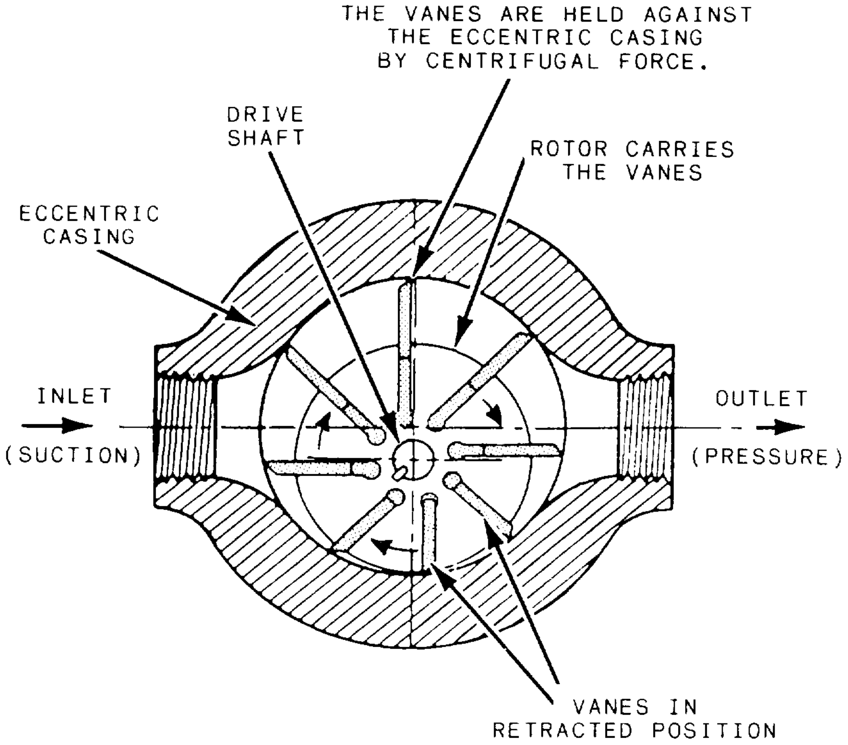


Figure 10-7.-Typical vane type of hydraulic pump.

Reciprocating Pumps

Reciprocating pumps are most commonly used for applications requiring high pressures and accurate control of the discharge volume. There are many variations of this pump, which is normally refereed to as a piston pump in support equipment; however, they are generally based on the axial piston or hand pump principle. There are also radial piston pumps, but they are hardly ever used in design of support equipment systems.

It is not within the scope of this TRAMAN to cover all the variations of the piston pump since there are more than 20 manufacturers of these pumps; each has its own patented improvements to achieve efficiency and reduce wear. You should consult the appropriate technical manual for specific pump maintenance and repair information.

AXIAL-PISTON PUMPS.— Axial-piston pumps are classified as either constant volume or variable volume. The paragraphs below explain the overall operation of the pump and the means designed into the variable volume pump to provide stroke reduction.

Constant Volume Piston Pump.— The constant volume piston pump (fig. 10-8) produces a constant flow of fluid for any given rpm. The pistons, usually about nine (always an odd number), are fastened by a universal linkage to a drive shaft. The universal link in the center drives the cylinder block; it is held at an angle to the drive shaft by the pump housing. Everything within the pump housing rotates with the drive shaft. As the piston is rotated to the upper position, its movement forces fluid out of the pressure port. As the same piston moves from the upper position to the lower position, it draws in fluid through the intake port. Since each piston is always somewhere between the upper and lower position, constant intake and output of fluid results. The volume output of the pump is determined by the angle between the drive shaft and the cylinder block, as the degree of angle decreases or increases the piston stroke. The larger the angle, the greater the output per revolution.

If you follow one piston through one complete revolution, you can see how the pump operates. Start with the piston at the top of its cylinder (fig. 10-8). It has just completed its pressure stroke and is ready to begin its intake stroke. As the cylinder starts its rotation from this point, the piston immediately aligns with the intake port as it moves toward the bottom of the cylinder. The partial vacuum created by the movement of the piston in the cylinder and the gravity pressure (in some cases, boost pressure) on the fluid cause the space above the piston to fill with fluid. When the cylinder has gone through 180 degrees or one-half revolution, the piston reaches the bottom of the cylinder; the cylinder is now full of fluid.

As rotation continues beyond this point, the piston now aligns with the outlet port slot. Thus, when the last 180 degrees have been completed, the piston will have moved forward in the cylinder; the fluid will have been forced into the outlet line. At this point, the piston and cylinder are again ready to start another cycle. There are several pistons performing the same function just described. Since the pump rotates rapidly, there is a constant flow of fluid through the outlet port.

This pump normally uses case pressure and fluid flow for cooling and lubricating. Fluid seeps by the pistons in the cylinder block and fills all the space inside the pump. The fluid is prevented from escaping through the drive end of the pump by a drive shaft seal. Excessive case pressure is prevented by routing the fluid back to the inlet port of the pump through one or more relief

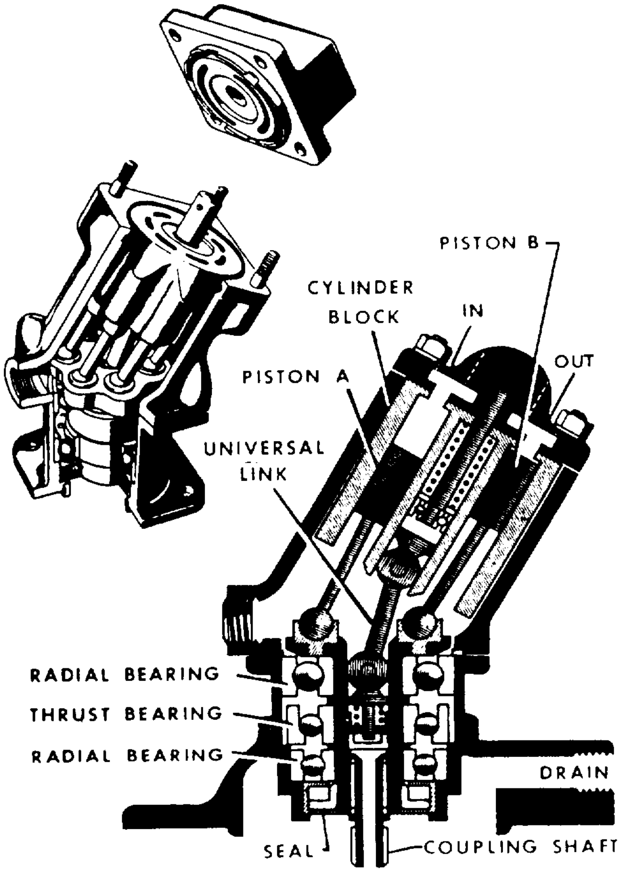
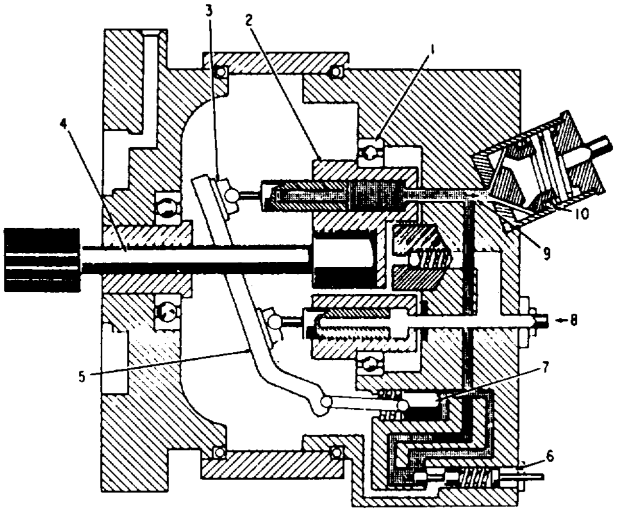


Figure 10-8.-Example of a constant volume piston pump.



1. **Bearing**
2. **Cylinder**
3. **Piston plate**
4. **Drive shaft**
5. **Cam plate**
6. **Compensator valve**
7. **Stroking piston**
8. **Inlet**
9. **Outlet**
10. **Check valve**

Figure 10-9.-Example of a variable volume, stroke reduction pump with variable cam plate.

valves. These valves are usually set at about 15 psi; this ensures circulation of fluid in the pump.

The piston pump discussed is a constant displacement type; that is, for any given rpm, the volume output is constant. However, there is another version of the piston pump used more extensively than the constant volume pump; that is, the variable volume pump.

Variable Volume Piston Pump.— There are many versions of the variable volume pump; several different control methods are used to vary the fluid flow through the pump. Some of the pumps vary the volume by controlling the inlet fluid; some vary it by changing the angle between the pump drive shaft and the piston cylinder block; others by using a system bypass within the pump to vary volume output.

One advantage of the variable volume pump is that it eliminates the need for a system pressure regulator. A second advantage is that it provides a more stable pressure, thus reducing pressure surges and the need for a system accumulator; however, they are retained for use during peak load occurrences.

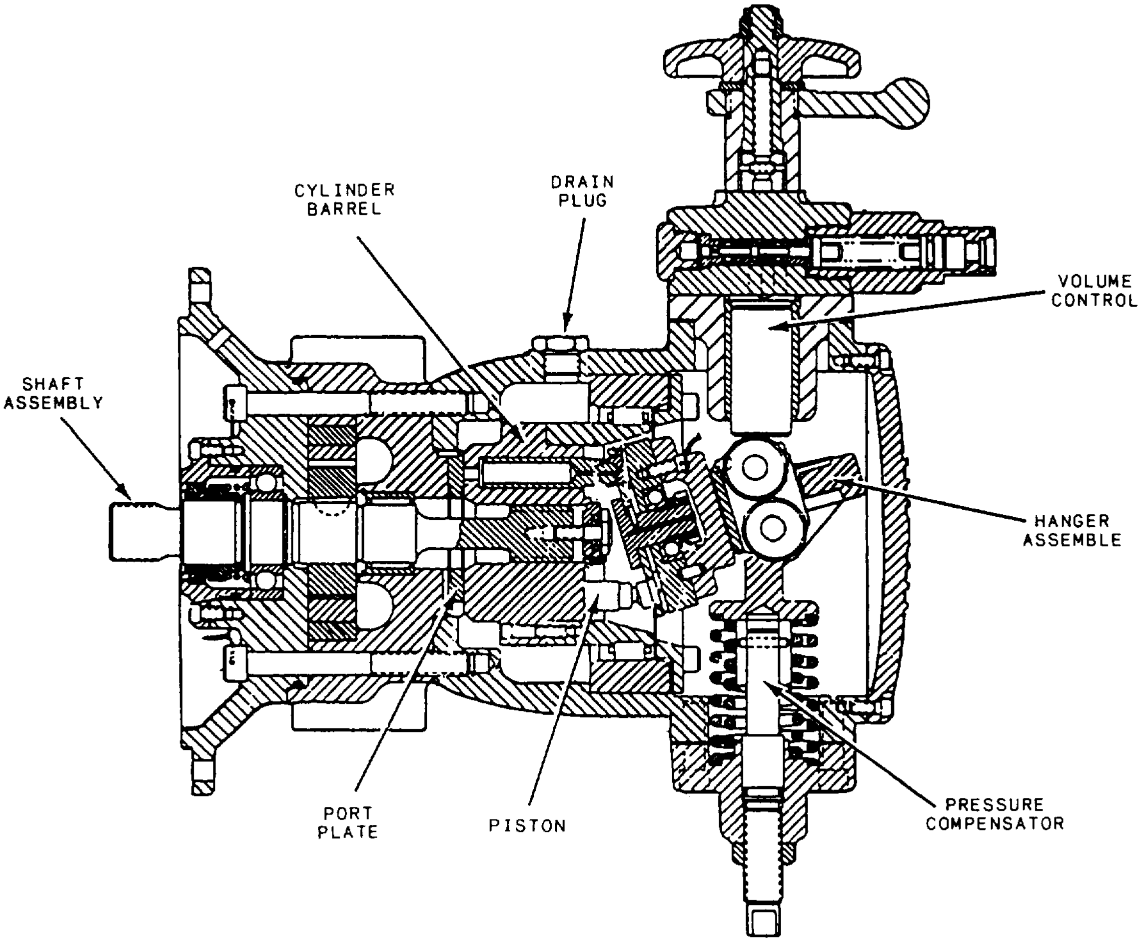


Figure 10-10.-Variable displacement axial-piston pump.

As stated previously, the output of the constant volume pump is determined by pump rpm and the fixed angle between the drive shaft and the rotating cylinder block. If the angle was not fixed and could be varied, the piston stroke would be changed, thus varying the pump output. Changing the pump piston stroke is the method used on most variable volume pumps found in support equipment.

The stroke reduction pumps (figs. 10-9 and 10- 10) are fully automatic variable volume pumps. The pressure compensating valves shown in both figures use system pressure to control and vary the piston stroke of the pump, thus changing the output.

NOTE: The piston stroke of the pump (fig. 10-10) is determined by the angle of the cam plate. The drive shaft passes through, but does not touch, the inclined cam plate to rotate the cylinder block and pistons. The hanger assembly in figure 10-10 provides this same function as the cam plate in figure 10-9.

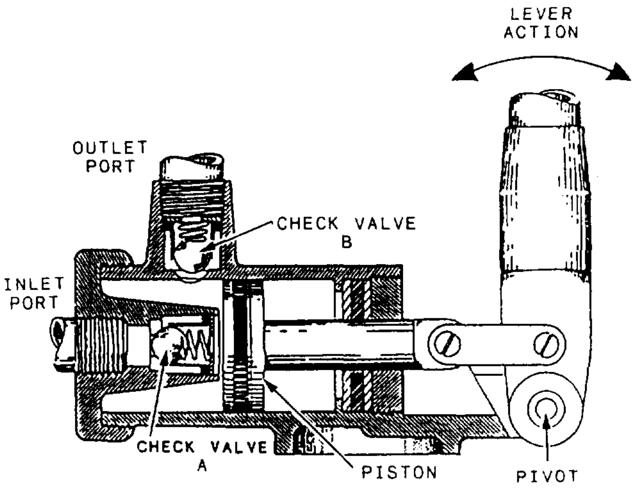
The pumps may also be configured to allow manual volume control of the pump. Manual volume is controlled by a handwheel to vary the piston stroke or may use manual pressure compensating valves such as those used on many hydraulic test stands.

HAND PUMPS.— The hand pump normally serves as a substitute for the main power pump on most hydraulic systems; however, the hand pump is widely used as the only power source in some equipment. Examples are hydraulic jacks, hydraulically actuated workstands, and similar equipment.

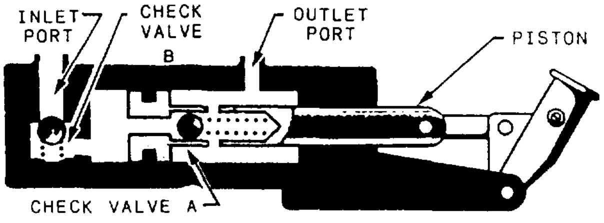
The two designs of hand pumps you will be using are *single action* and *double action* (fig. 10- 11). The double-action hand pump creates the flow of fluid with each stroke of the pump handle; two strokes are required for the single-action pump. There are several versions of single- and double-action hand pumps but all operate on the reciprocating piston principle. The unit shown in figure 10-11, view A, consists of a cylinder, a piston, an operating handle, and two check valves-check valve A and check valve B. The inlet port is connected to the reservoir, and the outlet port is connected to the pressure system. As the piston is moved to the right by the pump handle, fluid from the reservoir flows through check valve A into the pump cylinder. As the piston is moved to the left, check valve A closes and check valve B opens. The fluid in the pump cylinder is forced out of the outlet port into the pressure line. Thus, with each two strokes of the hand, a single pressure stroke is produced.

The double-action hand pump (fig. 10-11, view B) consists of a cylinder, a piston containing a built-in check valve A, a large piston rod, an operating handle, and check valve B at the inlet port.

When you move the piston to the right, check valve A closes and check valve B opens. Fluid from the reservoir then flows into the cylinder through the inlet port. When you move the piston to the left, check valve B closes. The pressure created in the fluid then opens check valve A, admitting fluid behind the piston. (Note that the large piston rod takes up much of the space behind by the piston rod.) Because of the space occupied by the piston rod, there is room for only part of the fluid; thus, the remainder of fluid is forced through the outlet port into the pressure line. This is one pressure stroke. Again if you move the piston to the right, check valve A closes. The fluid behind the piston is forced through the outlet port. At the same time fluid from the reservoir flows into the cylinder through check valve B. his pump has a pressure stroke for each stroke of the handle.



A. SINGLE-ACTION HAND PUMP



B. DOUBLE-ACTION HAND PUMP

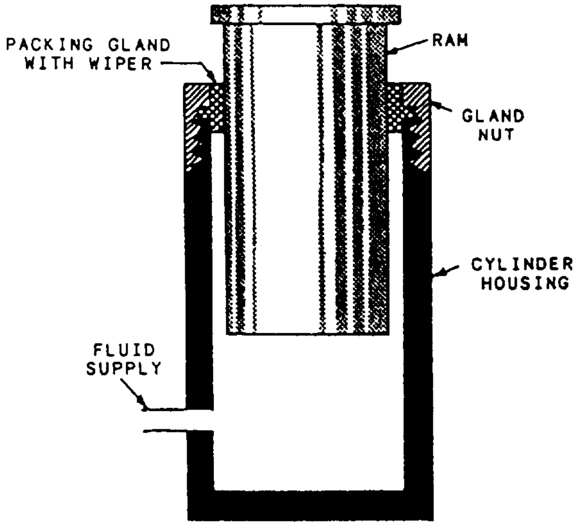
Figure 10-11-Typical hand pumps.

ACTUATORS

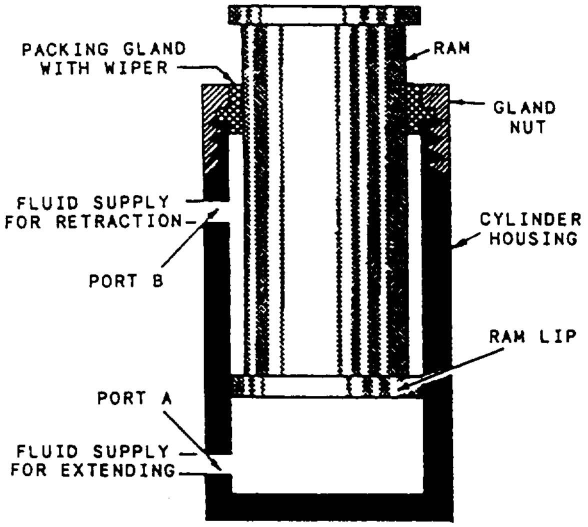
The purpose of hydraulic actuators is to transform fluid pressure into mechanical energy. They are used where linear motion or rotary motion is required. Actuators are generally of the cylinder or motor design.

Cylinders

An actuating cylinder is a device that converts fluid power to linear or straight-line force and motion. Since linear motion is a back-and-forth motion along a straight line, this type of actuator is sometimes referred to as a reciprocating or linear motor. The cylinder consists of a ram or piston operating within a cylindrical bore.



A. SINGLE-ACTING RAM TYPE ACTUATING CYLINDER



B. DOUBLE-ACTING RAM TYPE ACTUATING CYLINDER

Figure 10-12.-Example of ram type of cylinders.

Actuating cylinders for pneumatic and hydraulic systems are similar in design and operation. Some of the variations of ram- and piston-type actuating cylinders are described in the paragraphs below.

RAM TYPE OF CYLINDER.— The ram type of cylinder (fig. 10-12) is used primarily for push functions rather than pull. Some applications simply require a flat surface on the external part of the ram for pushing or lifting the unit to be operated. Other applications require some mechanical means of attachment, such as a clevis or eyebolt. The design of ram-type cylinders varies in many other respects to satisfy the requirements of different applications. Some of these various designs are discussed in the paragraphs below.

Single-Acting Ram.— The single-acting ram (fig. 10-12, view A) applies force in only one direction. Fluid directed into the cylinder displaces the ram and forces it outward. Since there is no provision for retracting the ram by the use of fluid power, the retracting force can be gravity or some mechanical means, such as a spring. This type of actuating cylinder is often used in the hydraulic jack.

Double-Acting Ram.— A double-acting ram type of cylinder is illustrated in figure 10-12, view B. In this cylinder, both strokes of the ram are produced by pressurized fluid. There are two fluid ports–one at or near each end of the cylinder. To extend the ram and apply force, fluid under pressure is directed to the closed end of the cylinder through port A. To retract the ram and reduce force, fluid is directed to the opposite end of the cylinder through port B.

PISTON TYPE OF CYLINDER.— This type of cylinder is normally used for applications that require both push and pull functions. Thus, the piston type serves many more requirements than the ram type; therefore, it is the most common type used in fluid power systems.

The housing consists of a cylindrical barrel that usually contains either external or internal threads on both ends. End caps with mating threads are attached to the ends of the barrel. These end caps usually contain the fluid ports. The end cap on the rod end contains a hole for the piston rod to pass through. Suitable packing must be used between the hole and the piston rod to prevent external leakage of fluid and the entrance of dirt and other contaminants. The opposite end cap of most cylinders is provided with a fitting for securing the actuating cylinder to some structure. For obvious reasons, this end cap is referred to as the anchor end cap.

The piston rod may extend through either or both ends of the cylinder. The extended end of the rod is normally threaded for the attachment of some type of mechanical connector, such as an eyebolt or a clevis, and a locknut. This threaded connection of the rod and mechanical connector provides for adjustment between the rod and the unit to be actuated. After correct adjustment is obtained, the locknut is tightened against the connector to prevent the connector from turning. The other end of the eyebolt or clevis is connected, either directly or through additional mechanical linkage, to the unit to be actuated.

To satisfy the many requirements of fluid power systems, you may get piston type cylinders in various designs. Two of the more common designs (fig. 10-13) are described in the paragraphs below.

Single-Acting Piston.— The single-acting piston-type cylinder (fig. 10-13, view A) is similar in design and operation to the single-acting ram-type cylinder previously covered. The single-acting piston-type cylinder uses fluid pressure to apply force in only one direction. In some designs of this type, the force of gravity moves the piston in the opposite direction; however, most cylinders of this type apply force in both directions. Fluid pressure provides the force in one direction, and spring tension provides the force in the opposite direction. In some single-acting cylinders, compressed air or nitrogen is used instead of a spring for movement in the direction opposite that achieved with fluid pressure.

The end of the cylinder opposite the fluid port is vented to the atmosphere. This prevents air from being trapped in this area. Any trapped air would compress during the extension stroke, creating excess pressure on the rod side of the piston. This would cause sluggish movement of the piston and could eventually cause a complete lock, preventing the fluid pressure from moving the piston.

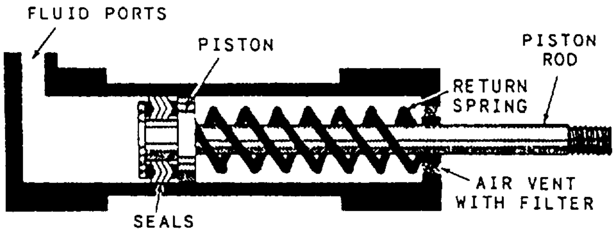
You should note that the air vent ports are normally equipped with an air filtering attachment to prevent ingestion of contaminates when the piston retracts into the cylinder.

A three-way directional control valve is normally used to control the operation of this type of cylinder. To extend the piston rod, fluid under pressure is directed through the port and into the cylinder. This pressure acts on the surface area of the blank side of the piston and forces the piston to the right. This action, of course, extends the rod to the right through the end of the cylinder. This moves the actuated unit in one direction. During this action, the spring is compressed between the rod side of the piston and the end of the cylinder. Within limits of the cylinder, the length of the stroke depends upon the desired movement of the actuated unit.

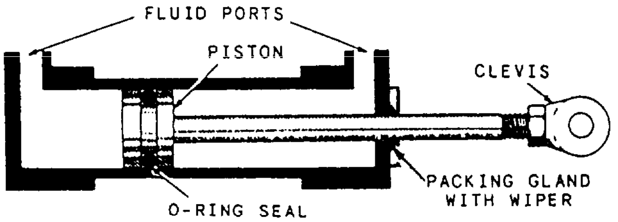
Double-Acting Piston.— Most piston type actuating cylinders are double-acting, which means that fluid under pressure can be applied to either side of the piston to provide movement and apply force in the corresponding direction.

One design of the double-acting piston type actuating cylinder is illustrated in figure 10-13, view B. This cylinder contains one piston and piston rod assembly. The stroke of the piston and piston rod assembly in either direction is produced by fluid pressure. The two fluid ports, one near each end of the cylinder, alternate as inlet and outlet, depending upon the direction of flow from the directional control valve.

This is referred to as an unbalanced actuating cylinder; that is, there is a difference in the effective working areas on the two sides of the piston. Assume that the cross-sectional area of the piston is 3 square inches and the cross-sectional area of the rod is 1 square



A. SINGLE-ACTING, SPRING-LOADED PISTON TYPE/ACTUATING CYLINDER



B. DOUBLE-ACTING PISTON ACTUATING CYLINDER

Figure 10-13.-Example of piston type of cylinder.

inch. In a 2,000-psi system, pressure acting against the blank side of the piston creates a force of 6,000 pounds (2,000 x 3). When the pressure is applied to the rod side of the piston, the 2,000 psi acts on 2 square inches (the cross-sectional area of the piston less the cross-sectional area of the rod) and creates a force of 4,000 pounds (2,000 x 2). For this reason, this type of cylinder is normally installed in such a manner that the blank side of the piston carries the greater load; that is, the cylinder carries the greater load during the piston rod extension stroke.

A four-way directional control valve is normally used to control the operation of this type of cylinder. The valve can be positioned to direct fluid under pressure to either end of the cylinder and allow the displaced fluid to flow from the opposite end of the cylinder through the control valve to return/exhaust.

Motors

A fluid power motor is a device that converts fluid power to rotary motion and force. Basically, the function of a motor is just the opposite as that of a pump; however, the design and operation of fluid power motors are very similar to pumps. In fact, some hydraulic pumps can be used as motors with little or no modifications; therefore, your having a thorough knowledge of the pumps will be extremely helpful to you in understanding the operation of fluid power motors.

Motors serve many applications in fluid power systems. In hydraulic power drives, pumps and motors are combined with suitable lines and valves to form hydraulic systems. The pump, commonly referred to as the A-end, is driven by some outside source, such as a diesel or gasoline engine. The pump delivers fluid to the motor. The motor, referred to as the B-end, is actuated by this flow, and, through mechanical linkage, conveys rotary motion and force to the work.

Fluid motors are usually classified according to the type of internal element, which is directly actuated by the flow. The most common types of elements are the gear, vane, and piston. All three of these types are adaptable for hydraulic systems, while only the vane type is used in pneumatic systems.

GEAR TYPE.— The gears of the gear-type motor are of the external type and may be of the spur, helical, or herringbone design. These designs are the same as those used in gear pumps.

The operation of a gear-type motor is illustrated in figure 10-14. Both gears are driven gears; however, only one is connected to the output shaft. As fluid under pressure enters chamber A, it takes the path of least resistance and flows around the inside surface of the housing, forcing the gears to rotate as indicated. The flow continues through the outlet port to return. This rotary motion of the gears is conveyed through the attached shaft to the work unit.

Although the motor illustrated in figure 10-14 shows operation in only one direction, the gear-type motor is capable of providing rotary motion in either direction. The ports alternate as inlet and outlet, To reverse the direction of rotation, the fluid is directed through the port-labeled outlet, into chamber B. The flow through the motor rotates the gears in the opposite direction, thus actuating the work unit accordingly.

VANE TYPE.— A typical vane-type air motor is illustrated in figure 10-15, view A. This particular motor provides rotation in only one direction. The rotating element is a slotted rotor mounted on a drive shaft. Each slot of the rotor is fitted with a freely sliding rectangular vane. The rotor and vane are enclosed in the housing–the inner surface of which is offset with the drive shaft axis. When the rotor is in motion, the vanes tend to slide outward because of centrifugal force. The distance the vanes slide is limited by the shape of the rotor housing.

This motor operates on the principle of differential areas. When compressed air is directed into the inlet port, its pressure is exerted equally in all directions. Since area A is greater than area B, the rotor will turn counterclockwise. Each vane, in turn, assumes the No. 1 and No. 2 position and the rotor turns continuous y. The potential energy of the compressed air is thus

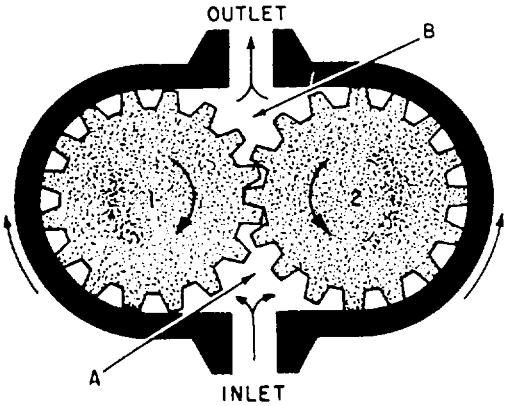
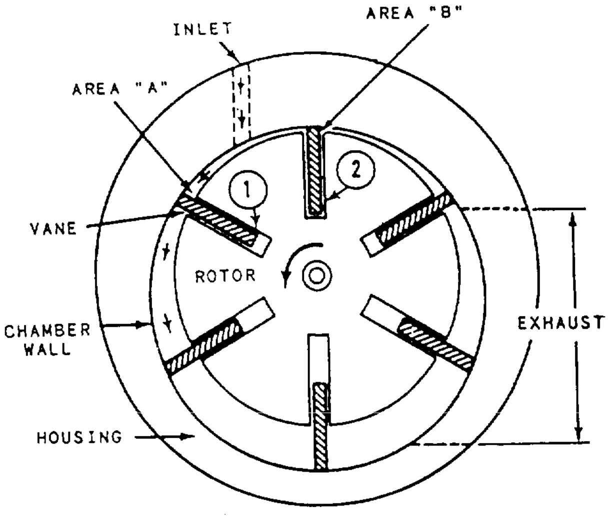
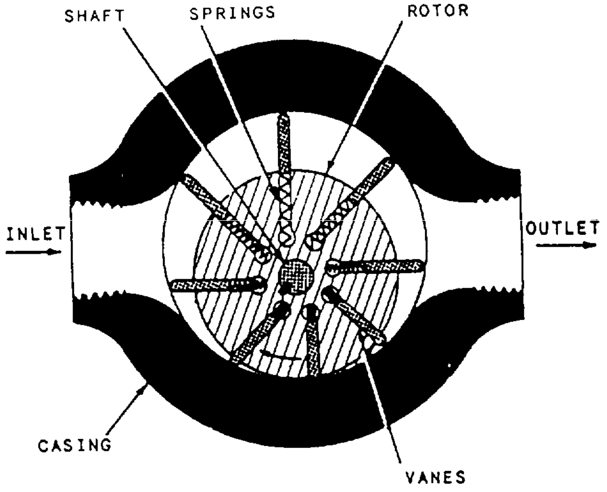


Figure 10-14.-Example of a gear-type of hydraulic motor.



A. VANE TYPE OF AIR MOTOR



B. VANE TYPE OF HYDRAULIC MOTOR

Figure 10-15.-Typical vane type of hydraulic motor.

converted into kinetic energy in the form of rotary motion and force. The air at reduced pressure is exhausted to the atmosphere. The shaft of the motor is connected to the unit to be actuated.

Many vane-type motors are capable of providing rotation in either direction. A motor of this design is illustrated in figure 10-15, view B. The principle of operation is the same as that of the vane type of motor previously described. The two ports may be alternately used as inlet and outlet, thus providing rotation in either direction. Note the springs in the slots of the rotors. Their purpose is to hold the vanes against the housing during the initial starting of the motor, since no centrifugal force exists until the rotor begins to rotate. Springs are not required in vane-type pumps because the drive shaft provides the initial centrifugal force.

PISTON TYPE.—Like piston (reciprocating) type pumps, the most common design of the piston type of motor is the axial. This type of motor is the most commonly used in hydraulic systems.

Although some piston-type motors are controlled by directional control valves, they are often used in combination with variable displacement pumps. This pump-motor combination (hydraulic transmission) is used to provide a transfer of power between a driving element (for example, an electric motor or gasoline engine) and a driven element. Some of the applications for which hydraulic transmissions may be used are speed reducer, variable speed drive, constant speed or constant torque drive, and torque converter. Some advantages of hydraulic transmission over mechanical transmission of power are as follows:

1. Quick easy speed adjustment over a wide range while the power source is operating at constant (most efficient) speed. Rapid, smooth acceleration or deceleration.
2. Control over maximum torque and power.
3. Cushioning effect to reduce shock loads.
4. Smoother reversal of motion.

While you are studying the description of the piston type of motor in the paragraphs below, it may be necessary to refer back to the piston type of pump for a review of the operation and particularly the parts nomenclature.

The operation of the axial-piston motor (fig. 10-16) is similar to that of a radial piston motor. Fluid from the system flows through one of the ports in the valve plate and enters the bores of the cylinder block that are open

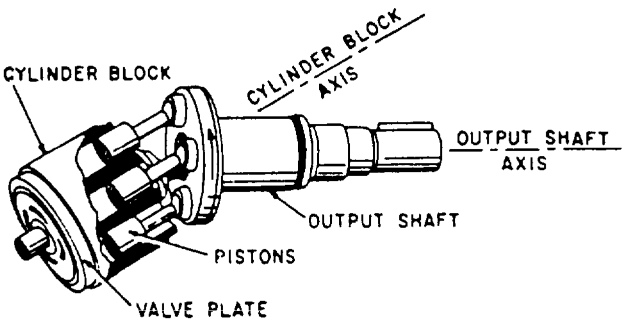


Figure 10-16.-Example of a piston type of hydraulic motor.

to the inlet port. (For example, in a nine piston motor, four cylinder bores are receiving fluid while four are discharging.) The fluid acting on the pistons in those bores forces the pistons to move away from the valve plate. Since the pistons are held by connecting rods at a fixed distance from the output shaft flange, they can move away from the valve plate only by moving in a rotary direction. The pistons move in this direction to a point around the shaft axis, which is the greatest distance from the valve plate. Therefore, driving the pistons axially causes them to rotate the drive shaft and cylinder block. While some of the pistons are being driven by liquid flow from the system, others are discharging flow from the outlet port.

This type of motor may be operated in either direction of rotation. The direction of rotation is controlled by the direction of flow to the valve plate. The direction of flow may be instantly reversed without damage to the motor. This design is found mainly on construction equipment as an auxiliary drive motor.

The speed of the rotation of the motor is controlled by the length of the piston stroke in the pump. When the pump is set to allow a full stroke of each piston, each piston of the motor must move an equal distance. In this condition, the speed of the motor will equal that of the pump. If the tilting plate of the pump (normally called a swash plate or hanger assembly) is changed so that the piston stroke of the pump is only one half as long as the stroke of the motor, it will require the discharge piston one full stroke; therefore, in this position of the plate, the motor will revolve just one half as fast as the pump. If there is no angle on the tilting plate of the pump, the pumping pistons will not move axially, and liquid will not be delivered to the motor; therefore, the motor will deliver no power.

If the angle of the tilting plate is reversed, the direction of flow is reversed. Liquid enters the motor through the port by which it was formally discharged. This reverses the direction of rotation of the motor.

An additional benefit to this axial-piston pump/axial-piston motor configuration is the dynamic braking effect created when the motor, in a coasting situation, in effect, becomes a pump itself and attempts to reverse-rotate the hydraulic pump. In this situation the pump now becomes a motor and attempts to reverse-rotate the prime mover. The degree of reverse angle on the tilting plate in the pump determines the effectiveness of the dynamic braking.

VALVES

Once the pump has begun to move the fluid in a hydraulic system, valves are usually required to control, monitor, and regulate the operation of the system. While the pump is recognized as the heart of the system, the valves are the most important devices for providing flexibility in today's complex hydraulic systems.

Valves are included in a hydraulic system to control primarily (1) the direction of fluid flow, (2) the volume of fluid going to various parts of the system, and (3) the pressure of the fluid at different points in the system.

It is beyond the scope of this training manual to cover all of the many different valves in use today; however, since most of these valves are almost always combinations and elaborations of basic types, an understanding of their operation can be obtained by a review of the basic types.

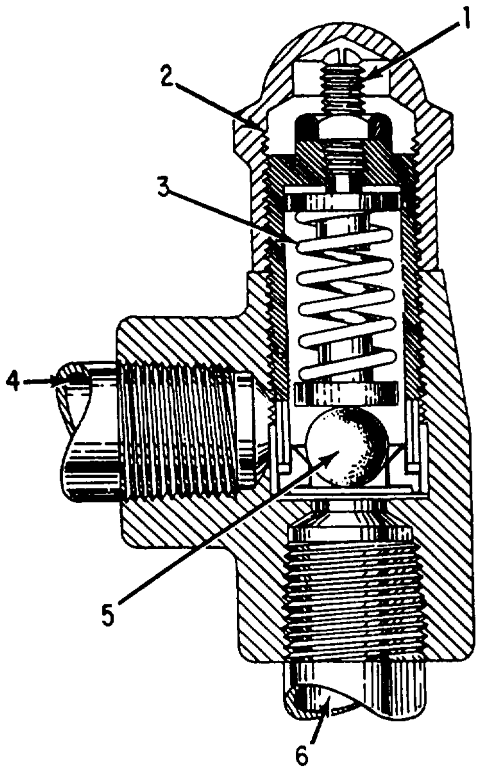
The basic valves are those designed to do one of the primary functions mentioned above; that is, control direction of flow, control volume, and regulate fluid pressure.

Valves, like pumps, are precision made. Usually, no packing is used between the valve element and the valve seat since leakage is reduced to a minimum by machined clearances. (Packing is required around valve stems, between lands of spool valves, etc.) Here again is an important reason for preventing system contamination. Even the most minute particle of dirt, dust, and lint can do considerable damage to hydraulic valves.

Relief Valves

A relief valve is a simple pressure-limiting device. It is incorporated in most hydraulic systems and acts as a safety valve, used to prevent damage to the system in case of overpressurization.

A simple two-port relief valve is shown in figure 10-17. An adjustment is provided so that the valve may be regulated to any given pressure; therefore, it can be used on a variety of systems. Before the system pressure can become high enough to rupture the tubing or damage the system units, it exceeds the pressure required to overcome the relief valve spring setting. This pushes the ball off its seat and bypasses excess fluid to the reservoir. If the system pressure decreases, the spring setting reseats the ball; the ball then remains seated until the pressure again reaches the predetermined maximum.



1. Adjusting screw
2. Adjusting screwcap
3. Spring
4. Return port
5. Ball
6. Pressure port

Figure 10-17.-Typical relief valve.

Pressure Regulator Valves

As the name implies, the pressure regulator valve is designed to regulate system pressure between a maximum operating pressure and a minimum operating pressure. This valve is often referred to as an unloading valve. It is designed to remove the system load from the pump once system pressure has been reached.

The functions performed by the regulator valve are accomplished by its two operational phases-cut-in and cutout. The regulator is said to be cut-in when it is directing fluid under pressure into the system. The regulator is cutout when fluid is bypassed into the return line and back to the reservoir. Figure 10-18 shows atypical pressure regulator in the cut-in position. Figure 10-19 shows the regulator in the cut out position. Notice the check valve in these figures. The check valve can bean integral part of the regulator or a separate unit, but it is necessary that a check valve be used, as shown in the figures.

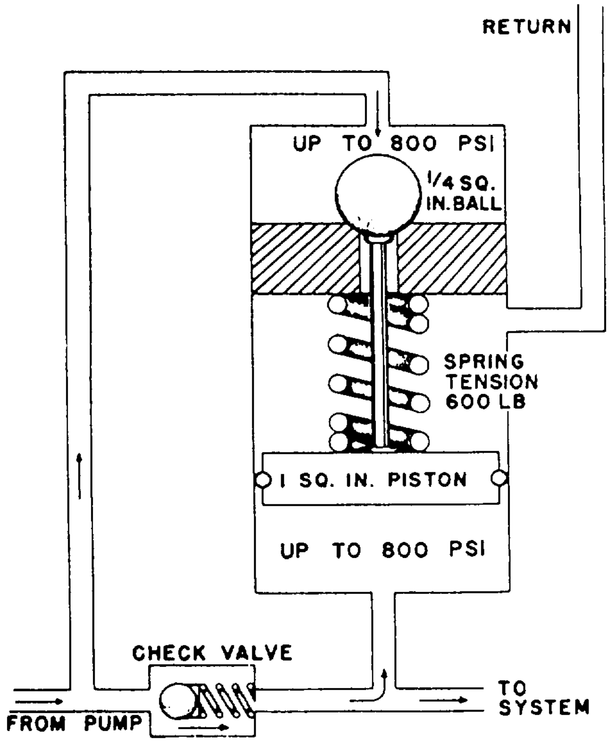


Figure 10-18.-Pressure regulator at the cut-in position.

Referring back to figure 10-18, you can see the pump supplies a pressure to the top and bottom of the regulator valve. By finding the pressure areas of the ball and piston, plus the 600-pound spring tension, you can find the balanced state of the valve-in this case, 800 psi. This means that any pressure in excess of 800 psi unseats

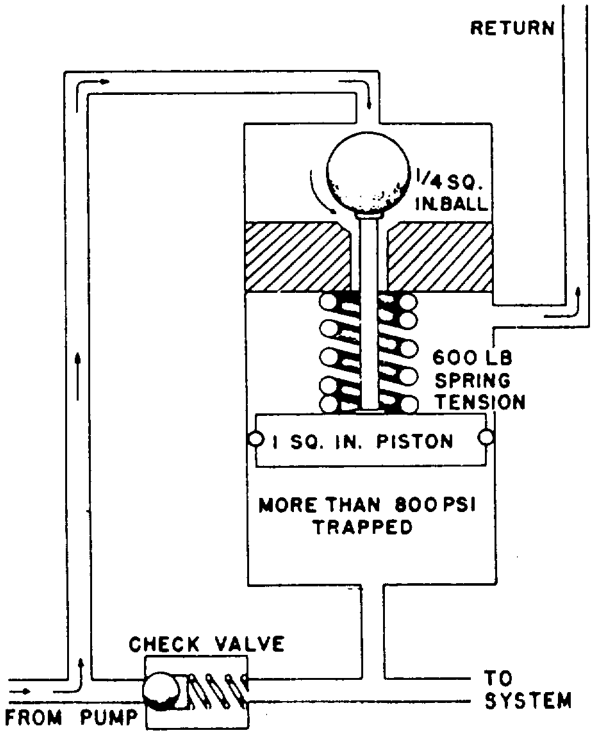


Figure 10-19.-Pressure regulator at the cut out position.

the regulator ball and provides the pump with an unrestricted fluid flow back to the reservoir.

In figure 10-19 the regulator ball is unseated. When this happens, pressure drops immediately. Now the importance of the check valve can be seen. With the sudden reduction in pressure, the check valve snaps shut; and the fluid trapped in the system line continues to hold the regulator piston in the raised position. This trapped fluid also maintains pressure on the system until the mechanism actuates or is relieved by leakage, either of which can cause the regulator to cut-in.

Hydraulic systems using a constant volume pump require a pressure regulator valve; those using a variable volume pump do not.

Selector Valves

The purpose of a selector valve is to control the direction of fluid flow; this, in turn, controls the operation or direction of the mechanism. Although all selector valves share the common purpose of controlling the direction of fluid flow, they vary considerably in physical characteristics and operation.

The valving element of these units may be one of three types: the poppet type, in which a piston or ball moves on and off a seat; the rotary sped type, in which the spool rotates about its axis; or the sliding spool type, in which the spool slides axially in a bore. Selector valves may be actuated mechanically, manually, electrically, hydraulically, or pneumatically.

POPPET VALVE.— Figure 10-20 illustrates the operation of a simple poppet valve. The valve consists primarily of a movable poppet that closes against a valve seat. In the closed position, fluid pressure on the inlet side tends to hold the valve tightly closed. A small amount of movement from a force applied to the top of the poppet stem opens the poppet and allows fluid to flow through the valve.

The poppet, usually made of steel, fits into the center bore of the seat. The seating surfaces of the poppet and the seat are lapped or closely machined, so the center bore will be sealed when the poppet is seated. The action of the poppet is similar to the valves of an automobile engine. An O-ring seal is usually installed on the stem of the poppet to prevent leakage past this portion of the housing. In most valves the poppet is held in the seated position by a spring. The number of poppets in a particular valve depends upon the design and purpose of the valve.

ROTARY SPOOL VALVE.— The rotary spool type of directional control valve has a round core with one or more passages or recesses in it. The core is mounted within a stationary sleeve (fig. 10-21). As the core is rotated (generally by a hand lever or a knob) within the stationary sleeve, the passages or recesses connect or block the ports in the sleeve. The ports in the sleeve are connected to the appropriate pressure, working and return lines of the fluid power system.

SLIDING SPOOL VALVE.— The sliding spool valve is probably the most common type of valving element used in directional control valves. The operation of a simple sliding spool directional control valve is illustrated in figure 10-22. The valve is so named because the shape of the valving element resembles that of a spool and because the valving element slides back and forth to block and uncover ports in the housing.

The valve is shown in neutral position (no fluid flow); but by moving the spool valve to the left position,

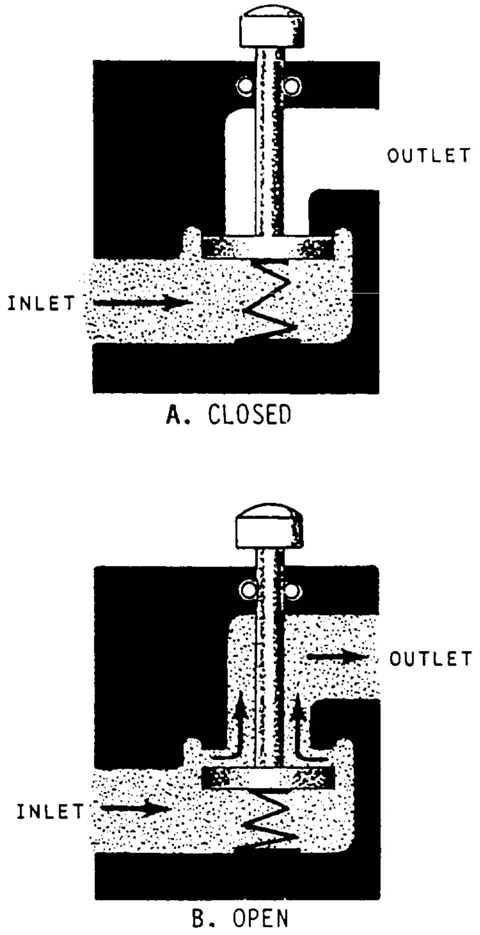
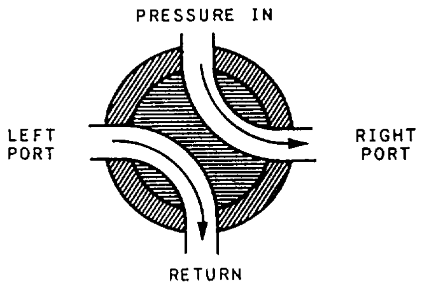
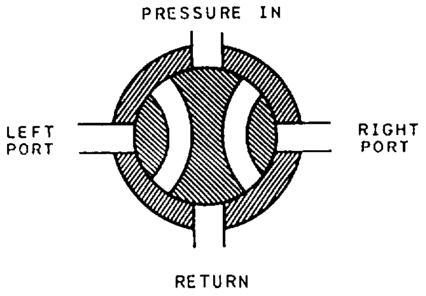


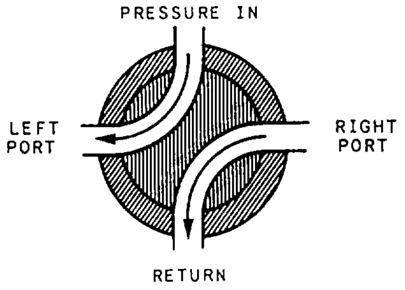
Figure 10-20.-The basic operation of a simple poppet valve.



A. FORWARD



B. NEUTRAL



C. REVERSE

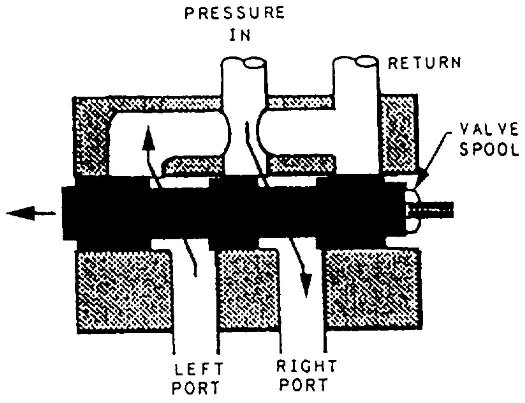
Figure 10-21.-Operation of a rotary spool valve.

fluid flows from the pressure line out through the right port; fluid returns back through the left port to the return line. Movement of the spool to the right position gives similar results; the left port becomes a pressure port and the right port becomes the return port.

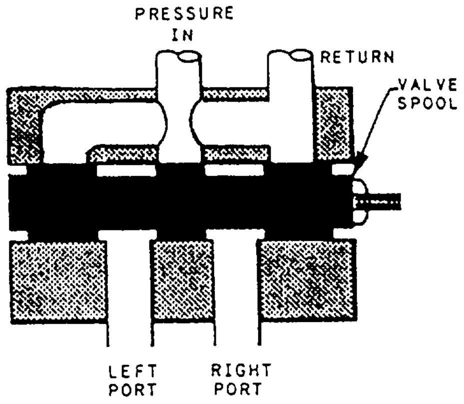
Like all classes of directional control valves, various methods are used for positioning the sliding spool valve. Some of the most common methods are by hand levers, cam angle plates, directional control arms, and self-regulating poppet valve linkage.

Check Valves

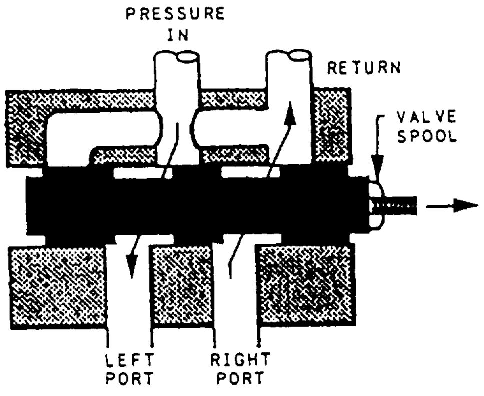
Some authorities classify check valves as flow control valves. However, since the check valve permits flow in one direction and prevents flow in the other direction, most authorities classify it as a one-way directional control valve-the "diode" of the hydropneumatic world.



A. LEFT POSITION



B. NEUTRAL



C. RIGHT POSITION

Figure 10-22.-Operation of a spool selector valve.

Regardless of their classification, check valves are probably the most widely used valves in fluid power systems. The check valve may be installed independently in a line to allow flow in one direction only. This is indicated in the simple system described earlier with the hand pumps. Check valves are also incorporated as an integral part of some other valve, such as the sequence valve, the counterbalance valve, and the pressure regulator valve, also described earlier. A modification of the check valve-the orifice check valve-allows free flow in one direction and a limited or restricted flow in the opposite direction.

Check valves are available in various designs. As stated previously, the ball and the cone, or sleeve, are commonly used as the valving elements. The poppet, piston, spool, or disk are also used as valving elements in some types of check valves. The force of the fluid in motion opens a check valve, while it is closed by fluid attempting to flow in the opposite direction aided by the action of a spring or by gravity.

RESERVOIRS

As stated previously, an adequate supply of the recommended fluid is an important requirement for the efficient operation of a fluid power system. The reservoir, which provides a storage space for fluid in hydraulic systems, differs to a great extent from the receivers used for this purpose in pneumatic systems. For this reason, the two components are covered separately in the paragraphs below.

The reservoir is the fluid storehouse for the hydraulic system. It contains enough fluid to supply the normal operating needs of the system and an additional supply to replace fluid lost through minor leakage. Although the function of a reservoir is to supply an adequate amount of fluid to the entire hydraulic system, it is more than just a vessel containing fluid. It is here that the fluid has the greatest potential danger of becoming contaminated. It is in the reservoir where any air entering the fluid system has the opportunity of escaping; dirt, water, and other matter settle to the bottom. Reservoirs are designed in a way that permit just clean hydraulic fluid to come to the top.

The construction features of a typical reservoir are shown in figure 10-23. These reservoirs have a space above the fluid, even when they are full. This space allows the fluid to foam, and thus purge itself of air bubbles that normally occur as the fluid makes its way

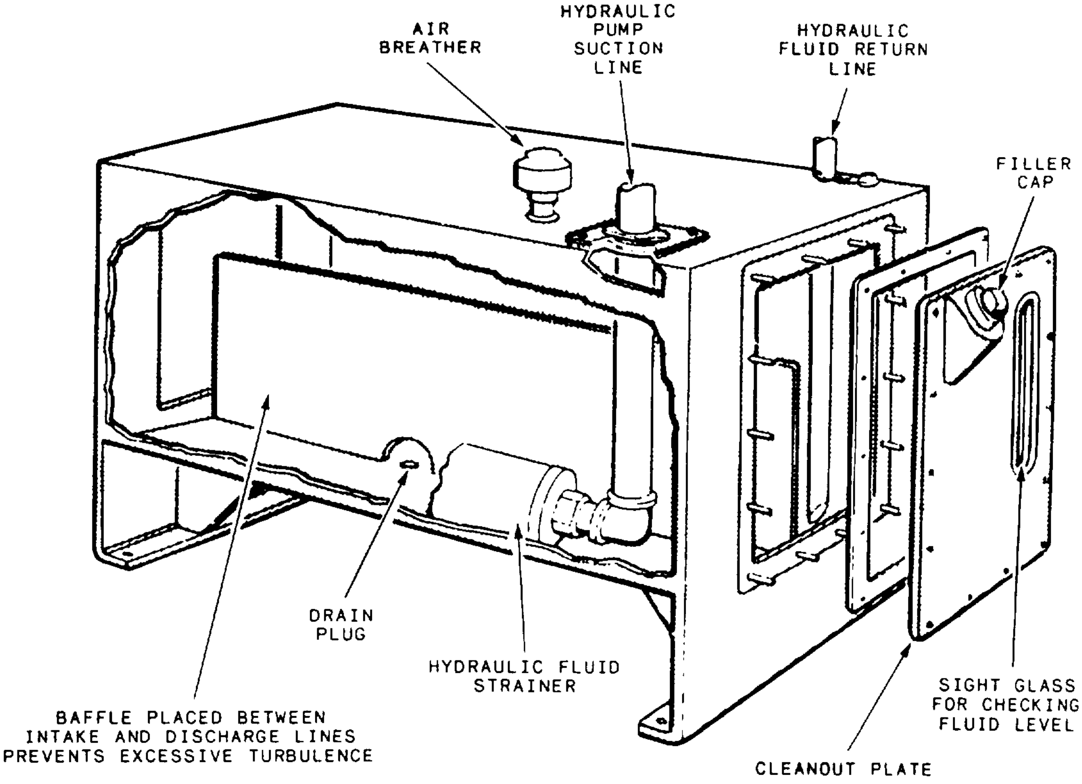


Figure 10-23.-Typical hydraulic reservoir.

from the reservoir, through the system, and back to the reservoir.

An air vent allows the air to be drawn in and pushed out of the reservoir by the ever-changing fluid level. An air filter is attached to the air vent to prevent drawing atmospheric dust into the system by the ever-changing fluid level. A securely fastened filling strainer of fine mesh wire is always placed below the system filler cap.

The sight gauge is provided so the normal fluid level can always be seen, as it is essential that the fluid in the reservoir be at the correct level. The baffle plate segregates the outlet fluid from the inlet fluid. Although not a total segregation, it does allow time to dissipate the air bubbles, lessen the fluid turbulence (contaminants settle out of nonturbulent fluid), and cool the return fluid somewhat before it is picked up by the pump.

Reservoirs used on CESE may vary considerably from that shown in figure 10-23; however, manufacturers retain as many of the noted features as possible, depending on design limits and use.

ACCUMULATORS

Hydraulic accumulators are incorporated in some hydraulic systems to store a volume of liquid under pressure for subsequent conversion into useful work or to absorb rapid fluid pulsations when valves are operated repeatedly. Two types of accumulators are the spring operated and the air operated.

Spring-Operated Accumulator

In this type of accumulator, the compression resulting from the maximum installed length of the spring or springs should provide the minimum pressure required of the liquid in the cylinder assembly. As liquid is forced into the cylinder (fig. 10-24), the piston is forced upward and the spring or springs are further compressed, thus providing a reservoir of potential energy for later use.

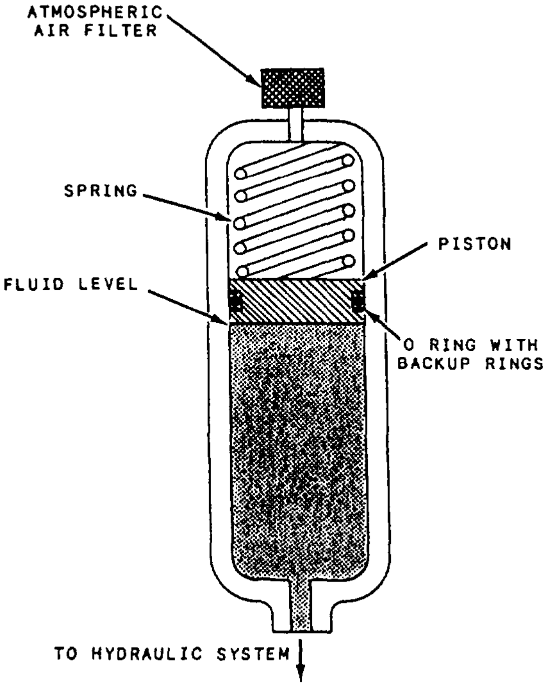


Figure 10-24.-Spring-operated accumulator.

Air-Operated Accumulators

The air-operated accumulator is often referred to as a pneumatic or hydropneumatic accumulator. This type of accumulator uses compressed gas (usually air or nitrogen) to apply force to the stored liquid. Air-operated accumulators are classified as either nonseparator or separator types.

NONSEPARATOR TYPE OF ACCUMULATOR.— In the nonseparator type of accumulator (fig. 10-25), no means are provided for separating the gas from the liquid. It consists of a fully closed cylinder, mounted in a vertical position, containing a liquid port on the bottom and a pneumatic charging port (Schrader valve) at the top.

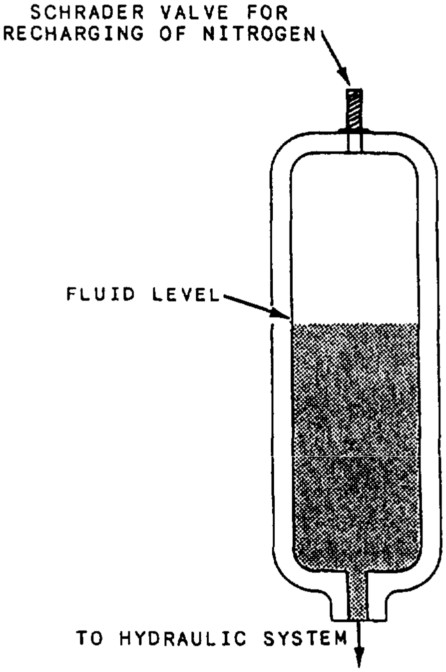


Figure 10-25.-Air-operated accumulator (nonseparator type).

SEPARATOR TYPE OF ACCUMULATOR.— In the separator type of air-operated accumulator, a means is provided to separate the gas from the liquid. The three styles of separators are bladder (bag), diaphragm, and piston (cylinder).

Figure 10-26 illustrates one version of an air-operated accumulator of the *bladder style.* This accumulator derives its name from the shape of the synthetic rubber bladder or bag that separates the liquid and gas within the accumulator.

Although there are several different modifications of the *diaphragm style* accumulator, it is usually spherical in shape. Figure 10-27 illustrates an example of this type. The shell is constructed of two metal hemispheres, that are either screwed or bolted together. The fluid and gas chambers are separated by a synthetic rubber diaphragm.

A *cylinder style* accumulator is illustrated in figure 10-28. This accumulator contains a free-floating piston that separates the gas and liquid chambers. The cylindrical accumulator consists of a barrel assembly, a piston assembly, and two end cap assemblies, The barrel assembly houses the piston and incorporates provisions for securing the end caps.

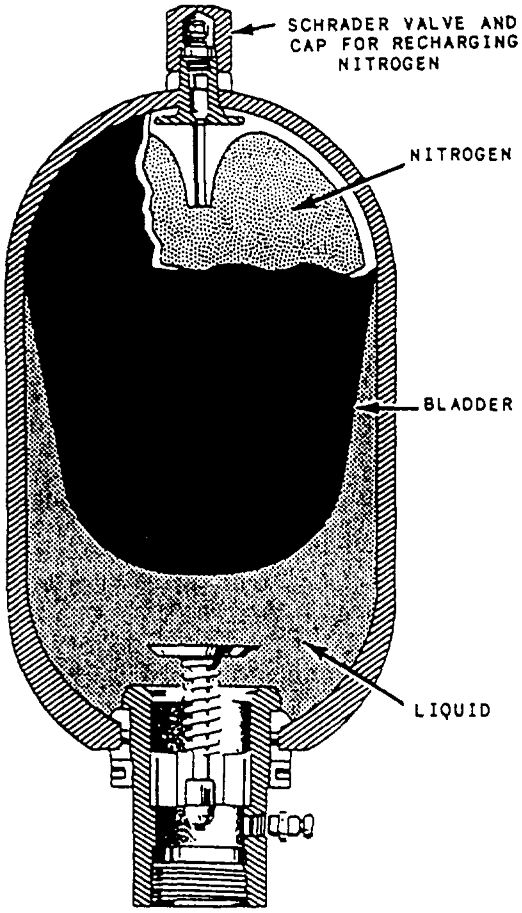


Figure 10-26.-Air-operated bladder type of accumulator (separator type).

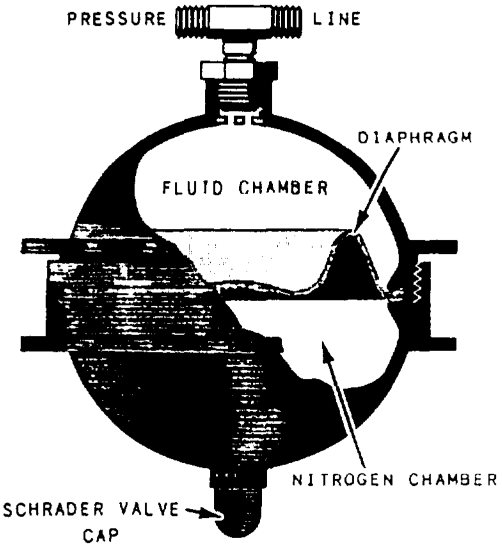


Figure 10-27.-Diaphragm type of accumulator.

APPLICATION

Much of today's CESE is equipped with one or more hydraulic accumulators that serve several purposes in the hydraulic system, as described in the paragraphs below. Some of the hydraulic systems illustrated and described later in this chapter show the applications of accumulators and their relationship to other components in the system.

Shock Absorber

A liquid, flowing at a high velocity in a pipe, will create a backward surge when stopped suddenly. Even the closing of a valve will develop instantaneous pressures two to three times the operating pressure of the system. This shock will result in objectional noise and vibration, which can cause considerable damage to tubing, fittings, and components. The incorporation of an accumulator will enable such shocks and surges to be absorbed or cushioned by the entrapped gas, thereby reducing their effects. The accumulator will also dampen pressure surges caused by the pulsating delivery from the pump.

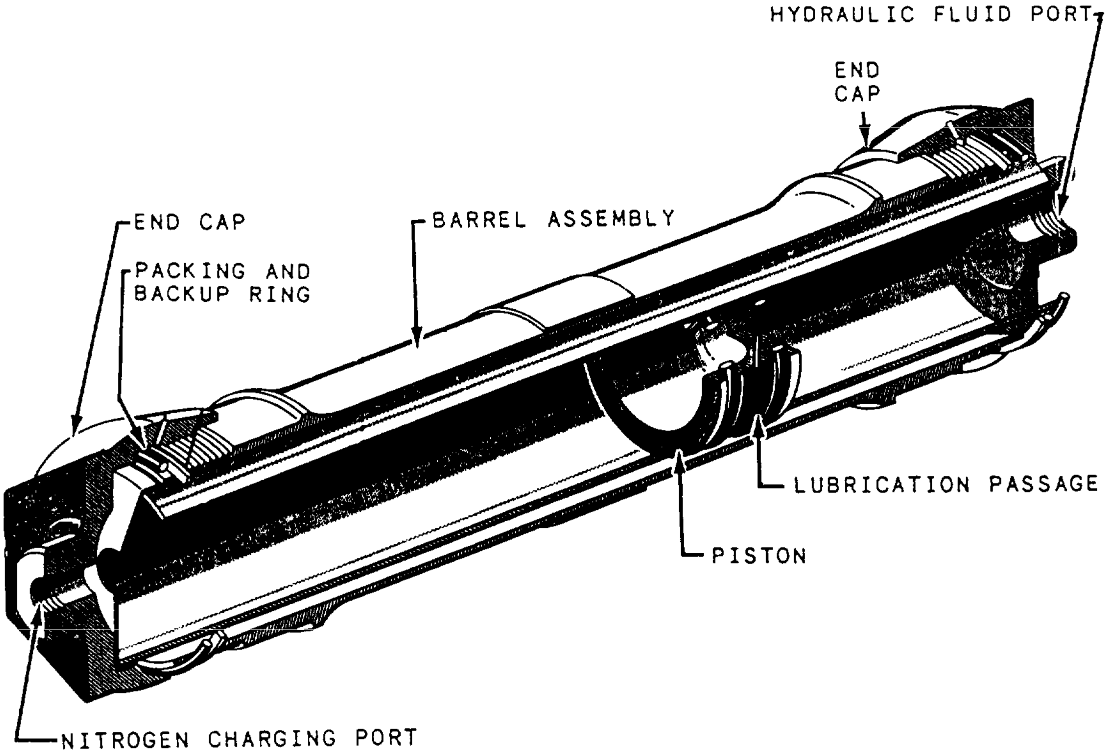


Figure 10-28.-Cylinder type of accumulator.

Emergency Power Supply

The energy stored in an accumulator may be used to actuate a unit in the event of normal hydraulic system failure; for example, the hydroboost power braking system used in the 1 1/4-ton tactical cargo truck or cucv has sufficient energy stored in the accumulator for limited emergency braking operation.

FILTERS

When small bits of metal, rubber, paper, dust, and dirt enter into a system, they contaminate the fluid. The fluid may be contaminated in many different ways. The contaminants may enter the system during the manufacturing of the components or during servicing and maintenance of the system; they can be created in the system by internal wear of the components, or because of deterioration of seals, hoses, and gaskets. These impurities can become suspended in the fluid and circulate throughout the system. Because of the close tolerance of the system components, the contamination in a system must be kept at an acceptable level; otherwise, the components are damaged, destroyed, or become clogged and inoperative. It is for these reasons that filters are essential in hydraulic and pneumatic systems.

A filter in a hydraulic system is a screening or straining device used to remove impurities from the hydraulic fluid. Filters may be located within the reservoir, in the pressure line, in the return line, or in other locations where they are needed to safeguard the hydraulic system against impurities. There are several different types and arrangements of filters. Their position in equipment and design requirements determine their shape and size.

Filter Elements

The filter element is the part or parts (single or dual element) of the filter that removes the impurities from the hydraulic fluid as the fluid passes through the filter. Filter elements are usually classified by either their material and/or their design and construction. The most common filter elements used in CESE equipment are wire mesh, micronic, and porous metal.

WIRE MESH FILTER.— A wire mesh filter element is made of a fine wire mesh (screen) and is usually used where the fluid enters and/or leaves a container or component (view (A) of fig. 10-29). The size of wire mesh openings varies with the particular filter element, but normally a wire mesh filter element removes only the larger particles of contamination from the fluid.

A wire mesh filter element can be reused. It should be removed, cleaned, and reinstalled at scheduled intervals or when it becomes dirty. Replace it when it cannot be properly cleaned or is damaged.

MICRONIC FILTER.— *Micronic*, a term derived from the word *micron*, can be used to describe any filter element. Through usage, micronic has become associated with a specific filter with a filtering element made of a specially treated cellulose paper. The paper is formed in vertical convolutions (wrinkles) and is made in a cylindrical pattern. A spring in the hollow core of the element holds the element in shape (view (B) of fig. 10-29).

Micron is a unit of measurement used to express the degree of filtration. A micron equals one millionth of a meter or 0.0000394 inch. For comparison value, consider that the normal lower level of visibility to the naked eye is about 40 microns. (A grain of table salt measures about 100 microns; the thickness of a human hair is about 70 microns; and a grain of talcum powder is about 10 microns.)

When it is used in CESE hydraulic systems, the micronic element normally prevents the passage of solids of 10 microns or greater in size. The micronic filter element is disposable.

POROUS METAL FTLTER.— Use porous metal filter elements in hydraulic systems in which high pressures exist and/or a high degree of filtration is required. The two porous metal elements discussed–sintered bronze and stainless steel–are capable of filtering out solid particles and 5 and 15 microns, respectively.

Porous metal filter elements are reusable. When the filter element becomes contaminated, it is removed from the system, cleaned, tested, and reinstalled for further use. The number of times a filter element can be cleaned and reused depends on the particular type of element and the system in which it is used. Likewise, if the filter element is damaged in any way or does not meet test requirements, it must be discarded.

Sintered Bronze Filter.— The sintered bronze element consists of minute bronze balls joined together as one solid piece while still remaining porous (view(C) of fig. 10-29).

Stainless Steel Filter.— Stainless steel filter elements are used in many of the Navy's most modern hydraulic systems. This element is similar in

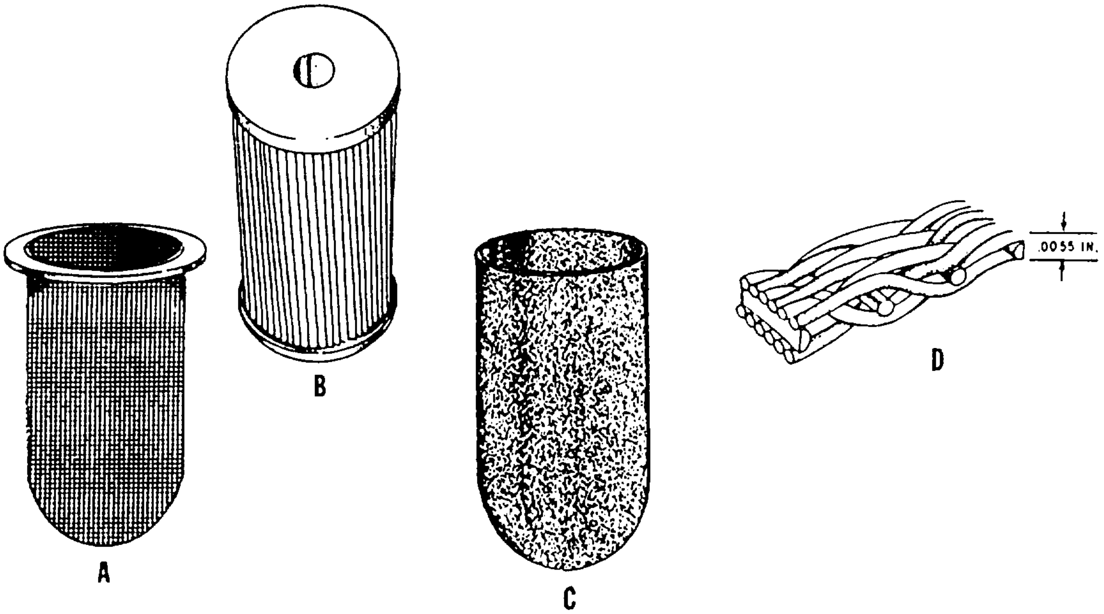


Figure 10-29.-Some typical types of hydraulic screens and filters.

construction to the sintered bronze element described previously. The design is usually a corrugated, sintered, stainless steel mesh, such as the magnified cross section shown in view (D) of figure 10-29. One manufacturer calls the design a "Dutch Twill" pattern. The curved passages of the filter element (through which the fluid passes) limit the length of the particles that pass through the element. Most filters that use the stainless steel are equipped with a contamination indicator, described later in this chapter.

Filter Classifications

The hydraulic systems of CESE use several different types of filters. There are a number of factors to be considered in determining the full classification of a particular type of filter. When hydraulic filters are being classified, the following factors are considered:

1. Flow characteristics
2. Filtering medium
3. Bypass characteristics
4. Contamination indicators

FLOW CHARACTERISTICS.— In the full-flow filter, all the fluid that enters the unit passes through the filter element, while in a proportional flow, only a portion of the fluid passes through the element. Practically all filters used in the hydraulic systems of CESE are full flow.

FILTERING MEDIUM.— The different filter elements–wire mesh, micronic, and porous–were discussed earlier. Normally, only one element is used in each filter; however, some equipment uses two or more elements in order to obtain the desired degree of filtration.

A full-flow, micronic, bypass filter is shown in figure 10-30. This filter provides a positive filtering action; however, it offers resistance to flow, particularly when the element becomes dirty. For this reason, a full-flow filter usually contains a bypass valve; the valve automatically opens to allow the fluid to bypass the element when the flow of fluid is restricted because of contamination buildup on the element.

Hydraulic fluid enters the filter assembly through the inlet port in the body and flows around the filter element inside the filter bowl. Filtering takes place as the fluid passes through the filter element and into the hollow core, leaving dirt and impurities deposited on the outside of the filter medium. The filtered fluid then flows from the hollow core, through the outlet port, and continues on through the system.

BYPASS CHARACTERISTICS.— TMS bypass relief valve in the body allows the fluid to bypass the filter element and pass directly into the outlet port if the filter element becomes clogged. In many micronic filters, the relief valve is set to open when the differential in pressure exceeds 50 psi; for example, if the pressure at the filter inlet port is 90 psi and the pressure at the outlet drops below 40 psi, the bypass valve opens and allows the liquid to bypass the element.

ATTENTION: Oil that bypasses the hydraulic oil filter is unfiltered oil. his is a clear indication of a hydraulic system in need of serious maintenance, repair or both.

CONTAMINATION INDICATORS.— Contamination indicators are often used on bypass filters. The full-flow, porous metal, bypass electrical-indicating

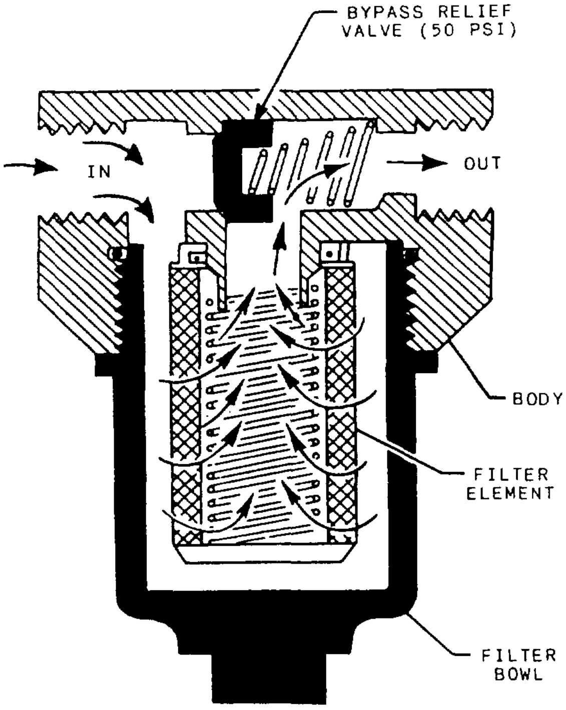


Figure 10-30.-Full-flow, bypass type of hydraulic filter.

hydraulic filter (fig. 10-31) is used in some hydraulic systems. This filter uses one or a combination of the contamination indicators previously described.

Under normal conditions the fluid enters the inlet of the filter (view (A) of fig. 10-31), passes through the filter element, and leaves the filter through the outlet. As the fluid passes through the filter element, impurities are deposited on the outside of the element. As the deposits accumulate, they cause a differential pressure to build up between the inlet and outlet of the filter. The pressure is sensed across the contamination indicator switch; on this particular filter, the switch closes at 70 ÷ 10 psi, actuating a warning device (light, horns, etc.). The equipment should be stopped and the filter serviced, cleaned, or replaced. An important fact for you to remember is that cold hydraulic fluid can produce a false pressure indication. To prevent needless changing of filters, fluid should beat operating temperature for a true

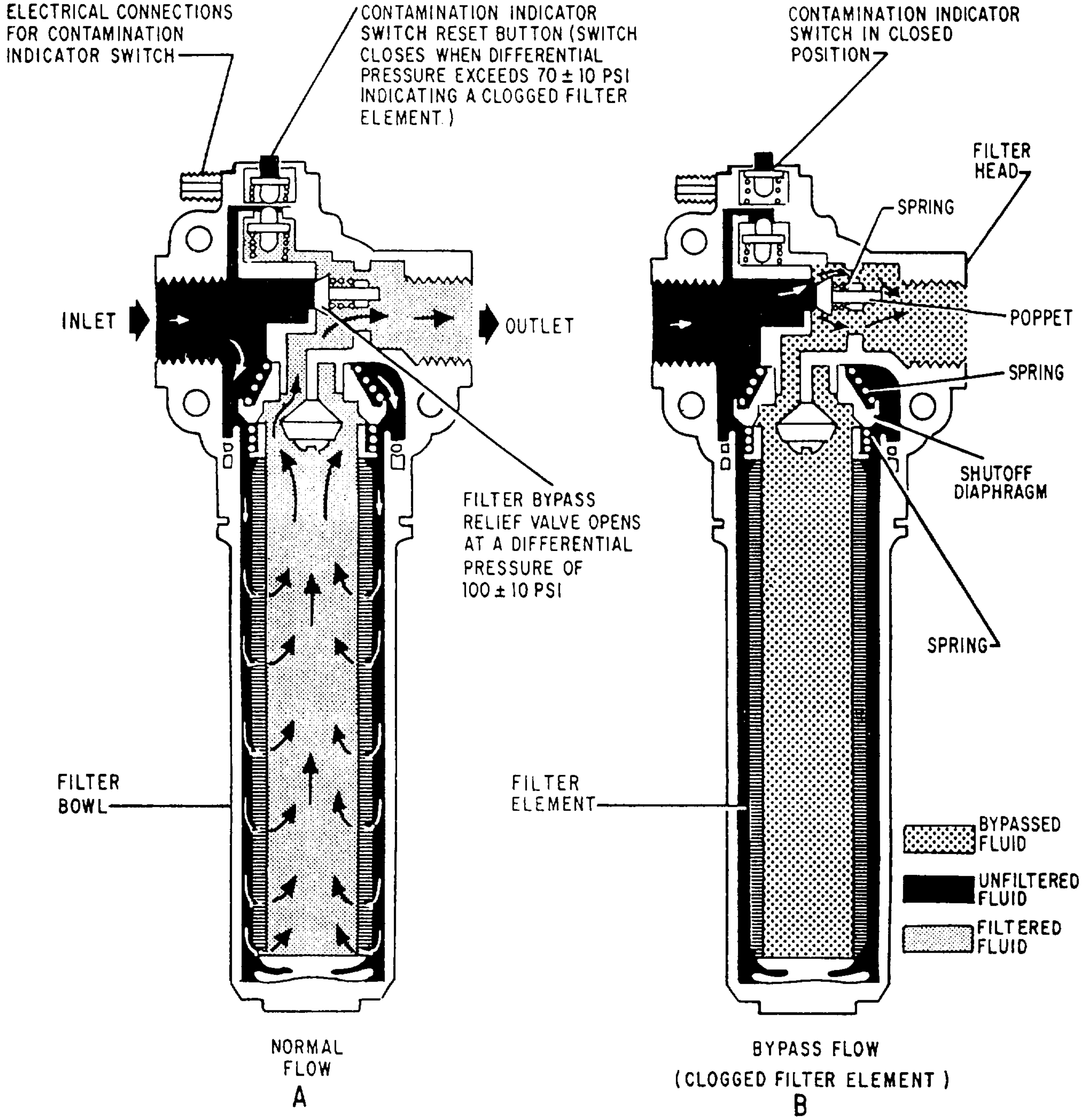


Figure 10-31.-Full-flow, porous metal, bypass electrical-indicating hydraulic filter.

indication of a contaminated filter. Some filters have a button to reset the switch after the filter has been serviced; however, on other filters, the switch resets automatically when the differential pressure is relieved.

If the filter is not properly serviced following the contamination indication and the equipment is kept in operation, the differential pressure continues to build. At 100 ÷ 10 psi, the bypass valve will open and allow the fluid to flow straight through, bypassing the filter element (view (B) of fig. 10-31). But on this filter the contamination indicator is to warn the operator that the filter element is clogged. The equipment can then be stopped before the bypass valve opens, thus preventing contaminated fluid from being passed through the hydraulic system.

HYDRAULIC SYSTEMS

In spite of the great variety of support equipment, all hydraulic systems–from the simplest to the most complex-operate according to the basic principles and make use of the components discussed thus far in this chapter.

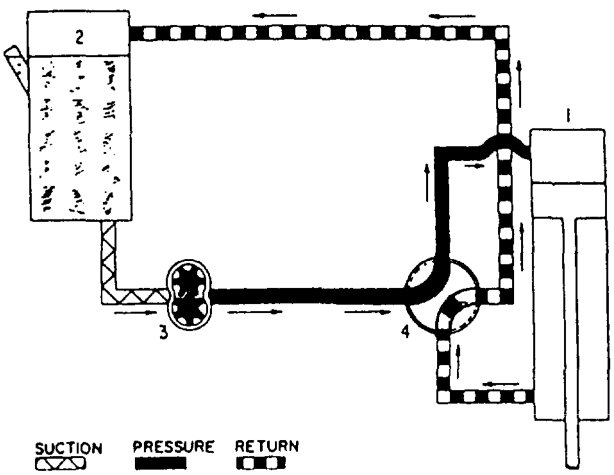
As a CM1 you are responsible for analyzing the malfunctions of hydraulic equipment, ranging from the simple jack to large earth-moving equipment. Thus, the development, piece by piece, of a representative system should assist you in analyzing any hydraulic system.

REPRESENTATIVE HYDRAULIC SYSTEM

Basically, any system must contain the following units: PUMP, ACTUATOR, RESERVOIR, CONTROL VALVE, and TUBING. Figure 10-32 shows a simple system that uses only these essentials.

The flow of hydraulic fluid can be easily traced from the reservoir through the pump to the selector valve. With the selector valve in the position indicated by the solid lines, the flow of fluid created by the pump flows through the valve to the upper end of an actuating cylinder. Fluid pressure then forces the piston down, and at the same time, forces out the fluid on the lower side of the piston, up through the selector valve, and back to the reservoir.

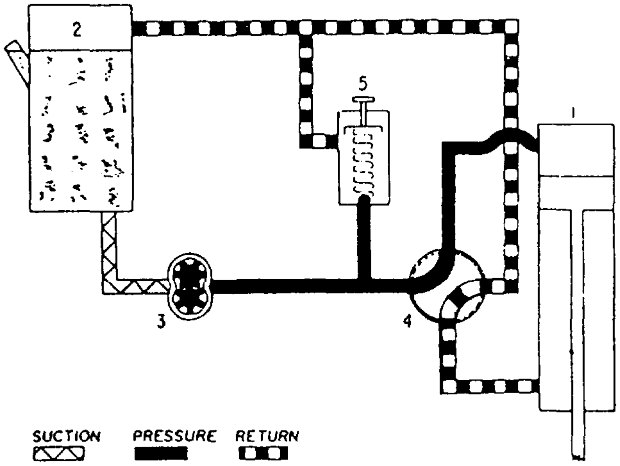
When the selector valve is rotated 90 degrees, the fluid from the pump then flows to the lower side of the actuating cylinder, thus reversing the process. The movement of the piston can be stopped at any time simply by moving the selector valve to the neutral position (45-degree movement either way). In this position, all four ports are closed and pressure is trapped in both working lines.



1. **Actuating cylinder**
2. **Reservoir**
3. **Power pump**
4. **Selector valve**

Figure 10-32.-A simple hydraulic system.

The hydraulic system just described would be practical if it were operated by a hand pump, such as a system common to the engine installation/removal stands and bomb trucks. However, since the illustrated pump is a power-driven, constant delivery gear pump, pressure builds up immediately to such proportions that either the pump fails or a line bursts. Therefore, a pressure relief valve is incorporated in the system to protect it, as shown in figure 10-33. This valve is set to



1. **Actuating cylinder**
2. **Reservoir**
3. **Power pump**
4. **Selector valve**
5. **Relief valve**

Figure 10-33.-Hydraulic system with a relief valve incorporated.

relieve system pressure before it becomes sufficient enough to rupture the system or damage the pump. The relief valve ball is unseated at a predetermined pressure, and excess fluid is bypassed to the reservoir.

At this point, figure 10-33 illustrates a workable system, but it is still impractical. After a few hours, an ordinary pump would probably fail because it has to maintain a constant load. (The pump is keeping the relief valve unseated except when the cylinder is being moved.) With the addition of a check valve and pressure regulator (fig. 10-34), the work load on the pump is relieved and the system is more efficient, safer, and more durable. (A variable volume pump with its own built-in pressure control serves the same purpose in a system as the pressure regulator valve in this system.) The pressure regulator maintains system pressure between two predetermined pressure limits and relieves the pump when no mechanisms are moving, bypassing the pump flow unrestricted back to the reservoir. When you are adding the regulator valve to the system, the relief valve becomes a safety valve, used to prevent system damage in case of regulator or variable volume pump control failure.

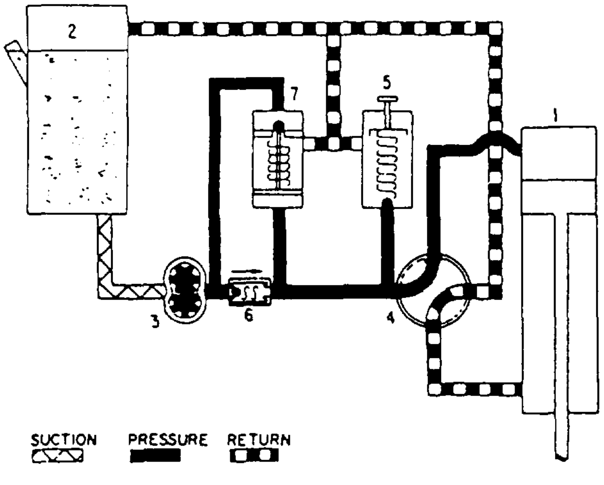
The hydraulic system (fig. 10-34) is a practical, workable system; however, today's more complex equipment normally incorporates more components for the purpose of increasing efficiency, safety, and emergency or standby operation.

A complete hydraulic system is shown in figure 10-35. In addition to the components already mentioned, this system includes more check valves, pressure gauge, filters, and a hand pump. The hand pump is added as art auxiliary system, normally used as an emergency power source in case of main power pump failure.

The complete hydraulic system discussed above may be further expanded by including a pressure manifold, more selector control valves, actuating mechanisms, and more power-driven pumps connected in parallel. You should remember that all systems can be broken down into a simplified system (as illustrated in figures 10-32 through 10-35). Thus, even the most complex system can be analyzed, not from the standpoint of a complex system but from that of a simple system.

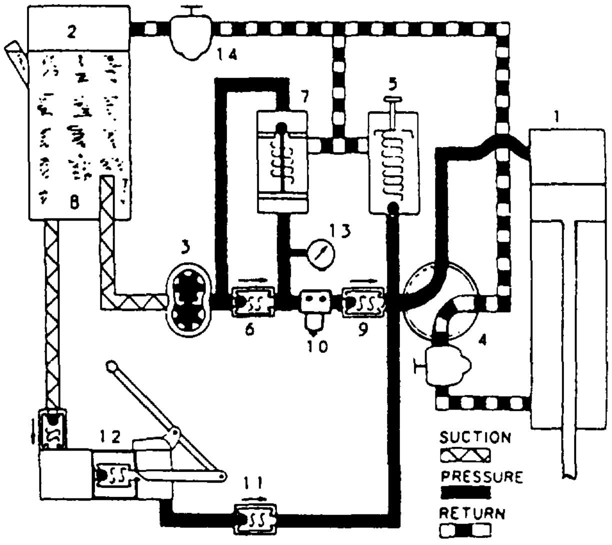
TYPES OF HYDRAULIC SYSTEMS

There are two types of hydraulic systems used in support equipment. A system may be either an open center or a closed center, or in some cases, both.



1. **Actuating cylinder**
2. **Reservoir**
3. **Power pump**
4. **Selector valve**
5. **Relief valve**
6. **Check valve**
7. **Pressure regulator**

Figure 10-34.-Hydraulic system with a relief valve and regulator incorporated.



1. **Actuating cylinder**
2. **Reservoir**
3. **Power pump**
4. **Selector valve**
5. **Relief valve**
6. **Check valve**
7. **Pressure regulator**
8. **Reservoir standpipe**
9. **Check valve**
10. **Pressure line filter**
11. **Check valve**
12. **Hand pump**
13. **Pressure gauge**
14. **Return line filter**

Figure 10-35.-Complete hydraulic system.

Open-Center System

An open-center system is one having fluid flow, but no pressure in the system whenever the actuating mechanisms are idle. Fluid circulates from the reservoir, through the pump, through the selector valves, and back to the reservoir. Pressure developed in the system of an open-center system is controlled by open-center selector valves and is limited by a system relief valve. Figure 10-36 shows an open-center system. Note the position of the selector valves and the fact that the valves are connected in series. In this type of system, there is no pressure in the system until one of the subsystems is actuated by the positioning of the selector valve. When in the neutral position (fig. 10-36, view A), the open-center selector valve directs the fluid to the return line. When the selector valve is positioned out of neutral, pressure builds up in the actuating section and operates the selected mechanism (fig. 10-36, view B). When an open-center system is not being used (no actuating mechanisms), the pump is said to be idling because there is no pressure buildup in the system; therefore, there is no load on the pump. Constant volume pumps are used in open-center systems and normally do not require a pressure regulator.

Closed-Center System

The closed-center system always has fluid stored under pressure whenever the pump is operating; however, when pressure is built up to predetermined value, the load is automatically removed from the pump by a pressure regulator or the integral control valve of the variable volume pump.

The representative hydraulic system discussed earlier is a closed-center system, but all closed-center systems are basically the same. Any number of subsystems may be incorporated into the closed-center system. This system differs from the open-center system in that the selector valves are arranged in parallel rather than in series.

HYDRAULIC SYSTEM TROUBLESHOOTING AND MAINTENANCE

Every hydraulic system has two major parts or sections: the power section and the actuating section. A power section develops, limits, and directs the fluid pressures that actuate various mechanisms on the equipment. The actuating section is the section

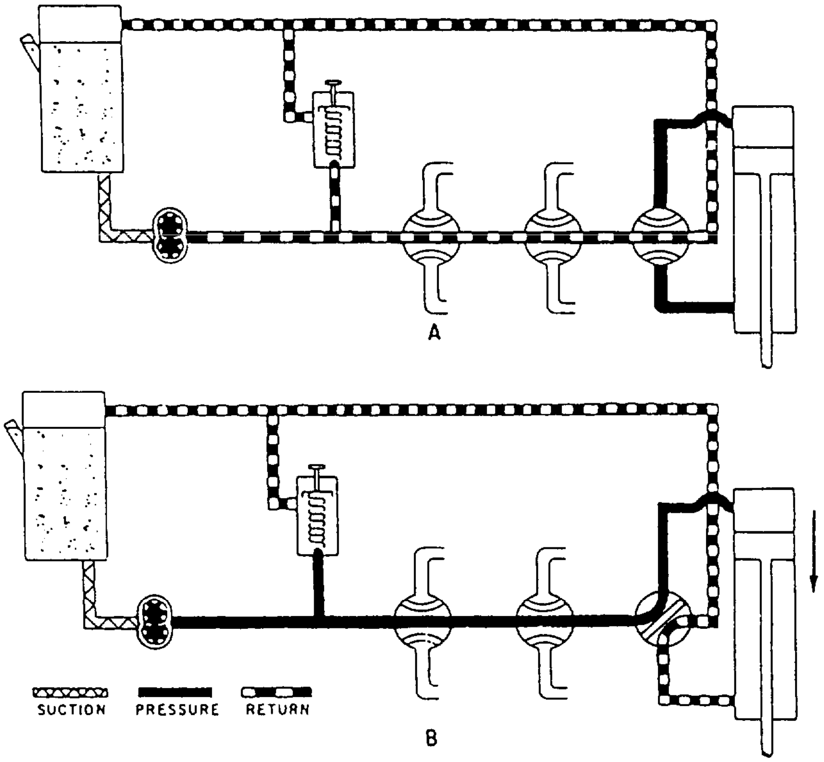


Figure 10-36.-Basic open-center hydraulic system.

containing the various operating mechanisms and their units, such as brakes, steering, lift cylinders, extend cylinders, and hydraulic motors.

Since an actuating mechanism is dependent on the power system, some of the troubles exhibited by the actuating system may be caused by difficulties in the power system. By the same token, a trouble symptom indicated by a unit of the power system may be caused by leakage from one of the units of an actuating system. When any part of the hydraulic system becomes inoperative, refer to the schematic diagrams located in the applicable technical manual (in conjunction with tests performed on the equipment) to assist in tracing the malfunction to its source. As previously stressed, NO UNIT SHOULD BE REMOVED AND REPLACED (OR ADJUSTED) UNLESS THERE IS SOUND REASON TO BELIEVE IT IS FAULTY.

Troubleshooting

Most hydraulic troubles can be included in one or more of the following categories: lack of fluid supply, external leaks, internal leaks, physically defective units, or related troubles caused by mechanical control linkages and electrical control circuits.

Insufficient fluid in the system results in no pump delivery or at best a sluggish or erratic operation. The reservoir must always contain sufficient fluid to till the system completely without letting the pump run dry. The proper fluid must always be used to replenish a low system. Do not mix hydraulic fluids or reuse old fluid. Make sure all replenishment fluid is properly filtered before it is dispensed into the reservoir. Remove and repair or replace defective units when there is an indication of external leakage of the unit.

If foreign particles are found when you remove and disassemble a unit, identify and trace them to the source; for example, a common source of foreign particles is found in flexible hose. Generally, the cause is improper installation or internal deterioration; either can release slivers of the lining into the system, causing units to leak or become inoperative.

To analyze malfunctions in hydraulic systems, like all other systems, you need to have a complete understanding of the system and its operating components. Also, you need to know the interrelationship of one component to another; for instance, a complete understanding of a pressure regulator lends itself to troubleshooting the entire system as well as the regulator itself.

Pressure regulators, like all hydraulic components, are normally reliable pieces of equipment; nevertheless, the y can malfunction. Keep in mind, though, that instead of being a source of trouble, the regulator can be a fairly reliable watchdog on the other units in the system. The particular behavior of the regulator may be the only indication of leakage in places where no other indication is available. It should be kept in mind that troubleshooting the regulator is done only after the obvious steps have been taken, such as checking the system fluid level to check for external fluid loss and opening shutoff valves.

Troubleshooting the pressure regulator is done by timing the cycle of operation-from the cut-in position to the cutout and back to the cut-in position. A standard regulator operating in a normal system completes this cycle in a certain period of time. This time can be obtained from the equipment manual or closely estimated by maintenance personnel.

Since you normally use the pressure regulator only with a constant volume pump, it should take a certain definite time to buildup system pressure; for example, suppose a pump has a volume output of 6 gallons per minute, and the system requires 1 gallon of fluid to become completely tilled (pressurized). As the system takes only one sixth of the pump output to build up pressure, it should require only one sixth of a minute (10 seconds) to pressurize the system. This is true if the system is in good operating condition. But what if the system contains an internal leak? In the 10 seconds usually required to build up pressure, the pump is still delivering 1 gallon, but some of the fluid is being lost. Thus, at the end of 10 seconds, the system cannot be pressurized; therefore, the regulator cannot be cutout. The cut-in and cutout pressure of the regulator can be seen on the system pressure gauge. Once the regulator is cut out, the system should hold fluid under pressure for a reasonable length of time; however, if the system leaks, pressure drops fast and the regulator cuts in faster than normal. These indications may mean that the regulator is faulty or the other components in the system are faulty; however, by isolation techniques, such as subsystem operation, and checking shutoff valves, the problem can be located.

If the fault is the regulator, it is probably leaking at the regulator check valve or at the regulator bypass valve.

A leaking regulator check valve is one of the most common and easily recognized troubles. Again the regulator cycle is affected. With the regulator cut-in, the check valve is open, and fluid is flowing into the system.

When the system pressurizes, the check valve closes, and the regulator is cut out; therefore, a leaking check valve does not effect the cutout time of the regulator, but it does affect the cut-in time.

The purpose of the check valve is to trap fluid under pressure in the system during the regulator cutout operation; however, it cannot do this if there is leakage around the seat. Even a slight leak around the valve seat causes the regulator to cut in faster than it should, but a bad leak causes the regulator to cycle rapidly (chatter). This rapid cycling, as indicated on the system pressure gauge, is usually caused only by a leaking valve. Thus, a leaking check valve gives normal regulator cutout and faster than normal cut-in operation.

The regulator bypass valve may also leak, causing an indication that affects the cycle of the regulator. If the bypass leaks, part of the fluid from the pump, which should be going into the system, bypasses and returns to the reservoir. This bypass causes the regulator to take longer than usual to cut out. Once the regulator has cut out, the bypass opens; therefore, it does not affect the regulator cut-in cycle.

Maintenance

Hydraulic systems maintenance includes servicing, preoperational inspections, periodical (scheduled) inspections, repair, and test/check following repair. The key to hydraulic system dependability is the attention given to the cleanliness of the repair facilities. Externally introduced contaminants are credited for more component failure than any of the self-induced contaminations during normal operating conditions. Hydraulic contamination is discussed in great length later in this chapter. The various repair procedures for the more common hydraulic system components are addressed in the paragraphs below.

HYDRAULIC PUMPS.— All hydraulic pumps have one thing in common–precision construction. In general, damaged or worn pump parts should be replaced, as they do not lend themselves readily to repair; however, some manufacturers do allow restoration of sealing surfaces to their original flat plane if it can be done by lapping. Also, very minor scratches, scoring, and corrosion can be removed with a crocus cloth.

Generally, the maintenance of hydraulic pumps consists of disassembly, inspection repair (including replacement of parts and reassembly), and testing. After disassembly, thoroughly clean and critically inspect all parts for nicks, cracks, scratches, corrosion, or other damage that might cause pump malfunction. Inspect all threaded parts and surfaces for damage; inspect pistons, piston shafts and springs for distortion, and all check valves for proper seating. Replace all defective parts, and before reassembly, lubricate all internal parts with the specified type of clean hydraulic fluid.

Because of the many different versions of pumps and the complexity of most piston pumps, refer to the applicable technical manual for repair limits, procedures, and testing information.

The test after repair of hydraulic pumps is a must. This should be done by activities that have proper test machines. Hydraulic shops usually have the correct testing machines and trained personnel to test these pumps along with other accessories, such as relief valves, selector valves, and actuating cylinders.

ACTUATORS.— Maintenance of cylinders in general is relatively simple-the most common trouble is leakage. As with all other hydraulic units discussed in this chapter, consult the technical manual for the specific cylinder for all maintenance information.

Maintenance of hydraulic motors is generally the same as that discussed earlier for hydraulic pumps.

HYDRAULIC VALVES.— Hydraulic valves, like most other hydraulic units, normally require little maintenance if the fluid is kept clean; however, they do occasionally fail. Internal leakage and control adjustments are the most common valve problems.

Generally, the maintenance of hydraulic valves consists of disassembly, inspection, repair, and testing. The amount of maintenance that can be performed is primarily determined by the type of valve and the available facilities. Some valves are not repairable; in this case, return them to supply or scrap the valve and install a new one.

Replace all defective parts that are not repairable, including all kitted parts and cure-dated parts at each disassembly. Before reassembly, lubricate all internal parts with the specified type of clean hydraulic fluid After you reassemble a valve, test it on a test machine. The tests normally include flow control, pressure settings (for relief valves and regulators), and internal leakage. Consult the applicable technical manual for maintenance, testing, and repair information.

RESERVOIRS.— Reservoirs are fairly simple tanks that require periodic flushing and cleaning. Since the reservoir collects much foreign material contaminants in the bottom, the drain valve in the bottom of the tank should be opened to allow any sediment to be purged.

Additionally, most reservoirs are designed with cleanout covers, illustrated earlier in figure 10-23, to assist in inspection and maintenance.

ACCUMULATORS.— Accumulators, being designed like cylinder actuators, are similarly repaired using the same techniques. Caution must be exercised to ensure that the pneumatic pressure has been relieved before disassembly of an air-operated accumulator.

FILTERS.— Maintenance of filters is relatively simple since it mainly involves cleaning the filter housing and replacing or cleaning the filter elements. Replace the element on filters, using the micronic (paper) element, and clean the elements on filters using the porous metal elements according to the applicable technical manuals.

Completely test the filters that have been cleaned and repaired before reinstalling them in the system. This test includes pressure setting of the relief valve, operation of the contamination indicators, leakage tests, and proof pressure test. Consult the technical manual for the equipment or the filter design for the test information.

HYDRAULIC SYSTEM CONTAMINATION

Contamination is the director indirect cause of more hydraulic system failures than any other single source; therefore, contamination prevention is a major concern for all who operate, service, and maintain hydraulic systems.

A small mistake involving injection of contaminants can result in damage to equipment that cannot have a money value placed upon it; for example, a hydraulic in a line tester that contains contaminated fluid is used to service construction equipment. This can result in damage to expensive equipment, loss of CESE costing thousands of dollars, or injury and loss of life to personnel on the jobsite.

For further reading, NAVEDTRA 12964 (latest edition) is an excellent publication on the subject of hydraulic contamination (see your ESO for this correspondence course).

Classes of Contamination

The two general contamination classes are as follows:

1. Abrasives. This includes such particles as dust, dirt, core sand weld spatter, machining chips, and rust.

2. Nonabrasives. This includes things that result from oil oxidation and soft particles worn or shredded from seals and other organic components.

The mechanics of the destructive action by abrasive contaminants are clear. When the size of the particles circulating in the hydraulic system is greater than the clearance between moving parts, the clearance openings act as filters and retain such particles. Hydraulic pressure then embeds these particles into the softer materials; the reciprocating or rotating motion of component parts develops scratches on finely finished surfaces. Such scratches result in increased tolerances and decreased efficiency.

Oil-oxidation products, usually called sludge, have no abrasive properties; nevertheless, sludge may prevent proper functioning of a hydraulic system by clogging valves, orifices, and filters. Frequent changing of hydraulic system liquid is not a satisfactory solution to the contamination problem. Abrasive particles contained in the system are not usually flushed out, and new particles are continually created as friction products; furthermore, every minute remnant of sludge acts as an effective catalyst to speed up oxidation of the fresh fluid. (A catalyst is a substance that, when added to another substance, speeds up or slows down chemical reaction, but is itself unchanged at the end of the reaction.)

Origin of Contaminants

The origin of contaminants in hydraulic systems can be traced to the following areas:

PARTICLES ORIGINALLY CONTAINED IN THE SYSTEM. These particles originate during fabrication of welded system components, especially in reservoirs and pipe assemblies. The presence is minimized by proper design; for example, seam-welded overlapping joints are preferred; arc welding of open sections is usually avoided. Hidden passages in valve bodies, inaccessible to sandblasting, are the main source of core sand entering the system. Even the most carefully designed and cleaned casting occasionally frees some sand particles under the action of hydraulic pressure. Rubber hose assemblies always contain some loose particles, most of which can be removed by flushing; others withstand cleaning and are freed later by the action of hydraulic pressure and heat.

Rust or corrosion initially present in a hydraulic system can usually be traced to improper storage of replacement materials and component parts. Particles can range in size from large flakes to abrasives of microscopic dimensions (remember the discussion earlier on the size of a single micron). Proper preservation of stored parts is helpful in eliminating corrosion.

PARTICLES OF LINT FROM CLEANING MATERIAL. These can cause abrasive damage in hydraulic systems, especially to closely fitted moving parts. In addition, lint in a hydraulic system packs easily into clearances between packings and contacting surfaces, leading to component leakage and decreased efficiency. Also, lint helps clog falters prematurely.

PARTICLES INTRODUCED FROM OUTSIDE FORCES. Particles can be introduced into hydraulic systems at points where either the liquid or certain working parts of the system (e.g., piston rods) are at least in temporary contact with the atmosphere. The most common danger areas are at the refill and breather openings and at cylinder rod packings. Contamination arising from carelessness during servicing operations is minimized by the use of an approved dispensing cart using proper filters and filler strainers in the filling adapters of hydraulic reservoirs. Hydraulic cylinder piston rods incorporate wiper rings and dust seals to prevent the dust that settles on the piston rod during its outward stroke from being drawn into the system when the piston rod retracts. Similarly, single-acting actuating cylinders incorporate an air filter in the vent to prevent ingestion of airborne contamination during the return stroke (refer back to view A of figure 10-13).

PARTICLES CREATED WITHIN THE SYSTEM DURING OPERATION. Contaminants created during system operation are of two general types: mechanical and chemical. Particles of a mechanical nature are formed by wearing of parts in frictional contact, such as pumps, cylinders, and packing gland components. Additionally, overaged hydraulic hose assemblies tend to breakdown inside and contaminate the system. These particles can vary from large chunks of packings and hose material down to steel shavings of microscopic dimensions that are beyond the retention potential of system filters.

The chief source of chemical contaminants in hydraulic liquid is oxidation. These contaminants are formed under high pressure and temperatures and are promoted by the catalytic action of water and air and of metals, like copper or iron oxides. Oil-oxidation products appear initially as organic acids, sludge, gums, and varnishes-sometimes combined with dust particles as sludge. Liquid soluble oxidation products tend to increase liquid viscosity, while insoluble types form sediments and precipitates, especially on colder elements, such as heat exchanger coils.

Liquids containing antioxidant have little tendency to form gums under normal operating conditions; however, as the temperature increases, resistance to oxidation diminishes. Hydraulic liquids that have been subjected to excessively high temperatures (above 250°F) break down in substance, leaving minute particles of asphalting suspended in the liquids. The liquid changes to brown in color and is referred to a decomposed liquid. This explains the importance of keeping the hydraulic liquid temperature below specified levels.

The second contaminant producing chemical action in hydraulic liquids is one that permits these liquids to establish a tendency to react with certain types of rubber. This causes structural changes in the rubber, turning it brittle, and finally causing its complete disintegration. For this reason, the compatibility of system liquid with seals and hose material is an important factor.

PARTICLES INTRODUCED BY FOREIGN LIQUIDS. One of the most common foreign-fluid contaminants is water, especially in hydraulic systems that require petroleum base oils. Water, which enters even the most carefully designed systems by condensation of atmospheric moisture, normally settles to the reservoir bottom. Oil movement in the reservoir disperses the water into fine droplets; agitation of the liquid in the pump and in high-speed passages forms an oil-water-air emulsion. Such an emulsion normally separates out during the rest period in the system reservoir; but when fine dust and corrosion particles are present, the emulsion is catalyzed by high pressures into sludge. The damaging action of sludge explains the need for water-separating qualities in hydraulic liquids.

Control of Contamination

Filters (discussed earlier) provide adequate control of the contamination problem during all normal hydraulic system operations. Control of the size and amount of contamination entering the system from any other source must be the responsibility of the personnel who service and maintain the equipment; therefore, precaution must be taken to ensure that contamination is held to a minimum during service and maintenance. Should the system become excessively contaminated, the filter element should be removed and cleaned or replaced.

As an aid to exercising contamination control, the following maintenance and servicing procedures should be adhered to at all times:

1. Maintain all tools and the work area (workbenches and test equipment) in a clean, dirt-free condition.

2. A suitable container should always be provided to receive the hydraulic fluid which is spilled during component removal or disassembly procedures.

NOTE: The reuse of hydraulic fluid is not recommended; however, in some large-capacity systems, the reuse of fluid is permitted. When liquid is drained from the latter systems, it must be stored in a clean and suitable container. This liquid must be strained and/or filtered as it is returned to the system reservoir.

3. Before disconnecting hydraulic lines or fittings, clean the affected area with an approved dry-cleaning solvent.

4. All hydraulic lines and fittings should be capped or plugged immediately after disconnecting.

5. Before assembly of any hydraulic components, wash all parts with an approved dry-cleaning solvent.

6. After cleaning parts in dry-cleaning solvent, dry the parts thoroughly and lubricate them with the recommended preservative or hydraulic liquid before assembly.

NOTE: Use only clean, lint-free cloths to wipe or dry component parts.

7. All packings and gaskets should be replaced during the assembly procedures.

8. All parts should be connected with care to avoid stripping metal slivers from threaded areas. All fittings and lines should be installed and torqued according to applicable technical instructions.

9. All hydraulic servicing equipment should be kept clean and in good operating condition.

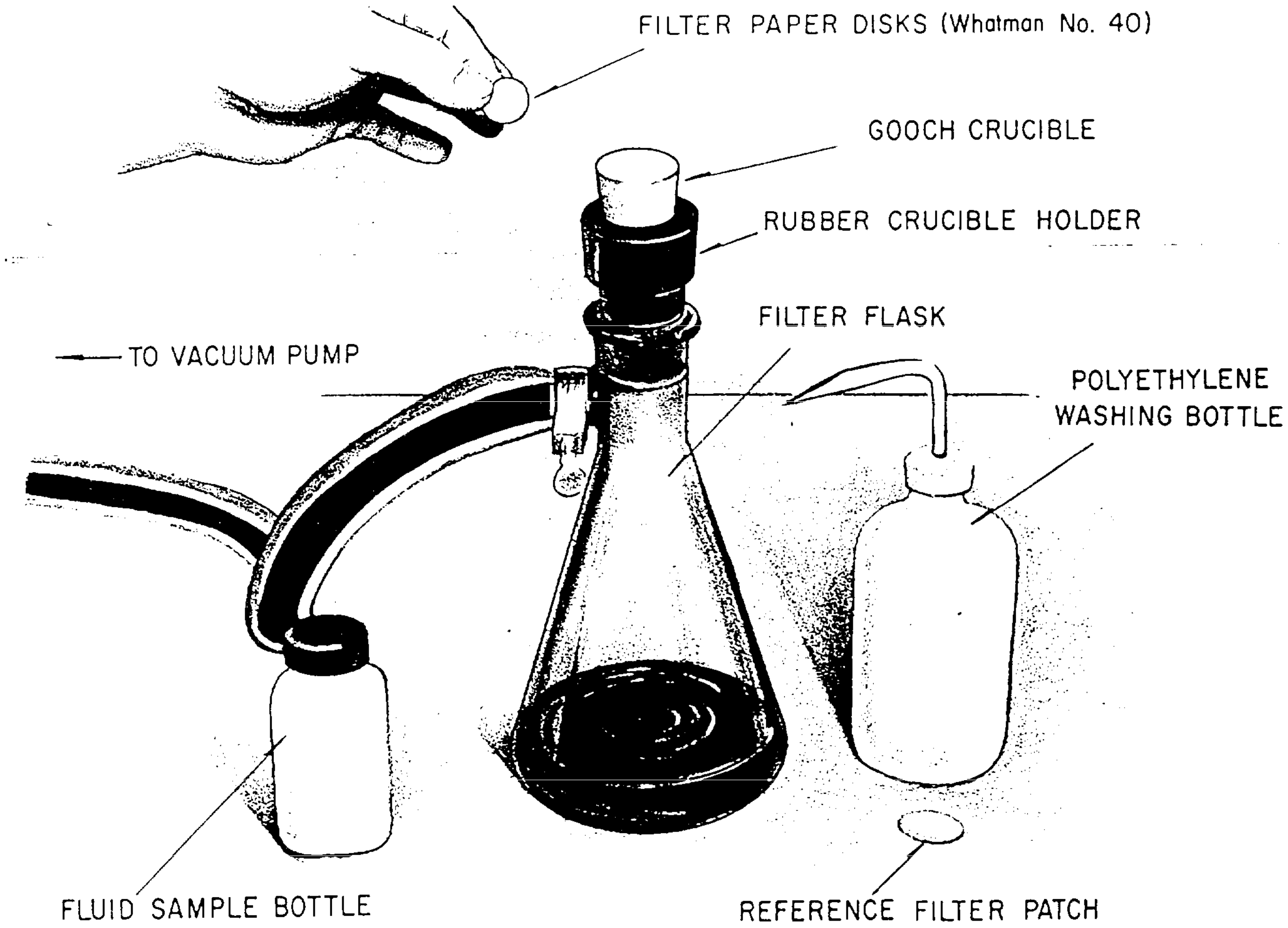


Figure 10-37.—One example of a hydraulic liquid contamination test kit.

Checks for Contamination

Whenever it is suspected that a hydraulic system has become excessively contaminated or the system has been operated at temperatures in excess of the specified maximum, a check of the system should be made. The filters inmost hydraulic systems are designed to remove most foreign particles that are visible to the naked eye; however, hydraulic liquid which appears clean to the naked eye may be contaminated to the point that it is unfit for use.

Thus, visual inspection of the hydraulic liquid does not determine the total amount of contamination in the system. Large particles of impurities in the hydraulic system are indications that one or more components in the system are being subjected to excessive wear. Isolating the defective component requires a systematic process of elimination. Liquid returned to the reservoir may contain impurities from any part of the system. In order to determine which component is defective, liquid samples should be taken from the reservoir and various other locations in the system.

FLUID SAMPLING.– Liquid samples should be taken according to the instructions provided in applicable technical publications for the particular system and the contamination test kit. Some hydraulic systems are provided with permanently installed bleed valves for taking liquid samples; while on other systems, lines must be disconnected to provide a place to take a sample. In either case, while the liquid is being taken, a small amount of pressure should be applied to the system. This ensures that the liquid will flow out of the sampling point and thus prevent dirt and other foreign matter from entering the hydraulic system. Hypodermic syringes are provided with some contamination test kits for the purpose of taking samples.

CONTAMINATION TESTING.– Various procedures are recommended to determine the contaminant level in hydraulic liquids. The filter patch test provides a reasonable idea of the condition of the fluid. This test consist basically of filtration of a sample of hydraulic system liquid through a special filter paper. This filter paper darkens in degree in relation to the amount of contamination present in the sample and is compared to a series of standardized filter disks which, by degree of darkening, indicates the various contamination levels. The equipment provided with one type of contamination test kit is illustrated in figure 10-37.

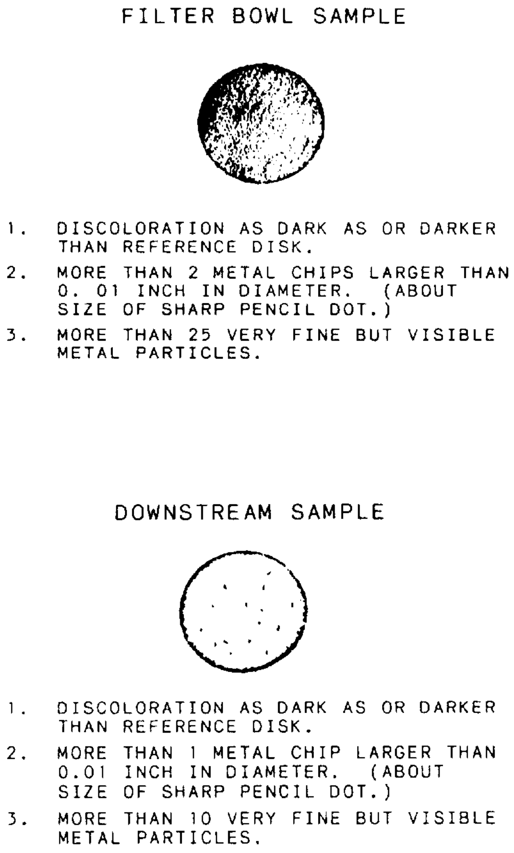
When you are using the liquid contamination test kit, the liquid samples should be poured through the filter disk (fig. 10-37), and the test filter patches should be compared with the test patches supplied with the test kit. A microscope is provided with the more expensive test kits for the purpose of making this comparison. Figure 10-38 shows test patches similar to those supplied with the testing kit.

To check liquid for decomposition, pour new hydraulic liquid into a sample bottle of the same size and color as the bottle containing the liquid to be checked. Visually, compare the color of the two liquids. Liquid which is decomposed will be darker in color.

At the same time the contamination check is made, it may be necessary to make a chemical analysis of the liquid. This analysis consists of a viscosity check, a moisture check, and a flash point check; however, since special equipment is required for these checks, the liquid samples must be sent to a laboratory where a technician will perform the test.

Flushing the System

Whenever a contamination check indicates impurities in the system or indicates decomposition of



FILTER BOWL SAMPLE

1. DISCOLORATION AS DARK AS OR DARKER THAN REFERENCE DISK.
2. MORE THAN 2 METAL CHIPS LARGER THAN 0. 01 INCH IN DIAMETER. (ABOUT SIZE OF SHARP PENCIL DOT.)
3. MORE THAN 25 VERY FINE BUT VISIBLE METAL PARTICLES.

DOWNSTREAM SAMPLE

1. DISCOLORATION AS DARK AS OR DARKER THAN REFERENCE DISK.
2. MORE THAN 1 METAL CHIP LARGER THAN 0.01 INCH IN DIAMETER. (ABOUT SIZE OF SHARP PENCIL DOT.)
3. MORE THAN 10 VERY FINE BUT VISIBLE METAL PARTICLES.

Figure 10-38.—Hydraulic fluid contamination test patches.

the hydraulic liquid, the hydraulic system must be flushed.

NOTE: The presence of foreign particles in the hydraulic system indicates a possible component malfunction that you should correct before flushing the system.

A hydraulic system in which the liquid is contaminated should be flushed according to current applicable technical instructions. Flushing procedures are normally recommended by the manufacturer. The procedure varies with different hydraulic systems. One method is as follows:

Drain out as much of the contaminated liquid as possible. Drain valves are provided in some systems for this purpose; while on other systems, lines and fittings must be disconnected at the low points of the system to remove any trapped fluid in the lines and components. Close all the connections and till the system with the applicable flushing medium. Any of the hydraulic liquids approved for use in power-transmission systems may be used for flushing purposes.

CAUTION

Diesel fuel oil must not be used for flushing hydraulic systems in active service, because of its poor lubricating qualities and its contaminating effect on the subsequent till of hydraulic liquid.

While being flushed with an approved hydraulic liquid, power-transmission systems can be operated at full load to raise the temperature of the liquid. Immediately following the warming operation, the system should be drained by opening all drain outlets and disconnecting the hydraulic lines to remove as much of the flushing medium as possible. All filter elements, screens, and chambers should be cleaned with new fluid before filling the system with the required service liquid.

CAUTION

The system should not be operated while or after draining the liquid.

Power-transmission systems and their interconnected hydraulic controls whose inner surfaces have been inactivated and treated with a corrosion prevention or preservation compound must be flushed to remove the compound. The latest current instructions for flushing and other operations required to reactivate a particular system must be strictly followed to prevent damage.

Some hydraulic systems are flushed by forcing new liquid into the system under pressure, forcing out the contaminated or decomposed liquid.

Hydraulic liquid which has been contaminated by continuous use in hydraulic equipment or has been expanded as a flushing medium must not be used again but should be discarded according to the prevailing instructions.

CAUTION

Never permit high-pressure air to be in direct contact with petroleum base liquids in a closed system, because of the danger of ignition. If gas pressure is needed in a closed system, nitrogen or some other inert gas should be used.

ASSIGNMENT 9

Text book Assignment: "Hydraulic Systems," pages 10-1 through 10-34.

IN ANSWERING QUESTIONS 9-1 THROUGH 9-4, SELECT THE DEFINITION FROM COLUMN B THAT MATCHES EACH TERM LISTED IN COLUMN A. THE RESPONSES IN COLUMN B MAY BE USED ONCE, MORE THAN ONCE, OR NOT AT ALL.

A. TERMS	B. DEFINITIONS
9-1. Hydraulics	1. The branch of science that deals with the use of air in relation to the mechanical aspects of physics
9-2. Liquid	2. A substance composed of molecules and has the ability to flow easily
9-3. Pneumatics	3. The branch of science that deals with the use of liquids in relationship to the mechanical aspects of physics
9-4. Gas	4. The amount of force distributed over each unit on an area of an object

9-5. In regard to hydraulics and pneumatics, what are the two major differences between liquids and gases?

1. Weights and temperature
2. Colors and weights
3. Temperatures and compressibility
4. Expansion and compressibility

9-6. The basic law of fluids that applies to hydraulic and pneumatic systems is based upon which of the following statements?

1. Pressure applied anywhere on confined liquid is transmitted equally and undiminished only at right angles to the direction of application
2. Pressure applied anywhere on a confined liquid is transmitted through the liquid equally and undiminished in every direction
3. Pressure applied anywhere on a confined liquid multiplies the force only in the direction of application
4. Pressure applied anywhere on a confined liquid is transmitted equally and undiminished only in the direction of application

IN ANSWERING QUESTIONS 9-7 THROUGH 9-9, REFER TO FIGURE 10-2 IN YOUR TEXTBOOK AND THE FIRST BASIC RULE FOR TWO PISTONS USED IN A FLUID POWER SYSTEM.

9-7. What is the applied pressure exerted on a 200-square-inch output piston if a 100-pound force is applied to a 50-square-inch input piston?

1. 2 lb
2. 400 lb
3. 2 psi
4. 400 psi

9-8. What is the applied force on an 8-square-inch input piston if a force of 480 pounds is developed on a 24-square-inch output piston?

1. 160 psi
2. 160 lb
3. 480 psi
4. 480 lb

9-9. What is the surface area (in square inches) of an input piston if an input force of 60 pounds can lift a 480-pound load with an 80-square-inch output piston?

1. 6
2. 10
3. 60
4. 80

IN ANSWERING QUESTIONS 9-10 THROUGH 9-12, REFER TO FIGURE 10-2 IN YOUR TEXTBOOK AND THE SECOND BASIC RULE FOR TWO PISTONS IN THE SAME FLUID POWER SYSTEM.

9-10. How many inches will an output piston with a 24-square-inch surface area be moved if the input piston with a 6-square-inch surface area is moved 4 inches?

1. 24
2. 6
3. 4
4. 1

9-11. What is the area (in square inches) of an output piston that is moved 18 inches in reaction to a 12-square-inch input piston being moved 3 inches?

1. .5
2. 1.0
3. 1.5
4. 2.0

9-12. To produce a 10-inch movement on an output piston with a 5-square-inch surface area, how far (in inches) must an input piston with a 2.5-square-inch surface area move?

1. 12.5
2. 20.0
3. 25.5
4. 50.0

9-13. The force in any hydraulic system is generated by what component?

1. Accumulator
2. Actuating unit
3. Pump
4. Motor

9-14. A pump only causes the flow of fluid, thus the amount of pressure created in a system is not controlled by the pump, but by the workload imposed on the system and the pressure regulating valves.

1. True
2. False

9-15. Pumps are classified as a fixed delivery or a variable delivery and can be further divided into which of the following classifications?

1. Gear, piston, or vane
2. High pressure or low pressure
3. Piston, motor, or accumulator
4. Rotary, reciprocating, or centrifugal

9-16. What type of gear is illustrated in figure 10-3 of your textbook?

1. Helical
2. Spur
3. Crescent
4. Herringbone

9-17. Fluid is trapped between the teeth and the housing at the inlet port, and is carried around the housing to the outlet port. As the teeth mesh again, the fluid is displaced out the outlet port. What does this produce?

1. A partial vacuum that aids in lubrication of the pump
2. A low-pressure area to assist the gravity flow of the liquid
3. A positive flow of the liquid into the system
4. A means for the drive gear to rotate the driven gear hydraulically

9-18. Tooth one in figure 10-6 of your textbook is in mesh with space one at the start of the first revolution (view A). Following three complete revolutions, which tooth will be meshing with space one?

1. Tooth two
2. Tooth three
3. Tooth four
4. Tooth five

9-19. When a vane pump is operating, what forces the vanes against the housing wall?

1. Vane springs located in each slot
2. Centrifugal force acting on each vane
3. Hydraulic pressure on the backside of each vane
4. Magnetized vanes and a ferrous metal housing

9-20. Reciprocating pumps are based on three operating principles. Two of these operating principles are described by which of the following characteristics?

1. Balanced and unbalanced
2. Constant volume and variable volume
3. Closed loop and open loop
4. Axial piston or hand pump

IN ANSWERING QUESTIONS 9-21 THROUGH 9-26, REFER TO FIGURE 10-8 IN YOUR TEXTBOOK.

9-21. What is the function of the universal link in a constant volume pump?

1. To drive the cylinder block
2. To hold the cylinder at an angle to the driven shaft
3. To force the fluid out of the pressure port
4. To push the pistons into the cylinder bores

9-22. In this constant-volume piston pump, the volume output is determined by the angle between which of the following components?

1. The piston and drive shaft
2. The point of attachment and the universal link
3. The universal link and the drive shaft
4. The cylinder block and the drive shaft

9-23. As the piston moves toward the bottom of its stroke, what causes the cylinder to fill with fluid?

1. A boost pressure applied on the fluid and fluid expansion valve
2. A positive pressure locked in by a check valve and the pressure of the accumulator
3. A partial vacuum created by the movement of the piston and the gravity pressure
4. A vacuum created by an actuating control

9-24. When the piston is rotated toward the upper position, what happens to the fluid?

1. It is drawn into the intake point
2. It is released by the drive shaft
3. It is pressurized by the cylinder block
4. It is forced out of the pressure port

9-25. The constant-volume pump is cooled and lubricated by what means?

1. Fluid flow and air from a cooling fan
2. Fluid flow and case pressure
3. Engine radiator coolant and case pressure
4. Circulation of fluid through a heat exchanger and reservoir

9-26. The relief valves that prevent buildup of excessive case pressure are normally set for what psi?

1. 10
2. 15
3. 20
4. 25

9-27. The pressure-compensating valve in a stroke reduction type of variable-volume piston pump, such as the ones illustrated in figures 10-9 and 10-10, uses what process to control output volume?

1. System pressure to control and vary the piston stroke
2. Control of the fluid inlet volume
3. A system bypass within the pump
4. All of the above

9-28. An advantage of using the variable-volume pump in a hydraulic system is the elimination of which of the following components?

1. Pressure regulator
2. Relief valve
3. Boost pump
4. Heat exchanger

IN ANSWERING QUESTIONS 9-29 THROUGH 9-31, REFER TO FIGURE 10-11 IN YOUR TEXTBOOK.

9-29. What happens when the pump handle in view A is moved to “the” right?

1. Check valve A opens, check valve B closes, and fluid flows out through the outlet port
2. Check valve A opens, check valve B closes, and fluid flows in through the inlet port
3. Check valve A closes, check valve B opens, and fluid flows out through the outlet port
4. Check valve A closes, check valve B opens, and fluid flows in through the inlet port

9-30. In view A, why is fluid discharged through the outlet port when the piston is moved to the left?

1. The piston rod makes the inlet chamber smaller than the outlet chamber
2. Check valve A opens and lets fluid from the larger inlet chamber flow into the smaller outlet chamber and through the outlet port
3. Check valve B opens and admits fluid to the inlet port and the outlet port through valve A
4. Check valve A closes and lets fluid (in the larger inlet chamber) flow into the smaller outlet chamber and out through the outlet port

9-31. What would be a result in the actions of the pump in view B if check valve B could not close completely?

1. Fluid from the smaller chamber would be allowed to flow back into the larger chamber
2. Fluid from the larger chamber would be allowed to flow freely into the outlet port
3. Fluid under pressure in the outlet port would be allowed to flow back into the inlet port
4. Fluid under pressure would be allowed to flow from the larger chamber back into the inlet port

9-32. Actuators are generally classified as to what two common designs?

1. Cylinder or motor
2. Ram or piston
3. Single or double-acting
4. Gear or vane

IN ANSWERING QUESTIONS 9-33 THROUGH 9-35, REFER TO CYLINDER-TYPE ACTUATORS.

9-33. What is the primary difference in the use of the ram and piston-type cylinders?

1. The ram type is used primarily for push and pull application, and the piston type is used for push
2. The ram type is used for push application only, and the piston type is used for push and pull applications
3. The ram type is used for applying a rotary motion, and the piston type is used for reciprocating motion
4. The ram type is used to drive hydraulic pumps, and the piston type is used as directional valves

9-34. What is used in many applications on single-acting pistons to provide piston movement in the direction opposite that achieved with fluid pressure?

1. Spring tension
2. Gravity
3. Both 1 and 2 above
4. Reverse pressure

9-35. Why is a double-acting piston referred to as an unbalanced actuating cylinder?

1. One fluid port is larger than the other
2. The fulcrum point within a cylinder changes as the piston rod extends or retracts
3. The piston slides along the piston rod outer surface causing friction
4. The blank side of the piston has a larger working surface area than the rod side of the piston because of the cross-sectional area of the rod

9-36. Some hydraulic pumps can be used as hydraulic motors with little or no modification.

1. True
2. False

9-37. Of the three most commnon types of elements used in motors, which is the only one used in pneumatic systems?

1. Gear type
2. Vane type
3. Ram type
4. Piston type

9-38. What is a noteworthy difference between a vane-type pump and a vane-type motor?

1. The vane-type motor is not capable of providing rotation in either direction
2. Vanes in a vane-type motor advance through numerous slots during one rotation of the drive shaft
3. The vane-type motor requires springs of some sort to keep the individual vanes pressed against the housing while the motor is not rotating
4. Vane-type pumps require springs to keep the individual vanes pressed against the housing while the pump is not rotating

9-39. When it is used on CESE in the NCF, how is the axial-piston hydraulic motor used?

1. To assist with heavy loads
2. As a hydraulic pump
3. As an auxiliary drive motor
4. To assist the brakes of the vehicle

9-40. What creates the dynamic-braking effect in an axial-piston pump/axial-piston motor configuration?

1. The motor, when coasting, becomes a pump and attempts to rotate the drive pump, and in turn, the prime mover
2. The plate of the motor is moved to a neutral plane and hydraulic fluid is reverse-ported to the exhaust of the motor
3. The pump reverses direction which allows the motor to coast and allow mechanical braking on the brake shoes
4. The pump causes excessive pressure in the motor's inlet side of the pistons, causing the pump to apply pressure to a mechanical brake pad

9-41. Which of the functions listed below is NOT one of the primary uses of a basic valve?

1. Controlling direction of flow
2. Controlling volume of fluid
3. Filtering fluid flow
4. Regulating fluid pressure

IN ANSWERING QUESTIONS 9-42 THROUGH 9-45, SELECT FROM COLUMN B THE COMPONENT THAT PERFORMS EACH FUNCTION LISTED IN COLUMN A.

	A. FUNCTIONS	B. COMPONENTS
9-42.	Maintains system pressure between two predetermined operating pressures	1. Check valve 2. Pressure regulator valve 3. Selector valve
9-43.	Allows fluid flow in one direction only	4. Relief valve
9-44.	Safety valve limiting maximum system pressures to prevent over pressurization damage	
9-45.	Controls direction of fluid flow to control direction or operation of a mechanism	

9-46. Which of the following valves is the most common type of valving element used in directional control valves?

1. Rotary spool
2. Sliding spool
3. Expanding spool
4. Compressing spool

9-47. The reservoir used in a hydraulic system differs from a receiver used in a pneumatic system only in the external markings.

1. True
2. False

9-48. What is the main purpose for the space above the fluid in a hydraulic reservoir?

1. To prevent drawing atmospheric dust into the system
2. To segregate the outlet fluid from the inlet fluid
3. To allow the fluid to purge itself on air bubbles
4. To cool the returning fluid before it is picked up by the pump

9-49. An accumulator can be installed in a hydraulic system to provide what service?

1. Emergency hydraulic power supply
2. Flow-divider valve
3. Check valve
4. Reservoir air filter

9–50. Filter elements are usually classified by which of the following factors?

1. Type of material used for design and construction
2. Location and purpose within the system
3. Type of fluid used and system operating temperature
4. Type of fluid used and system operating pressure

9-51. The most common hydraulic filter elements used in CESE are what types?

1. Wire mesh and porous metal only
2. Wire mesh, porous metal, and micronic only
3. Wire mesh, micronic, porous metal, and sintered bronze
4. Wire mesh, porous metal, and stainless steel

9-52. How does a micron equate to an inch?

1. One micron is equal to approximately .0000394 inch
2. Three microns are equal to approximately .00012 inch
3. Four microns are equal to approximately .00250 inch
4. Five microns are equal to approximately .0001576 inch

9-53. Which type of filter element is not reusable (disposable)?

1. Micronic
2. Wire mesh
3. Porous metal
4. Stainless steel

9-54. The filter design most used in CESE hydraulic systems is of what type?

1. Bypass
2. Nonbypass
3. Full-flow
4. Partial-flow

9-55. The function of the bypass pressure relief valve in a filter housing is to provide what feature?

1. Allowing the fluid to bypass the element in the event the element becomes clogged
2. Allowing the fluid to bypass the element when the system pressure falls below a safe filtering value
3. Regulating the gallons per minutes (gpm) of fluid passing into the main pump
4. Providing an accumulator for pulsating fluid pressures

9-56. A contamination indicator in a hydraulic filter assembly uses what principle of operation?

1. A piston between the fluid and compressed nitrogen isolates the two systems to prevent aeration of the hydraulic fluid
2. The surface area on the face of the piston will be a greater value than the surface area on the backside of the piston because of the cross-sectional area of the rod
3. The output volume of the filter is controlled by a floating cam plate, which limits the piston stroke according to the back pressure applied to the element
4. The differential pressure built up between the inlet and outlet ports vice of the filter

9-57. Which of the following components is NOT a requirement for a basic hydraulic system to operate?

1. Pump
2. Accumulator
3. Control valve
4. Reservoir

IN ANSWERING QUESTIONS 9-58 THROUGH 9-60, REFER TO FIGURE 10–35.

9-58. With the selector valve in the position indicated, fluid is returned to the reservoir from what component?

1. The selector valve via the power pump
2. The power pump via the selector valve
3. The top of the actuating cylinder
4. The bottom of the actuating cylinder via the selector valve

9-59. The pressure regulator and the check valve perform which of the following functions?

1. They relieve the workload on the pump and make the system more durable, safe, and efficient
2. They relieve the pressure in the system in case of a mechanical failure
3. They enable the system to use a variable-volume pump
4. They determine the direction of the flow of fluid from the actuating cylinder

9-60. What is the purpose of the hand pump?

1. To maintain system pressure between two predetermined limits
2. To act as an emergency power source
3. To trap fluid to maintain pressure until a mechanism is actuated
4. To provide a buffer to suppress hydraulic surges

9-61. When the pump is idling, what is the path of fluid flow in an open-center hydraulic system?

1. Reservoir, selector valves, actuating cylinder, pump, selector valves, and reservoir
2. Reservoir, pump, selector valves, actuating cylinder, selector valves, and reservoir
3. Reservoir, selector valves, pump, actuating cylinder, and reservoir
4. Reservoir, pump, selector valves, and reservoir

9-62. A closed-center hydraulic system differs from an open-center hydraulic system in that the closed-center system has

1. fluid flowing under no pressure when its pump is idling
2. its selector valves arranged in parallel vice in series
3. a constant-volume pump
4. no need for a pressure regulator

9-63. Sluggish or erratic operation of a hydraulic system generally results from what cause?

1. Defective mechanical linkage
2. Defective electrical linkage
3. External or internal leaks
4. Insufficient fluid in the system

9-64. What is the key to a hydraulic system's dependability?

1. The proper setting of relief valves and gauges
2. The replacement of identical components
3. The attention given to the cleanliness of the repair facility
4. A sound understanding of the system's operation

9-65. Before reassembling a hydraulic valve, you should lubricate the internal parts by what means?

1. A thin coat of general-purpose oil
2. A thin coat of high-temperature grease
3. A clean lubricating oil
4. The specified type of hydraulic fluid

9-66. Particles, such as dust, rust, and weld splatter, are considered what type of contamination?

1. Restrictive
2. Nonabrasive
3. Abrasive
4. Sludge

9-67. At what time does the air filter of a single-acting hydraulic ram prevent ingesting of airborne contaminates?

1. During the outward stroke only
2. During the return stroke only
3. During the outward and return stroke
4. While in neutral

9-68. Chemical contamination of hydraulic liquid by oxidation is indicated when the liquid contains which of the following materials?

1. Sludge
2. Asphaltine particles
3. Organic acids
4. Each of the above

9-69. At what temperature, in degrees, does hydraulic fluid begin to break down in substance?

1. 200°
2. 250°
3. 300°
4. 350°

9-70. Diesel fuel is not to be used as a flushing medium in hydraulic systems.

1. True
2. False

CHAPTER 11

TROUBLESHOOTING TRANSMISSIONS, TRANSFER CASES, AND DIFFERENTIALS

It does not matter how well your engine is running, how good the road conditions are, or how proficient an operator you may be. If the power of the engine of the vehicle you are operating cannot be transmitted to the wheels, the vehicle may as well be on the deadline. It is the function of the transmission to match the vehicle load requirements to the power and speed of the engine. The transfer case is used for the same function and, in addition, allows for the coupling and uncoupling of the front-wheel drive components. The differential is used to change the rotational axis of engine torque 90 degrees from the propeller shaft to the front and rear axles. Another purpose of the differential is to divide engine torque between the driving wheels so that they are free to rotate simultaneously at varying speeds.

This chapter provides information on standard transmissions, transfer cases, differentials, and the various indications of abnormal operation so that you will be able to diagnose the problems with these units and prescribe corrective action. To obtain more detailed information on the operation and repair of these units, refer to the specific manufacturer's manuals. Figure 11-1 shows the location of each of the components discussed in this chapter.

THE STANDARD TRANSMISSION

The operation of standard transmissions on automotive vehicles is described in *Construction Mechanic 3 and 2,* NAVEDTRA 10644-G1. You should review chapter 8 of the training course before studying the material in this section.

Generally, you will not be doing troubleshooting or repair work yourself. Since you will supervise such operations, however, it is essential that you know the proper procedures for performing these duties and for solving particular maintenance problems.

All transmissions are designed to perform the same functions. In construction and application, of course, transmissions vary considerably. One example is shown

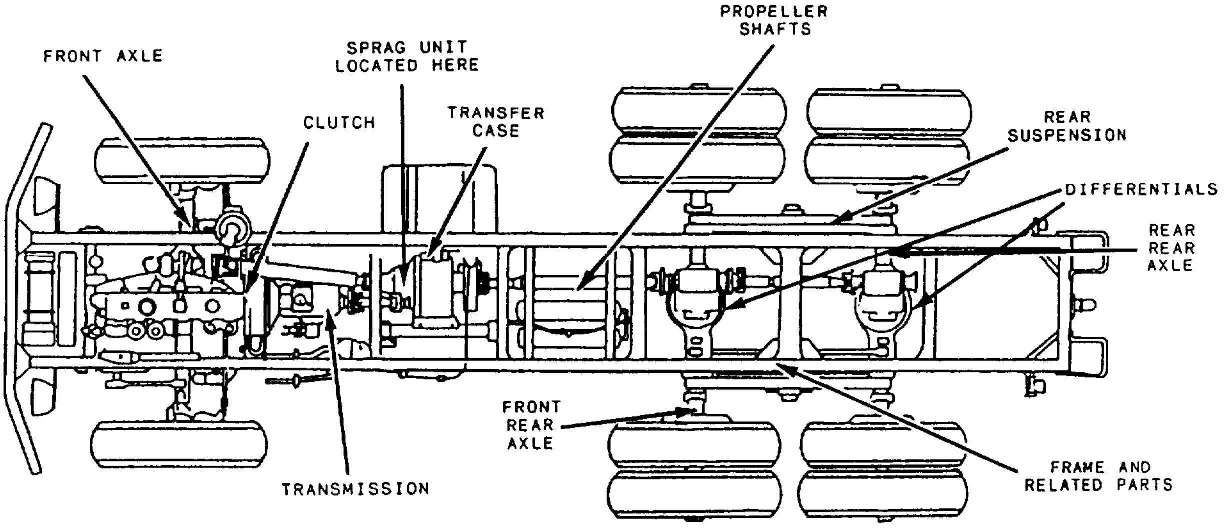


Figure 11-1.—Location of power train components in a military 5-ton vehicle.

in figure 11-2. Consequently, it is not possible to discuss all makes and models that you may encounter in the Navy. The information contained in this section is general; for problems and procedures on any particular transmission, consult the manufacturer's manual.

It is seldom that the transmission of a vehicle is manufactured by the same company that manufactured the vehicle. Some manufacturer who specialized in building automotive parts generally makes the transmission and sells it to the vehicle manager. A nameplate attached to the side of the transmission case will have the manufacturer's name and the model number of the transmission. The Spicer Company, for instance, uses a four digit number for a model number, such as 8051. The third digit of the number indicates the number of forward speeds available in that particular transmission. Therefore, the model 8051 is a five-speed transmission.

If a transmission does not have a nameplate, refer to the vehicle manufacturer's manual for identification.

TROUBLESHOOTING TRANSMISSIONS

It is important that transmissions troubleshooting be done by trained, experienced mechanics. Many times an operator will report transmission noise on the Operator's Trouble Report, when, in fact, the noise maybe coming from some other component of the power train of the vehicle.

Noises that appear to come from the transmission but actually originate at some other point are many and varied; for example, unbalanced propeller shaft, defective wheel bearings, or damaged tires on a vehicle may cause noises that are transmitted to the transmission. These noises have no particular or characteristic sounds that would indicate their origin; therefore, they are difficult to identify.

Torsional vibration is one of the most frequent causes of noises that appears to be in the transmission, but actually originates outside of it. Included among these possible outside torsional vibrations are the following:

1. Propeller shaft (drive shaft) out of balance
2. Worn universal joints
3. Drive shaft center bearings loose
4. Worn and pitted teeth on axle pinion and ring gear
5. Wheels out of balance

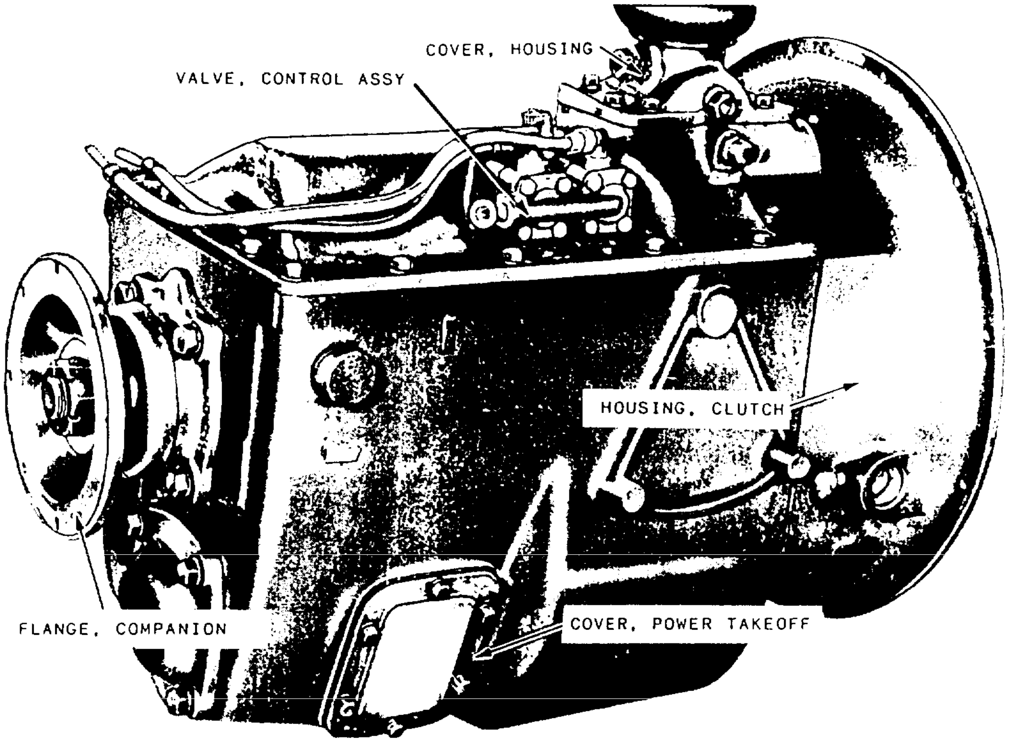


Figure 11-2.—Typical example of a heavy-duty truck transmission.

6. Worn spring pivot bearings
7. Loose frame or axle U-bolts
8. Engine cooling fan out of balance
9. Engine crankshaft, flywheel, and/or clutch plate out of balance
10. Tires or wheels wobbly or mismatched

This list, along with other troubles you have encountered in your own experience, can be used as a step-by-step guide in transmission noise troubleshooting. Make sure that all possibility of outside noise has been eliminated before you have your personnel remove the transmission.

When analyzing a vehicle for transmission noise, raise the vehicle so that the driving wheels are clear of the deck. Start and operate the vehicle in all the speed ranges, including COASTING with the shift lever in neutral. Listen carefully for noises and try to determine the origin. There are other procedures for checking transmission noises that may be used. Principally, any procedure used relies on the experience and good judgment of the mechanic doing the troubleshooting.

When it is determined that the noise is with the transmission, generally it is necessary for the transmission to be removed from the vehicle and disassembled.

Remember, however, you should never be satisfied with just finding and correcting the trouble. You should always try to find what caused the trouble. If you find a transmission with broken gear teeth, do not be satisfied with just replacing the transmission. Try to find out what caused the transmission to malfunction.

Whenever you find such components as the transmission in an unserviceable condition, talk to the driver. The driver may be able to explain exactly how the failure occurred and give you a clue as to the cause of the failure.

If you fail to find the cause, you will probably have to do the job over because the same trouble will most likely develop in the replacement transmission. Table 11-1 is a basic troubleshooting chart. As

Table 11-1.—Troubleshooting Transmissions (5-ton military)

Troubleshooting Transmissions (5-ton military)		
Malfunction	Probable Causes	Corrective Action
1. Transmission slips out of gear.	a. Shifter forks loose on shifter shafts.	a. Remove shifter housing and tighten shifter forks setscrews (fig. 11-3) and replace locking wires.
	b. Shifter shaft detent grooves worn.	b. Remove shifter housing (fig. 11-4) and install new shifter shafts.
	c. Gear teeth worn.	c. Disassemble transmission and replace worn gears (fig. 11-5).
	d. Excessive end play in main drive shaft.	d. Tighten main shaft companion flange nut.
2. Transmission operates satisfactorily in reverse and first, but will not shift to second or third.	Defective second and third speed gear synchronizer.	Disassemble transmission and replace gear synchronizer (fig. 11-6).
3. Transmission operates satisfactorily in reverse, first, second, and third, but will not shift into fourth or fifth.	Defective fourth and fifth speed synchronizer assembly.	Disassemble transmission and replace synchronizer assembly (fig. 11-7).

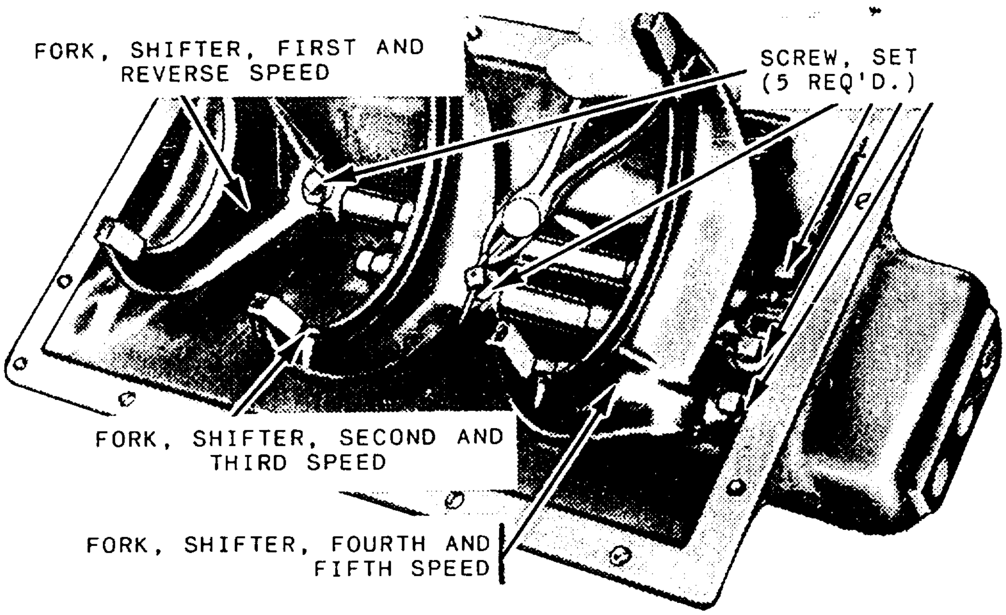


Figure 11-3.—Location of shifter fork setscrews.

referenced in the chart, you should refer to figures 11-3, 11-4, 11-5, 11-6, and 11-7 respectively.

Inspecting the Transmission

Leaking oil seals and gaskets are probably the most common causes of transmission problems. If such problems are not corrected in time, the gears, shafts, and bearings can be ruined.

There are many possible causes for oil seal or gasket failures, so always look for causes whenever you find such failures, and certainly before the unit is placed back in operation.

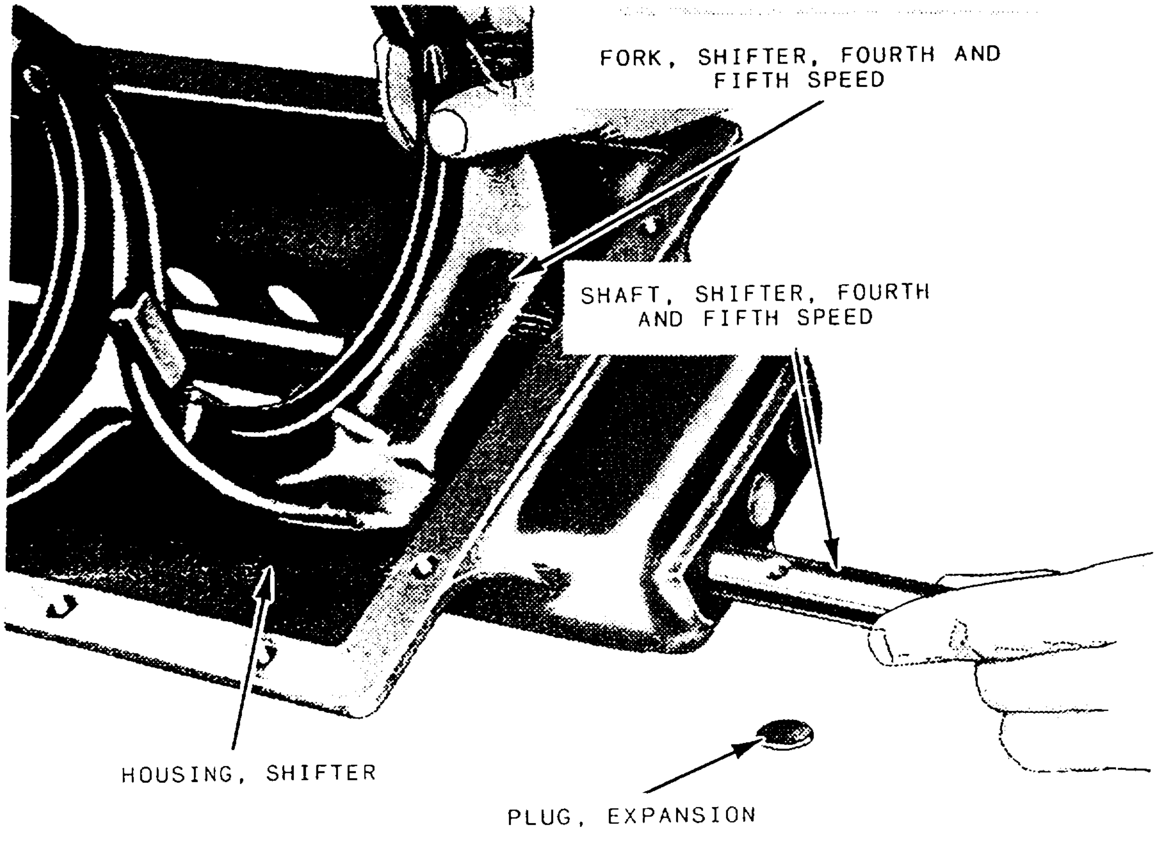
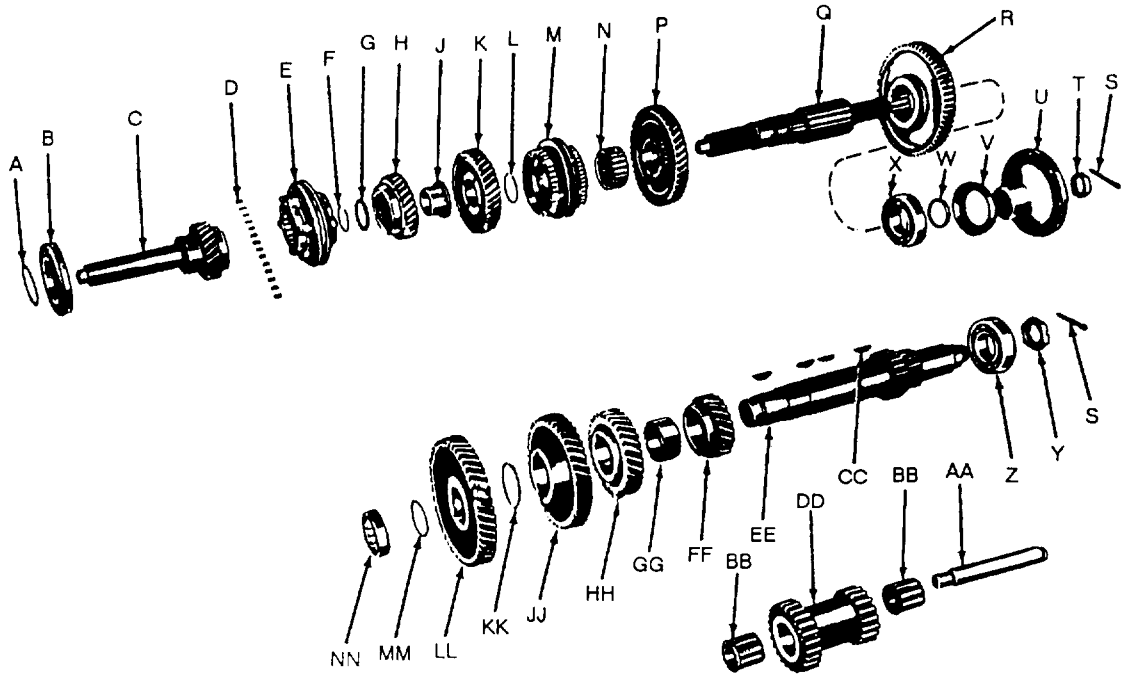


Figure 11-4.—Replacing shifter shafts and forks.



A. Ring, snap, bearing
B. Bearing, ball, input shaft
C. Shaft, input
D. Roller, pilot, bearing
E. Synchronizer, fourth and fifth speed gear
F. Ring, snap, fourth speed gear
G. Washer, thrust
H. Gear, fourth speed
J. Sleeve, fourth speed gear
K. Gear, third speed
L. Ring, snap, second and third speed clutch gear
M. Synchronizer, second and third speed gear
N. Gear, second and third speed clutch
P. Gear, second speed
Q. Shaft, main
R. Gear, first and reverse speed
S. Pin, cotter
T. Nut, slotted
U. Flange, companion
V. Slinger, dust
W. Washer, spacing, rear bearing
X. Bearing, ball, main shaft, rear nut, slotted
Z. Bearing, ball, countershaft, rear
AA. Shaft, reverse idler gear
BB. Bearing, roller, reverse idler gear
CC. Key, Woodruff
DD. Gears, reverse, idler
EE. Countershaft
FF. Gear, second speed, countershaft
GG. Spacer, countershaft
HH. Gear, third speed, countershaft
JJ. Gear, fourth speed, countershaft
KK. Ring, snap, fourth speed gear, countershaft
LL. Gear, drive, countershaft
MM. Ring, snap, drive gear, countershaft
NN. Bearing, roller, countershaft, front

Figure 11-5.—Transmission gears and shafts-exploded view.

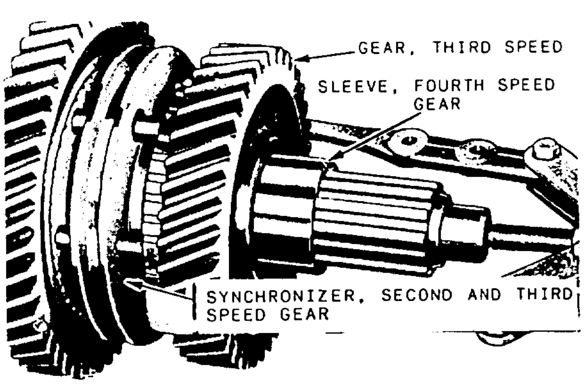


Figure 11-6.—Disassembling fourth speed gear sleeve.

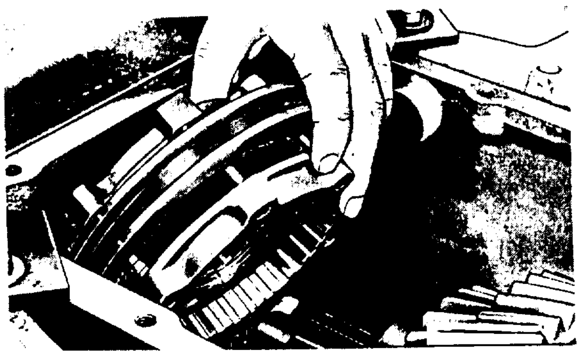


Figure 11-7.—Removing the fourth and fifth speed gear synchronizer from main shaft.

Cause of Leaking Lubricants

Now let us review some of the reasons why the lubricant is likely to leak at any one or several of these locations. First of all, a transmission (or almost any other gear case) will usually start leaking if the oil level is too high. To stiffen the oil used in gear cases, some manufacturers use soap and soda in the oil. As the gears operate, the oil is splashed all over the inside of the gear case. Because of the soap and partly because of the splashing and the heat, the oil starts to foam or fill with air bubbles. Thus the oil expands and takes up more room. This action creates excessive pressure inside the gear case. If the oil level is too high to start with, the pressure created inside the transmission many be more than the seals and gaskets can resist and the oil will start leaking out. Leaking can occur at any one or several locations.

The transmission oil level should only be checked after the vehicle has been parked for several hours or overnight. During this time, the bubbles or foam will cool and settle as a liquid in the bottom of the transmission case.

- With the transmission cold, remove the fill plug. The oil level should be at, or just below, the bottom of the till plughole.
- If the oil level is too high, allow the excess oil to run out the fill plughole.

Even if the oil level is correct, it is possible that the foaming action of the oil will cause the pressure inside the transmission to become too high. To permit the excess pressure to escape, a vent valve is used. This valve contains a seat and spring-loaded ball, and has a dust cap over the valve assembly.

To check the vent valve, first make sure the area around it is free of dust and dirt.

- Then try turning the dust cap with your fingers. It should turn freely in either direction. If it does not turn freely, replace it.

Gaskets or oil seals will always leak if the bolts securing the plates, covers, or retainers are loose. All of the bolts should be tightened uniformly with a torque wrench.

The bolts that secure the input shaft retainer, the gearshift housing cover, and the retainer seals should be tightened with a torque wrench to the manufacturer's specifications. If tightening the bolts fails to stop the leak at this point, the transmission should be disassembled and the source of the leak repaired.

Leaks around the threads of the fill plug, the drain plugs, or any of the bolts can usually be stopped by coating the threads of the plugs or bolts with a lead-based paint.

A loose gearshift retainer will also allow the lubricant to escape.

All of the seals need to be lubricated; otherwise, they will be ruined. Therefore, a little seepage around any seal is normal. A seal is not considered as leaking unless enough oil is escaping by the seal to drip on the ground and cause a small puddle.

Leaking Seals

With the power plant in the vehicle, you can inspect all seals except the input shaft retainer seal. If this seal is leaking, oil will drip out through the plughole in the bottom of the pan under the flywheel housing when the plug is removed.

If oil does drip out at the flywheel housing drain plug, examine the oil closely. It may be engine oil leaking from the engine crankshaft rear oil seal. The engine oil is much thinner (has less viscosity) than the transmission oil, so you should be able to tell which seal is leaking.

An oil leak, either from the engine or transmission input shaft seals, is serious, because the oil can ruin the clutch. An oil-soaked clutch disk will almost always slip or grab.

TESTING TRANSMISSIONS FOR MALFUNCTIONS

In addition to the leakage problems, there are other problems that can develop in the standard transmissions used in almost all trucks. We can classify these as mechanical problems.

The best way to locate mechanical problems in the transmission is to road test the vehicle. Before road testing, however, check for missing or loose bolts and be sure the oil is at the proper level in the transmission case. Check the parking brake mechanism for proper mounting and correct adjustment. Check all moisture seals or boots. Check the action of the gearshift levers.

The transmission is often blamed for problems that are elsewhere. For example, with the engine running and the vehicle standing still, disengage the clutch and move the gearshift lever into first or reverse. You should be able to shift into either of these gear positions without any gear clashing or without the vehicle moving. If the gears clash or the vehicle attempts to move with the clutch disengaged, the trouble is in the clutch and not the transmission.

Check the clutch pedal free travel and adjust it if necessary. The clutch must be correctly adjusted before the transmission can operate properly. The clutch must fully disengage every time the clutch pedal is pushed all the way down, and it must fully engage every time the pedal is released.

With the transmission in neutral, the engine running, and the clutch engaged, all of the constant-mesh gears in the transmission will be turning. There should be very little gear or bearing noise.

If the transmission is quiet in neutral with the clutch engaged, disengage the clutch. If a noise is now heard, the trouble is with the clutch and not the transmission. Usually, the clutch release bearing or the clutch shaft pilot bearing is at fault if a noise is heard only when the clutch is disengaged.

Sometimes, noises in other parts of the power train, such as U-points, propeller shafts, and differential, sound as if they are in the transmission. The misalignment of power train components usually produces a noise that may sound as if it is coming from the transmission. So be sure to check all mounting bolts on the engine, transmission, and differentials before road testing the vehicle. Also, check the propeller shafts and U-joints for evidence of wear or looseness.

Loose, bent, or shifted suspension system components will cause misalignment of the power train components that can produce a noise that may sound like a defective transmission.

Noises that may originate in the transmission are difficult to describe. A noise that may sound like a howl to you may sound like a squeal to someone else. Other terms often used to describe gear or bearing noises may include such words as “hum,” “knock,” “grind,” “whine,” and “thump.”

If a teeth is broken off of one of the gears, a distinct thumping noise will be heard once during a complete revolution of the gear. The thump will be more pronounced if torque is being delivered through that gear.

Gears with worn, rough teeth will usually produce a grinding noise, especially when torque is being transmitted through them.

Bearing noise is usually described as a howl, whine, or squeal. Actually, the type of noise made by a defective bearing will vary, depending on the type of defect and the load the bearing is supporting. In any event, loud noises coming from inside the transmission mean trouble.

Some whining or grinding noise can be expected, especially when the vehicle is being driven in first or reverse gear. The first-and-reverse sliding gear together with its mating countershaft gear and reverse idler gear are spur gears, Spur gears are always noisy, but, as you recall from a preceding lesson, they are frequently used because they are cheaper and do not produce thrust.

In the second-, third-, and fourth-speed ranges, the transmission should be much quieter than in first or reverse.

If, after a road test, you think the transmission is too noisy, be sure and report it to the maintenance supervisor. Be sure to describe the conditions under which the noise occurs.

Another common mechanical problem with transmissions of this type is slipping or jumping out of gear. Actually, the transmission is much less likely to slip or jump out of first or reverse than out of second-, third-, or fourth-speed gear. Second-, third-, and fourth-speed gears are all helical gears which, you recall, produce thrust.

The most likely causes of the transmission slipping out of gear are worn detent balls or springs in the shifter shaft cover. These spring-loaded balls hold the shifter shaft in position. If the spring does not have enough tension or if the balls are worn, the transmission will almost certainly slip or jump out of gear. Synchronizer damage will also cause the transmission to jump out of gear.

Slipping out of any gear is most likely to occur when the driver suddenly takes his or her foot off the accelerator pedal, especially when descending a steep hill. The thrust produced by the helical gears will tend to move all rotating gears and shafts to the rear of the transmission, as long as the torque provided by the engine is being delivered to the rear wheels by the transmission. However, when the driver takes his or her foot off of the accelerator pedal, the situation is changed. The rear wheels now try to drive the engine through the transmission. This reverses the direction of the torque being delivered through the transmission gears, and the thrust is now toward the front of the transmission. If this thrust is not controlled by the thrust washers and bearing retainers, it is likely to force the shifter shaft to move in spite of the spring-loaded ball that holds it. When this happens, the transmission slips out of gear.

Occasionally, a transmission slips out of gear because the driver does not fully engage the gear when moving the lever. However, when a transmission slips out of gear fairly often, it should be replaced.

OVERHAUL OF THE TRANSMISSION

Because of the variations in construction of transmissions, different procedures in the removal, disassembly, repair, assembly, and installation must be followed. These operations generally require from 5 to 7 hours, depending on the procedure followed. If you are working on a vehicle with which you are not familiar, always check the manufacturer's manual.

Before removing the transmission from the vehicle, make sure all accumulations of dirt or road mud are cleaned from the case and the attached parts. Note or mark by scratching the case with a sharp pointed tool, any moist oil spots or unusually heavy accumulations of oil-soaked road mud; these we good clues to the location of small cracks or holes that might escape notice in visual inspection. However, do not confuse these accumulations with those that result from leaking gaskets or oil seals. A leak at a gasket or a seal is more or less normal on a transmission that has been in service for any length of time.

Drain the lubricant from the transmission. Some manufacturers recommend flushing the transmission before removal. This is done by filling the transmission with a flushing oil and operating the engine with the transmission in neutral for several seconds. After this, drain the flushing oil from the transmission.

After removing the transmission case, complete the external cleaning operation with steam-cleaning equipment or by hand brushing the case, using an approved cleaning solvent.

After the transmission is disassembled, make sure all parts are cleaned thoroughly and individually.

Clean away all the parts of hardened oil, lacquer deposits, and dirt, paying particular attention to the small oil holes in the gears and to the lock ball bores in the shifter shaft housing. Remove all gaskets or parts of gaskets using a scraper or other suitable tool. Make sure the metal gasket surfaces are not gouged or scratched.

After all parts of the transmission have been thoroughly cleaned, inspect them to determine whether they can be reused or scrapped. The wear or damage to some of the parts will be evident to the eye, (fig. 11-8) whereas, in others, it may be necessary to use tools or gauges to determine their condition. Since the decision as to whether apart should be scrapped or reused is often a matter of opinion or judgment, you may want to do this job yourself. If you can not do the inspecting yourself, make sure the person doing it is experienced in transmission maintenance and overhaul.

When inspecting transmission parts, bear in mind that the inspection procedure has two objectives; first, to eliminate any part or parts that are unsuitable for use, or doubtful parts that may cause the premature failure of the overhauled transmission; second, and equally important, to reduce the wasteful practice of scrapping parts that still retain a high percentage of useful life.

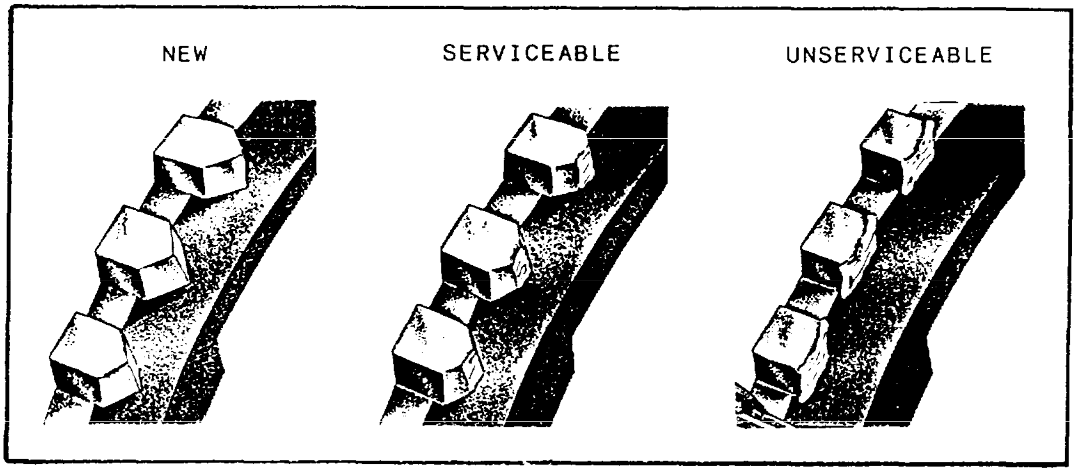


Figure 11-8.—An example of worn external teeth of a synchronizer clutch.

If a transmission part is to be repaired, make sure only good repairs are made. Makeshift or temporary repairs should not be permitted, except in an emergency. The principal purpose of repairs is to salvage components that would otherwise be scrapped. The decision as to whether apart is to be repaired rests upon three factors; First, the practicality of the repair, (That is, will the repair of the part return it to a near new condition?); second, the cost of the repair job as compared to the cost of a replacement; and third, the availability of the replacement part. If replacement parts are unavailable or in short supply, make every effort to salvage as many parts as possible.

Small holes or cracks in the transmission case, shifter shaft housing, or clutch housing maybe repaired by welding or brazing, provided they do not extend into the bearing bores or mounting surfaces. These pieces are gray (cast) iron, and special techniques are required to weld these materials satisfactorily; normally, ordinary welding methods and materials are not suitable.

To assemble a transmission, use a reverse procedure from that of disassembly. Check the manufacturer's manual for proper clearances and the wear limits of the parts.

All parts, whether new or used, should be lightly coated with lubricating oil. This is done immediately after inspection or repair. Oiling the parts gives them a necessary rust-preventative coating and facilitates the assembly operations.

Train your personnel to have all the necessary parts on hand before the assembly operation begins. This guarantees that the transmission can be completely assembled without interruptions.

As a CM1, it will be your responsibility to test the transmission after it is assembled. If all parts are correctly assembled, the transmission gears will all rotate freely without evidence of binding. Use a suitable wrench to rotate the input shaft at least ten full revolutions. Shift the transmission into all the speed ranges. If the transmission is noisy, extremely loose, or binds, it must be disassembled and further corrective measures taken.

TROUBLESHOOTING TRANSFER CASES

Transfer cases (fig. 11-9) are placed in the power trains of vehicles to allow them to operate in mud, snow, sand, and other unusual terrains. To do this, you have to have driving power available at the front wheels as well as the rear wheels so the vehicle will not get stuck. Therefore, certain wheeled vehicles include a second gearbox, called the transfer case. Its purpose is to take the output power from the transmission and divide it so

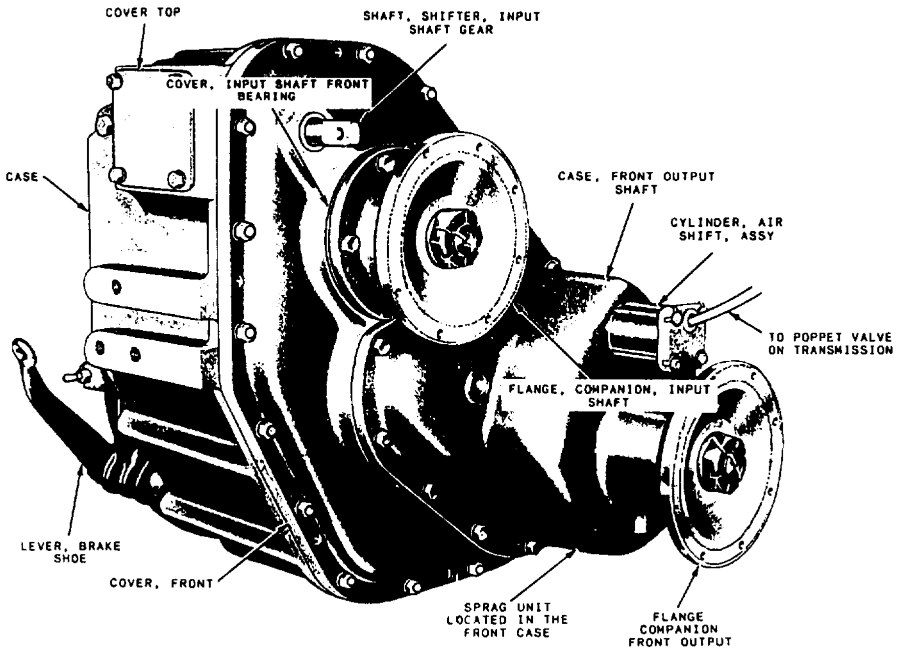


Figure 11-9.—Example of a transfer case assembly (5-ton truck, military).

that it will drive the rear wheels at all times and drive the front wheels when needed.

The transfer case can be mounted in several ways in a vehicle. It can be a separate component mounted to the rear of the transmission and driven by a propeller shaft connecting it to the output of the transmission. It can also be a part of the transmission (fig. 11-10) and driven by a gear or by the output shaft of the transmission. The transfer case performs one or more of the following functions:

- It transfers the transmission power to a point low enough so that a propeller shaft can be mounted under the engine and power the front axle.
- It provides an output to power one or more rear axles.
- It provides a high and low gear ratio for vehicles that do not have the necessary gear reductions in the transmission.
- It provides arrangements for engaging and disengaging front-wheel drive and high and low ranges when applicable.

One of the mechanic's jobs is to repair transfer cases; this means diagnosing trouble, dismantling, inspecting, and reassembling the unit. If you become familiar with the method of repairing one particular transfer case, you should not have much difficulty repairing others.

The first indication of trouble within a transfer case, as with other components of the power train, is usually "noisy" operation. If an operator reports trouble, make a visual inspection before removing the unit from the vehicle. Check for such things as oil level, oil leakage, and water in the oil.

Make sure the shift lever linkages are inspected. If the shift lever linkages are bent or improperly lubricated, it will be hard to shift the transfer case or, in some cases, will make shifting impossible. Make sure other possible troubles, such as clutch slippage, damaged propeller shaft, and damaged axles, have been eliminated.

Worn or broken gears, worn bearings, and excessive end play in the shafts will cause noisy operation of the transfer case. When it is determined that the trouble is within the transfer case, have your personnel remove the unit from the vehicle for repairs.

Make sure the transfer case is thoroughly cleaned before disassembly of the unit begins. When the unit is disassembled, have each part cleaned with an approved cleaning solvent. Inspection of the individual parts should follow the same procedure as outlined for transmissions. Avoid waste by using old parts that are in good condition. Table 11-2 is a troubleshooting chart for transfer cases. As referenced in the chart, you should refer to figures 11-11, 11-12, 11-13, and 11-14 respectively.

Personnel who are not thoroughly familiar with a particular make and model of a transfer case should be supplied with a manufacturer's repair manual. Check the job frequently to be sure the proper adjustments and assembly procedures are followed.

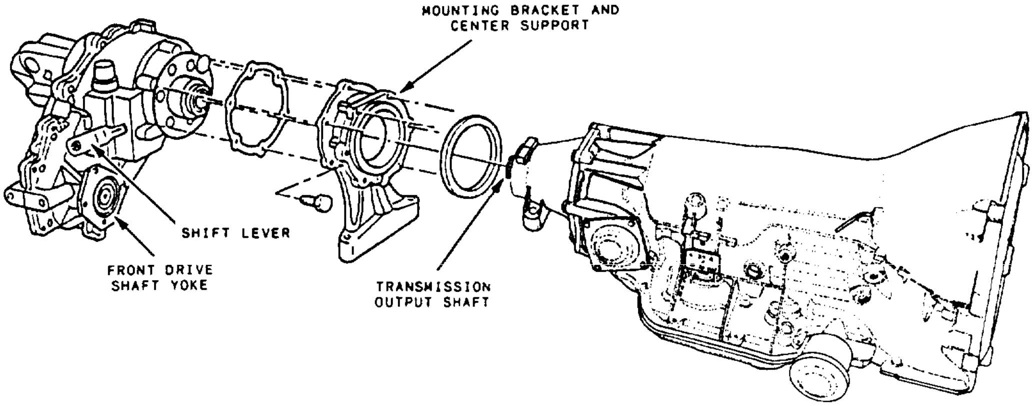


Figure 11-10.—Transfer case to the transmission.

Table 11-2.—Transfer Case Troubleshooting Chart

Transfer Case Troubleshooting Chart		
Malfunction	Probable Causes	Corrective Action
1. Transfer slips out of gear.	a. Shifter fork loose on shifter shaft.	a. Remove top cover and tighten setscrew (fig. 11-11).
	b. Shifter shaft poppet ball notches worn.	b. Disassemble transfer and install new shifter shaft (fig. 11-12).
	c. Gear teeth worn.	c. Disassemble transfer and replace worn gears.
2. Transfer will not shift.	Defective gear synchronizer.	Disassemble transfer and replace gear synchronizer (fig. 11-13).
3. Front wheels do not drive when rear wheels lose traction.	Defective sprag units. Defective front axle engagement system.	Remove transfer front output shaft case assembly and replace sprag units and other excessively worn parts.
4. Front wheels do not drive in reverse.	Defect sprag units.	Troubleshoot front axle engagement system (fig. 11-14) and replace as required.

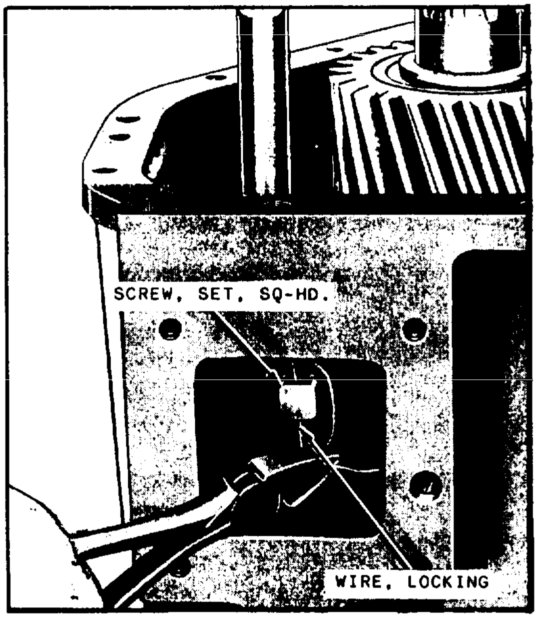
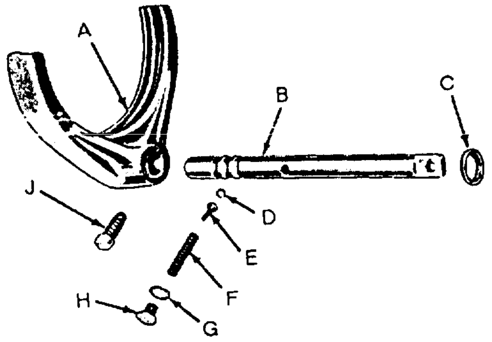
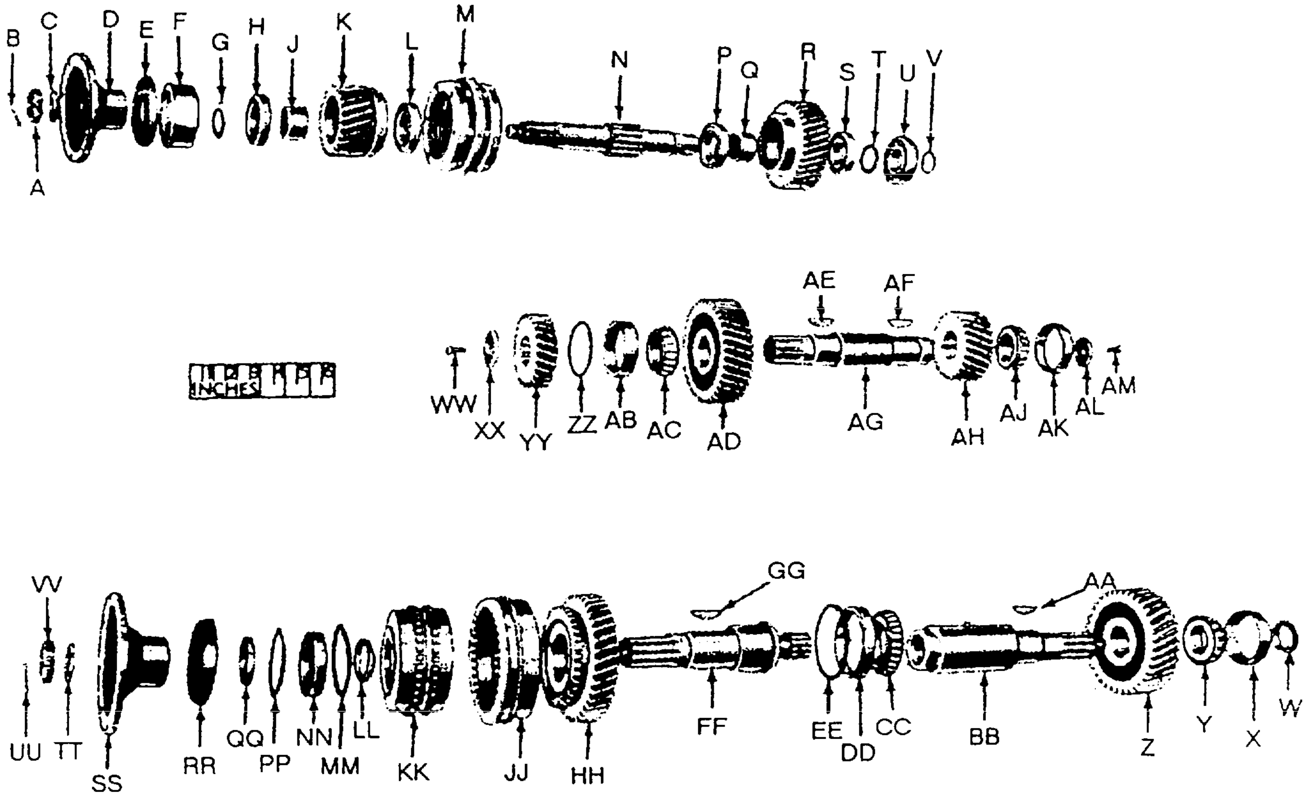


Figure 11-11.—Transfer case high low gearshift shaft, locking setscrew and locking wire.



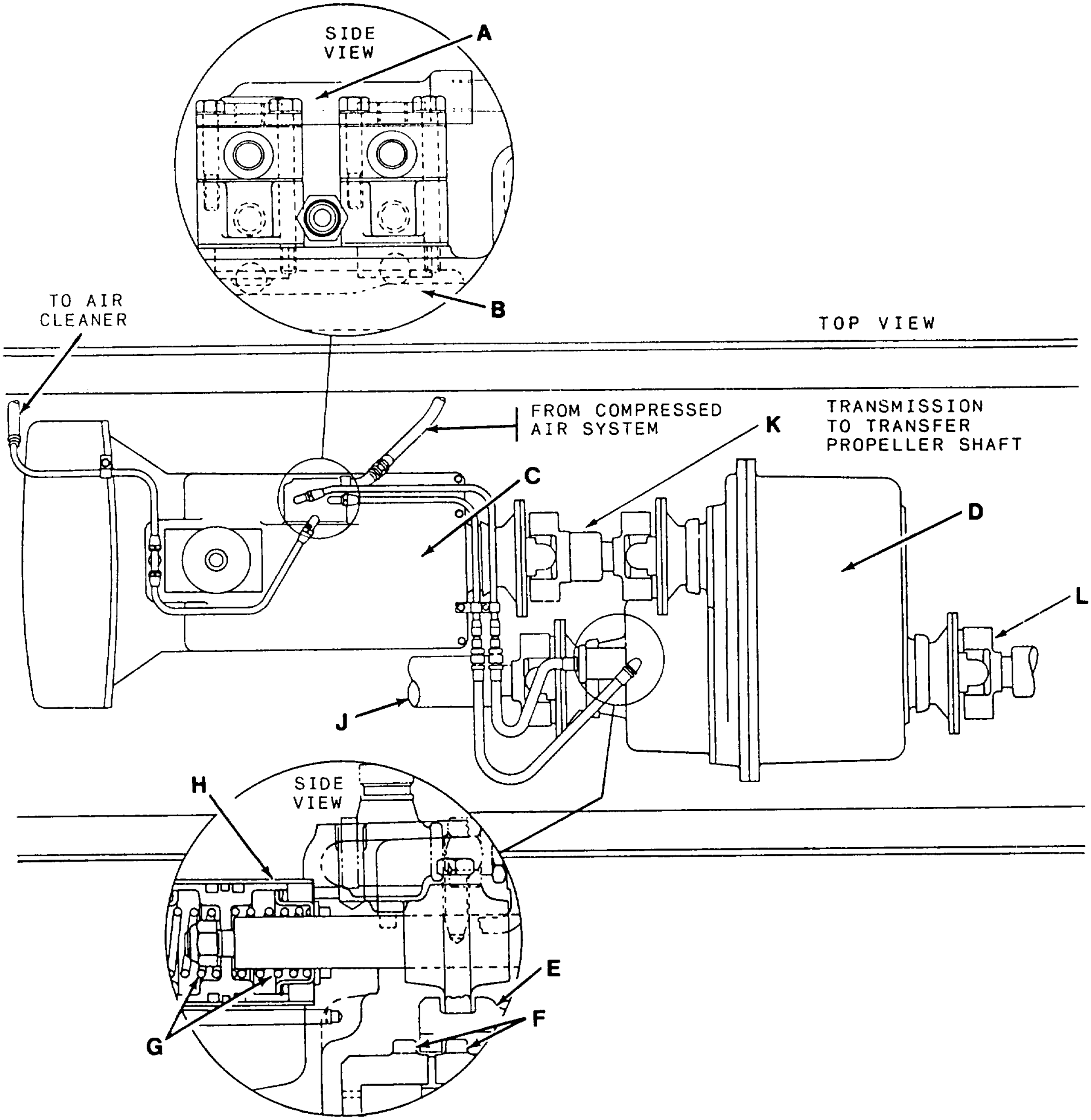
- A. Fork, shifter, high- and low-speed
- B. Shaft, shifter, input shaft gear
- C. Seal, oil, gear shifter shaft
- D. Ball, poppet
- E. Plunger, poppet ball
- F. Spring, compression, poppet ball
- G. Washer, lock internal teeth
- H. Screw, plunger
- J. Screw, set sq-hd

Figure 11-12.—High low shifter shaft and fork-exploded view-legend.



A. Nut, sltd
B. Pin, cotter
C. Washer, plain
D. Flange, companion, input shaft
E. Slinger, dust, flange
F. Bearing, ball, input shaft, front
G. Spacer, input shaft front bearing
H. Bearing, ball, input shaft low-speed gear, front
J. Spacer, input shaft low-speed gear
K. Gear, low-speed, input shaft
L. Bearing, ball, input shaft low-speed gear, rear
M. Synchronizer, gear
N. Shaft, input
P. Bearing, ball, input shaft high-speed gear, front
Q. Spacer, input shaft high-speed gear front bearing
R. Gear, high-speed, input shaft
S. Bearing, ball, input shaft high-speed gear, rear
T. Spacer, input shaft rear bearing
U. Bearing, ball, input shaft, rear
V. Ring, snap, input shaft, rear bearing
W. Washer, spacing, rear output shaft rear bearing
X. Cup, rear output shaft rear bearing
FF. Shaft, output, front
GG. Key, Woodruff
HH. Gear, driven, front output shaft
JJ. Collar, reverse shift
KK. Sprag unit
LL. Washer, spacing, front output shaft bearing, inner
MM. Ring, snap, front output shaft bearing, rear
NN. Bearing, ball, front output shaft
PP. Ring, snap, front output shaft bearing, front
QQ. Washer, spacing, bearing, outer
RR. Slinger, dust, flange
SS. Flange, companion, front output
TT. Washer, plain
UU. Pin, cotter
VV. Nut, sltd
WW. Screw, cap
XX. Washer, retaining
YY. Gear, drive, intermediate shaft
ZZ. Ring, snap, intermediate shaft front, bearing
AB. Cup, intermediate shaft front bearing
AC. Cone, intermediate shaft front bearing
AD. Gear, low-speed, intermediate, shaft
AE. Key, Woodruff
AF. Key, Woodruff

Figure 11-13.—Transfer shafts, bearing, and gears–exploded view–legend.



- A. Air cylinder control valve
- B. Reverse shift rail
- C. Transmission
- D. Transfer
- E. Reverse shift collar
- F. Sprag unit assembly
- G. Balanced spring loading
- H. Shift air cylinder assembly
- J. Front output shaft
- K. Propeller shaft
- L. Rear output shaft

Figure 11-14.—Front axle engagement air control diagram–legend.

TROUBLESHOOTING THE POWER TAKEOFF

Power takeoffs are attachments in the power train for power to drive auxiliary accessories. They are attached to the transmission, auxiliary transmission, or transfer case. A common type of power takeoff is the single-gear, single-speed type. This unit is bolted to art opening provided in the side of the transmission case, as shown in figure 11-15. The sliding gear of the power takeoff will then mesh with the transmission countershaft gear. The operator can move a shifter shaft control lever to slide the gear in and out of mesh with the countershaft gear. The spring-loaded ball holds the shifter shaft in position.

On some vehicles, you will find power takeoff units with gear arrangements that will give two speeds forward and one in reverse. Several forward speeds and reverse gear arrangements are usually provided in power takeoff units that operate winches and hoists. Their operation is about the same as the single-speed units.

The troubleshooting and repair procedures for the power takeoff are similar to those for the transfer case and are listed in table 11-3.

TROUBLESHOOTING THE PROPELLER SHAFT ASSEMBLY

The propeller shaft, or drive shaft, assembly consists of the shaft, a splined slip joint, and one or more universal joints. This assembly provides a flexible connection through which power is transmitted from the transmission to the differential. The propeller shaft is almost always tubular.

A splined slip joint is provided at one end of the propeller shaft to take care of end play. The driving axle, being attached to the springs, is free to move up and down while the transmission is attached to the frame and cannot move. Any upward or downward movement of the axle, as the springs are flexed, shortens or lengthens the distance between the axle assembly and the transmission. To compensate for this changing distance, the slip joint is provided at one end of the propeller shaft.

The usual type of splined slip joint consists of a splined stub shaft welded to the propeller shaft that fits into a splined sleeve. A cross-sectional view of the splined slip joint and universal joint is shown in figure 11-16.

A universal joint is a connection between two shafts that permits one to drive the other at an angle. Passenger

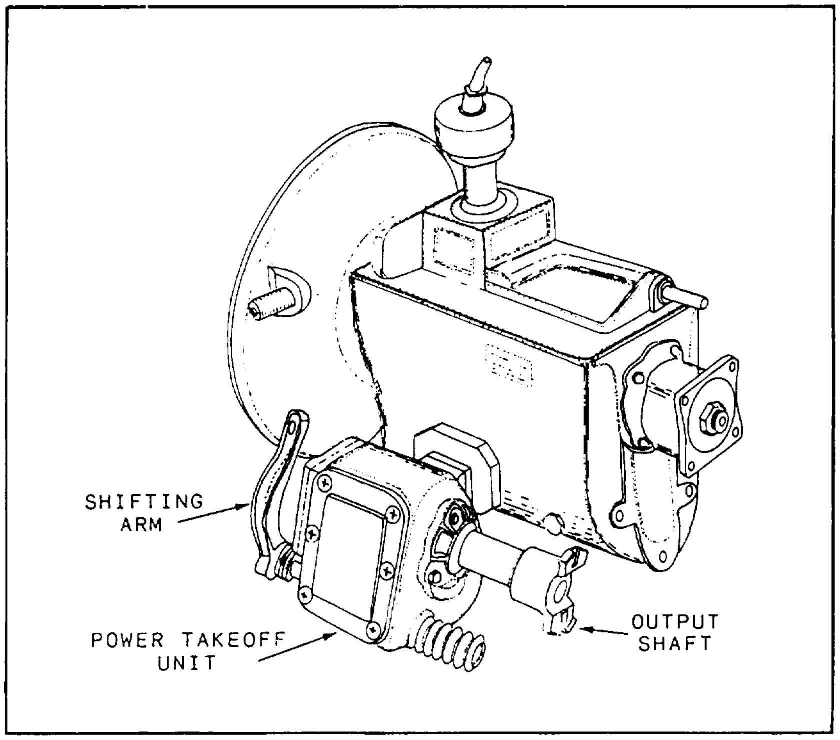


Figure 11-15.—Power takeoff mounted on a vehicle transmission.

Table 11-3.—troubleshooting the Power Takeoff

Troubleshooting the Power Takeoff		
Malfunction	**Probable Causes**	**Corrective Action**
1. Noisy power takeoff.	a. Stripped gears.	a. Replace defective gears.
	b. Worn bearings.	b. Replace defective bearings.
	c. Worn shaft splines.	c. Replace shafts.
2. Slipping out of gear.	a. Gears partially engaged.	a. Correctly adjust shift linkage.
	b. Weakened poppet springs.	b. Replace springs.

vehicles and trucks usually have universal joints at both ends of the propeller shaft.

Universal joints are double-hinged with the pins of the hinges set at right angles. They are made in many different designs, but they all work on the same principle.

Normally, universal joints do not require any maintenance other than lubrication. Some universal joints (U-joints) have grease fittings and should be lubricated when the vehicle has a preventive maintenance inspection. Others may require disassembly and lubrication periodically. When lubricating U-joints that have grease fittings, use a low-pressure grease gun to avoid damaging seals.

TROUBLESHOOTING THE DIFFERENTIAL

The purpose of the differential is easy to understand when you compare a vehicle to a company marching in mass formation. When the company makes a turn, the members in the inside tile must take short steps, almost marking time, while members in the outside file must take long steps and walk a greater distance to make the turn. When a motor vehicle turns a corner, the wheels

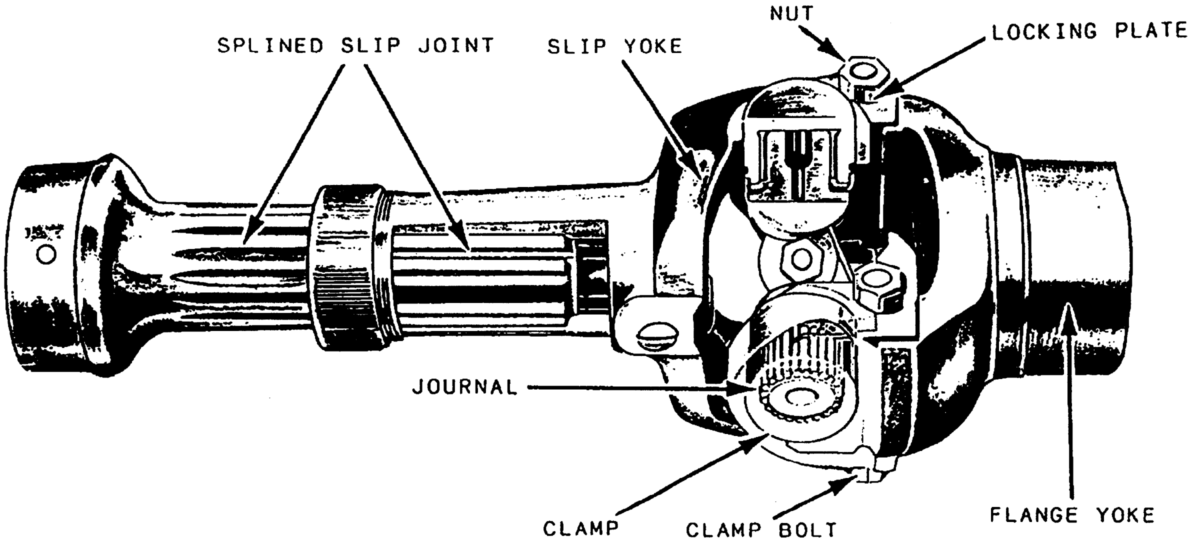


Figure 11-16.—An example of a splined slip joint and a common type of universal joint.

on the outside of the turn must rotate faster and travel a greater distance than the wheels on the inside. This causes no difficulty for the front wheels on the usual passenger car because each wheel rotates independently. However, for the rear wheels to be driven at different speeds, the differential is needed. It connects the individual axle shaft for each wheel to the bevel drive gear; therefore, each shaft can turn at a different speed and still be driven as a single unit. Refer to the illustration in figure 11-17 as you study the following discussion on differential operation.

The bevel drive pinion, connected to the propeller shaft, rotates the bevel drive gear and the differential case which is attached to it. Within the case, the differential pinions are free to turn on individual pivots called trunnions. Power is transmitted to the axle shafts through the differential pinions and the side gears. The axle shafts are splined to the side gears and keyed or bolted to the wheels.

When the resistance is equal on each rear wheel, the differential pinions, side gears, and axle shafts all rotate as ONE UNIT with the drive gear. In this case, there is no relative motion between the pinions and the side gears in the differential case; that is, the pinions do not turn on the trunnions, and their teeth will not move over the teeth of the side gears.

When the vehicle turns a corner, one wheel must turn faster than the other. The side gear driving the outside wheel will run faster than the side gear connected to the axle shaft of the inside wheel. To compensate for this difference in speed and to remain in mesh with the two side gears, the differential pinions must then turn on the trunnions. The average speed of the two side gears, axle shafts, or wheels is always equal to the speed of the bevel drive gear.

To overcome the situation where one spinning wheel might be undesirable, some trucks are provided with a DIFFERENTIAL LOCK. This is a simple dog clutch, controlled manual] y or automatically, which locks one axle shaft to the differential case and bevel drive gear. Although this device forms a rigid connection between the two axle shafts and makes both wheels rotate at the same speed, it is used very little. Too often, the driver forgets to disengage the lock after using it. There are, however, automatic devices for doing almost the same thing. One of these, which is used rather extensively today, is the high-traction differential. It consists of a set of differential pinions and side gears

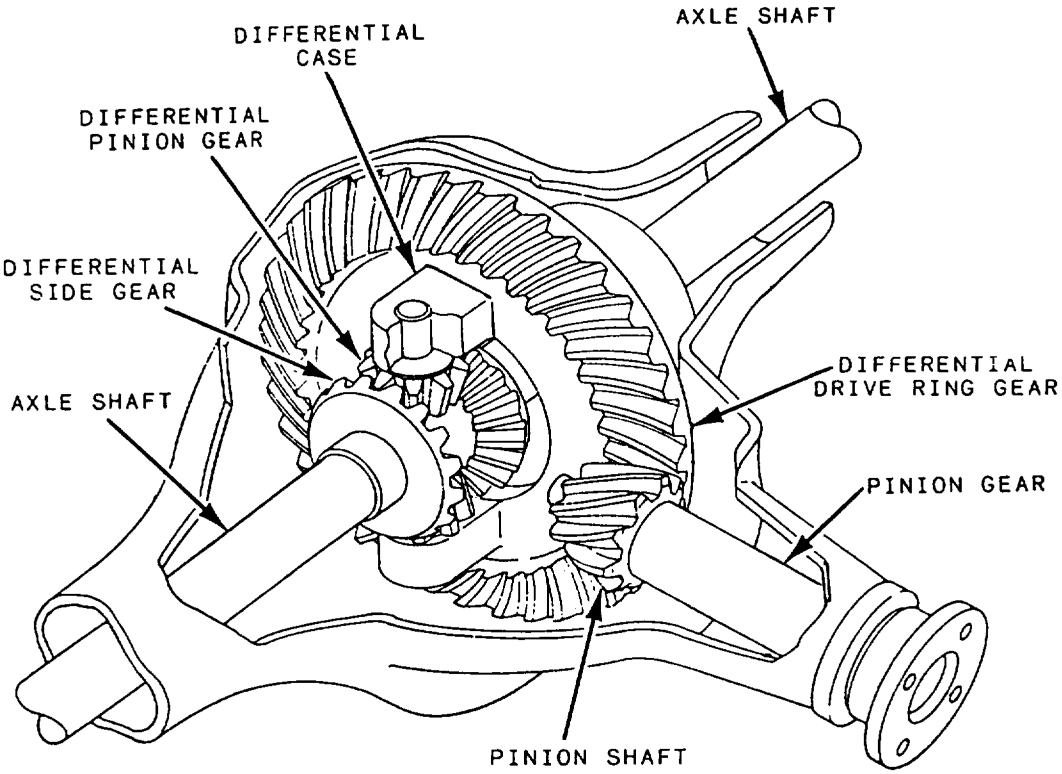


Figure 11-17.—Typical differential and axle assembly with ring and pinion.

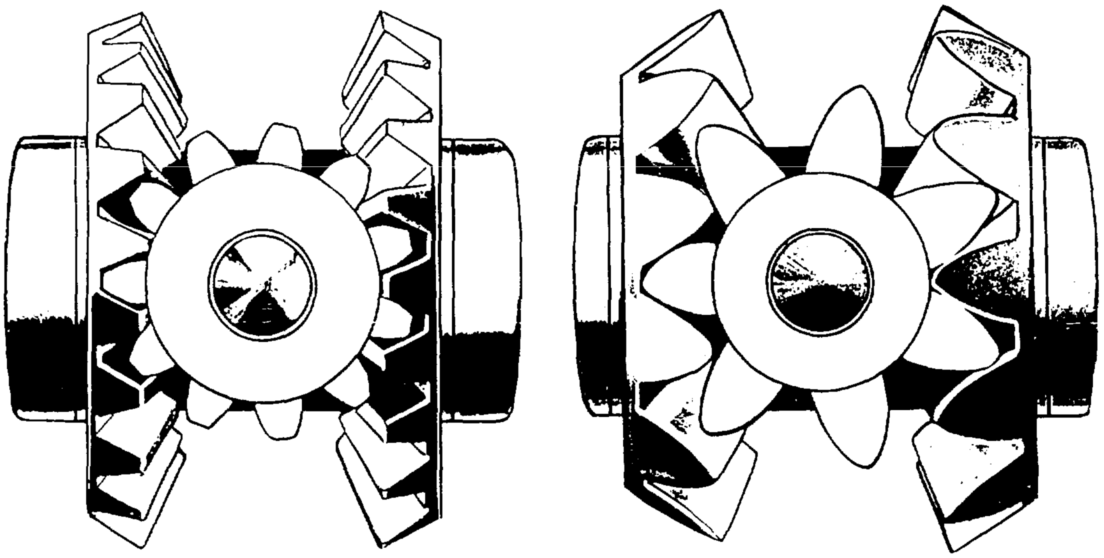


Figure 11-18.—Comparison of high-traction differential gears and standard differential gears.

that have fewer teeth and a different tooth form from the conventional gears. Figure 11-18 shows a comparison between these and standard gears. These differential pinions and side gears depend on a variable radius from the center of the differential pinion to the point where it comes in contact with the side gear teeth, which is, in effect, a variable lever arm. As long as there is relative motion between the pinions and side gears, the torque is unevenly divided between the two driving shafts and wheels; whereas, with the usual differential, the torque is evenly divided at all times. With the high-traction differential, the torque becomes greater on one wheel and less on the other as the pinions move around until both wheels start to rotate at the same speed. When this occurs, the relative motion between the pinion and side gears stops, and the torque on each wheel is again equal. This device assists considerably in starting the vehicle or keeping it rolling in cases where one wheel encounters a slippery spot and loses traction while the other wheel is on a firm spot and has traction. It will not work, however, when one wheel loses traction completely. In this respect, it is inferior to the differential lock.

With the non-spin differential (fig. 11- 19), one wheel cannot spin because of loss of tractive effort and thereby deprive the other wheel of driving effort; for

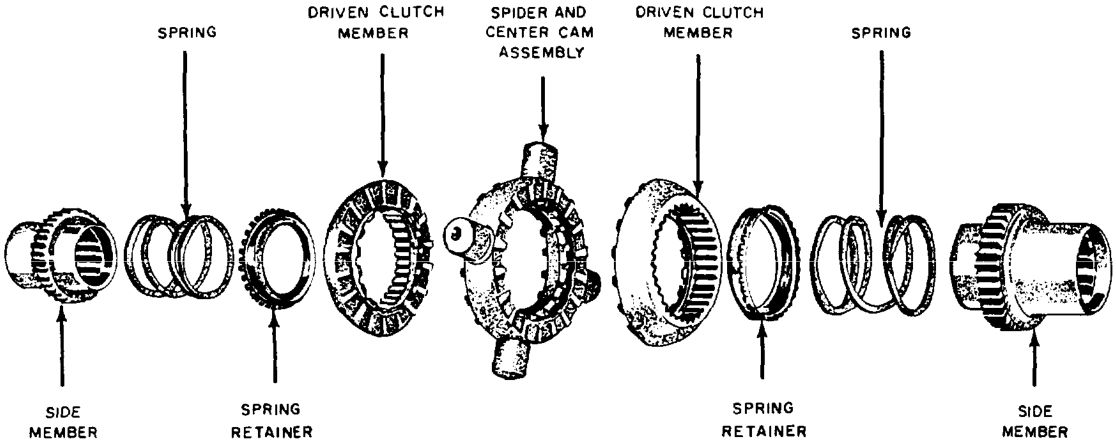


Figure 11-19.—No spin differential-exploded view.

example, one wheel is on ice and the other wheel is on dry pavement. The wheel on ice is assumed to have no traction. However, the wheel on dry pavement will pull to the limit of its tractional resistance at the pavement. The wheel on ice cannot spin because wheel speed is governed by the speed of the wheel applying tractive effort.

The no-spin differential does not contain pinion gears and side gears as the conventional differential does. Instead, it consists essentially of a spider attached to the differential drive ring gear through four trunnions, plus two-driven clutch members with side teeth that are indexed by spring pressure with side teeth in the spider. Two side members are splined to the wheel axles and, in turn, are splined into the driven clutch members.

The first hint of existing trouble in a differential is generally an unusual noise in the rear axle housing. However, to diagnose the trouble properly, you must determine the source of the noise and under what operating conditions the noise is most pronounced. Defective universal joints, rough rear wheel bearings, or tire noises may be improperly diagnosed by the inexperienced mechanic as differential trouble. Some clue may be gained as to the cause of trouble by your noting whether the noise is a growl, hum, or knock; whether it is hard when the car is operating on a straight road, or on turns only; and whether the noise is most noticeable when the engine is driving the vehicle or when it is coasting with the vehicle driving the engine.

A humming noise in the differential generally means the ring gear or pinion needs an adjustment. An improperly adjusted ring gear or pinion prevents normal tooth contact between the gears and, therefore, produces rapid gear tooth wear. If the trouble is not corrected immediately, the humming noise will gradually take on growling characteristics, and the ring gear and pinion will probably have to be replaced.

It is easy to mistake tire noise for differential noise. Tire noise will vary according to the type of pavement the vehicle is being driven on, and differential noise will not. To confirm a doubt as to whether the noise is caused by tire or differential, drive the vehicle over various types of pavement.

If a noise is present in the differential only when the vehicle is rounding a cornr, the trouble is likely to be in the differential case assembly.

AXLES, WHEELS, AND TRACKS

A live axle may support part of the weight of a vehicle and also drive the wheels connected to it. A dead axle carries part of the weight of a vehicle but does not drive the wheels. The wheels rotate on the ends of the dead axle.

Usually, the front axle of a passenger car is a dead axle, and the rear axle is a live axle. In four-wheel drive vehicles, both front and rear axles are live axles, and in six-wheel drive vehicles, all three axles are live axles. The third axle, part of a BOGIE DRIVE, is joined to the rearmost axle by a trunnion axle, as shown in figure 11-20. The trunnion axle is attached rigidly to the frame. Its purpose is to help in distributing the load on the rear of the vehicle to the two live axles which it connects.

There are three types of live axles used in automotive and construction equipment. The y are as follows: semifloating, three-quarter floating, and full-floating.

Semifloating Axles

The semifloating axle (fig. 11-21) used on most passenger cars and light trucks has its differential case independently supported. The differential carrier relieves the axle shafts from the weight of the differential assembly and the stresses caused by its operation. For this reason, the inner ends of the axle shafts are said to be floated. The wheels are keyed or bolted to outer ends of axle shafts, and the outer bearings are between the shafts and the housing. Therefore, the rude shafts, must take the stresses caused by turning or skidding of the wheels. The axle shaft in a semifloating live axle can be removed after the wheel and brake drum have been removed.

Three-Quarter Floating Axles

The axle shafts in a three-quarter floating axle (fig. 11-22) may be removed with the wheels that are keyed to the tapered outer ends of the shaft. The inner ends of the shafts are carried as in a semifloating axle. The axle housing, instead of the shafts, carries the weight of the vehicle because the wheels are supported by bearings on the outer ends of the housing. However, axle shafts must take the stresses caused by the turning, or skidding of the wheels. Three-quarter floating axles are used in some trucks but in very few passenger cars.

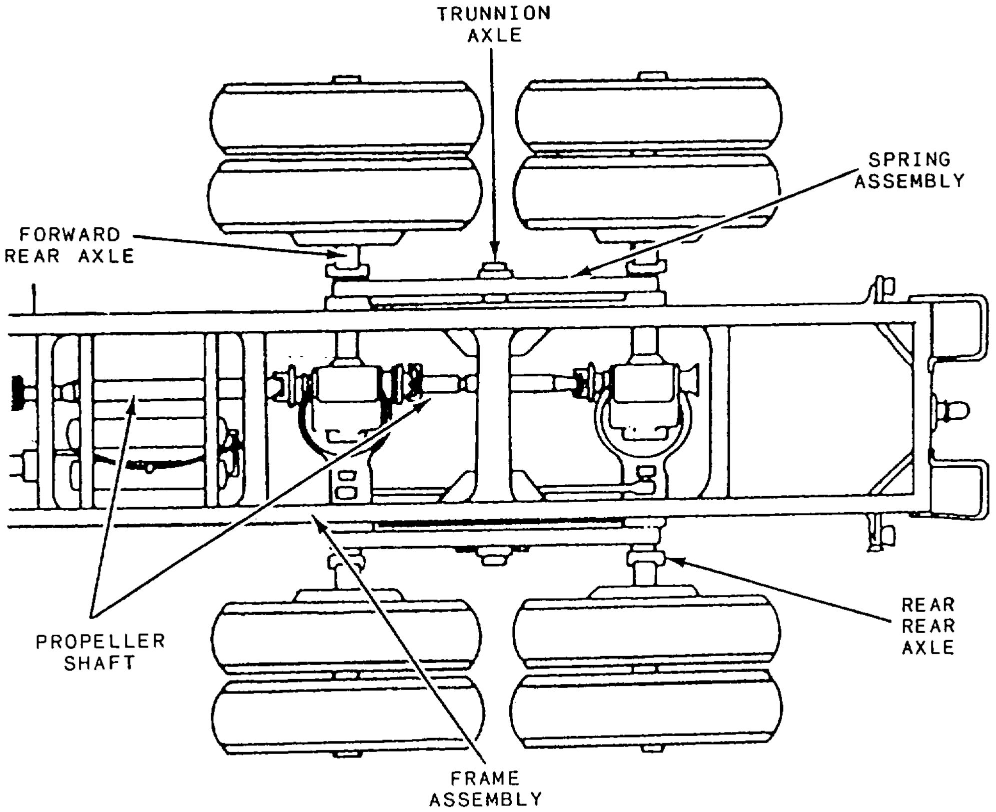


Figure 11-20.—Typical tandem axle system.

Full-Floating Axles

The full-floating axle is used in most heavy trucks. (See fig. 11-23.) These axle shafts may be removed and replaced without removing the wheels or disturbing the differential. Each wheel is carried on the end of the axle tube on two ball bearings or roller bearings, and the axle shafts are bolted to the wheel hub. The wheels are driven through a flange on the ends of the axle shaft which is bolted to the outside of the wheel hub. The bolted connection between the axle and wheel does not make

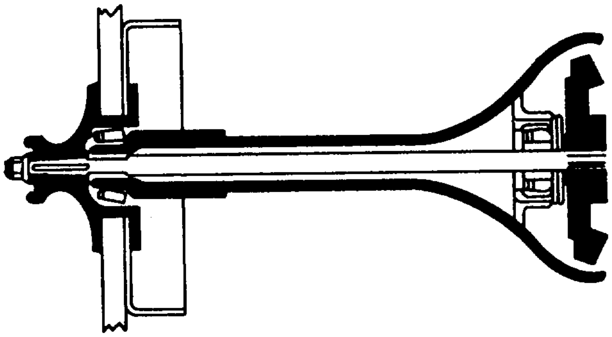


Figure 11-22.—Three-quarter floating rear axle.

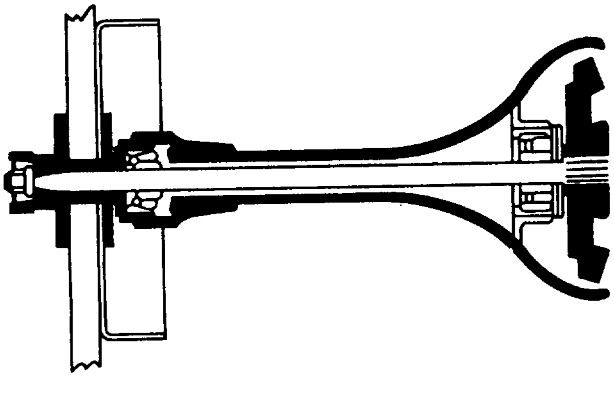


Figure 11-21.—Semifloating rear axle.

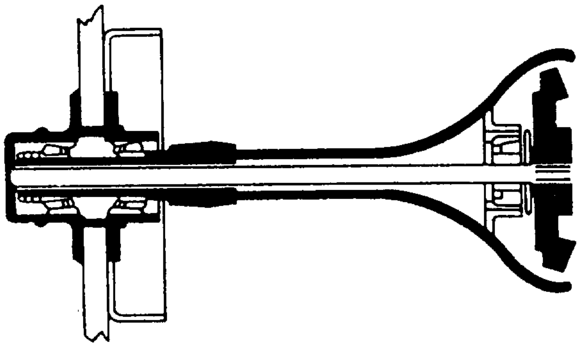


Figure 11-23.—Full-floating rear axle.

this assembly a true full-floating axle, but nevertheless, it is called a floating axle. A true full-floating axle transmits only turning effort or torque.

Driving Wheels

Wheels attached to live axles are the driving wheels. The number of wheels and number of driving wheels is sometimes used to identify equipment. You, as a mechanic, may identify a truck by the gasoline or diesel engine that provides the power. Then again, you may refer to it as a bogie drive.

Wheels attached to the outside of the driving wheels make up DUAL WHEELS. Dual wheels give additional traction to the driving wheels and distribute the weight of the vehicle over a greater area of road surface. They are considered as single wheels in describing vehicles; for example, a 4 x 2 could be a passenger car or a truck having four wheels with two of them driving. A 4 x 4 indicates a vehicle having four wheels with all four driving. In some cases, these vehicles will have dual wheels in the rear. You would describe such a vehicle as a 4 x 4 with dual wheels.

A 6 x 4 truck, although having dual wheels in the rear, is identified by six wheels, four of them driving. Actually, the truck has ten wheels but the four wheels attached to the driving wheels could be removed without changing the identity of the truck. If the front wheels of this truck were driven by a live axle, it would be called a 6 x 6.

The tracks on tracklaying vehicles are driven in much the same manner as wheels on wheeled vehicles. Sprockets instead of wheels are driven by live axles to move the tracks on the rollers. These vehicles are identified as either full-track, half-track or vehicles that can be converted.

Full-Track Vehicles

Full-track vehicles are entirely supported, driven, and steered by two tracks that replace all wheels.

SERVICE AND MAINTENANCE

There are very few adjustments to be made in power trains during normal operation. Most of your duties concerned with power trains will be limited to preventive maintenance. You will be working with the disassembly, repair, and reassembly of transmissions, rear axles, and propeller shaft assemblies when they break down. You will also inspect these units for indications of major repairs needed. Major repairs can be reduced by proper lubrication and periodic inspection of gear cases, propeller shafts, and wheel bearings.

Proper lubrication depends upon the use of the right kind of lubricant which must be put in the right places in the amount specified by the LUBRICATION CHARTS. The charts, provided with the vehicle, will also show what units in the power train will require lubrication, and where they are located. These units are similar to the ones described and illustrated in this chapter.

In checking the level of the lubricant in GEAR CASES and before you add oil, keep these two important points in mind: first, always carefully wipe the dirt away from around the inspection plugs and then use the proper size wrench to remove and tighten them. A wrench too large will round the corners and prevent proper tightening of the plug. For the same reason, never use a pipe wrench or a pair of pliers for removing plugs. Second, be sure the level of the lubricant is right-usually just below or on a level with the bottom of the inspection hole. Before checking the level, allow the vehicle to stand for a while on a level surface so the oil can cool and find its own level. Oil heated and churned by revolving gears expands and forms bubbles. Although too little oil in the gearboxes is responsible for many failures of the power train, do not add too much gear lubricant. Too much oil results in extra maintenance.

Excessive oil or grease can find its way past the oil seals or gear cases. It maybe forced out of a transmission into the clutch housing and result in a slipping clutch; or it may get by the rear wheel bearings from the differential housing to cause brakes to slip or grab. In either case, you will have extra work to do. Always clean differential and live axle housing vents to prevent pressure buildup (caused by heat), which can result in leaking seals.

UNIVERSAL JOINTS and SLIP JOINTS at the ends of propeller shafts are to be lubricated if fittings are provided. The same holds true for WHEEL BEARINGS. Some of these joints and bearings are packed with grease when assembled; others have grease fittings or small plugs with screwdriver slots that can be removed for inserting grease fittings. Do not remove these plugs until you consult the manual for instructions.

Some passenger cars and trucks have a leather boot or shoe covering the universal and slip joint. The boot prevents grease from being thrown from the joint and it also keeps dirt from mixing with the grease. A mixture of dirt and grease forms an abrasive that will wear parts in a hurry. Never use so much grease on these joints that the grease will be forced out of the boot. The extra grease will be lost and the added weight of the grease will tend to throw the propeller shaft out of balance.

When you are to give a vehicle a thorough inspection, inspect the power trains for loose gear housings and joints. Look for bent propeller shafts that are responsible for vibrations, and examine the gear housings and joints for missing screws and bolts. Check to see that the U-bolts fastening the springs to the rear axle housing are tight. A loose spring hanger can throw the rear axle assembly out of line and place additional strain on the propeller shaft and final drive. When making these inspections, always tighten the lugs that fasten wheels to live axles.

After tightening gear housings, loose connections, and joints, and finding that no repairs are required, road test the vehicle to see if the various units in the power train are working properly. Shift the gears into all operating speeds and listen for noisy or grinding gears.

CHAPTER 12

WHEEL AND TRACK ALIGNMENT

One of the most neglected areas in vehicle maintenance is front-end wheel alignment and track alignment. To assure the proper steering control and normal wear of tires and tracks, you must maintain proper alignment. As an inspector, floor supervisor, or shop supervisor, it will be your responsibility to identify, adjust, or supervise the corrective measures needed to keep your equipment in a safe, operating condition. This chapter covers the principles and adjustments of front-wheel alignment and the principles of track alignment.

STEERING GEOMETRY

"Front-end alignment" refers to the relationship between the wheels of the vehicle and its suspension and steering. These relationships are calculated using angles known as steering geometry. These angles are camber, caster, kingpin inclination, toe, turning radius, and tracking. The following paragraphs cover the definitions of these angles and their effects:

1. **CAMBER ANGLE.** As viewed from the front of the vehicle, the camber angle is the degree to which the wheel tilts inward or outward (fig. 12-1). It is measured in degrees and changes with the load of the vehicle and suspension movement. Positive camber is the outward tilt of the top of the wheel, and negative camber is the inward tilt. It is shown by a line drawn through the center of the wheel and a second line drawn straight up and down. They should intersect where the tire meets the road. Camber is a directional control angle and a tire wearing angle.

Originally, roads were built with high crowns; that is, they were high in the middle and sloped downward to the sides. A large amount of positive wheel camber was needed for the tire to contact the road squarely. If the tire does not set squarely on the road, it will wear on one side and will not get a good grip for positive steering control. Modern roads, however, are made flat with very little crown, so less camber is needed for this reason.

Even with flat roads, some camber is generally desirable, because it moves the point of contact between the tire and the road more directly under, and closer to, the steering knuckle pivot. This makes the wheels easier to pivot and reduces the amount of road shock sent to the vehicle suspension and steering linkage when the wheels hit bumps. It also places most of the load on the larger inner wheel bearing.

To avoid some bad effects, the amount of camber must be carefully considered when a vehicle is designed. If you have ever rolled a tire by hand, you soon learned that you did not have to turn the tire in order to turn a corner. All you had to do was tilt (camber) the tire to one side, and it rolled around the corner like a cone. This is not desirable for the wheels of a vehicle. The cone effect

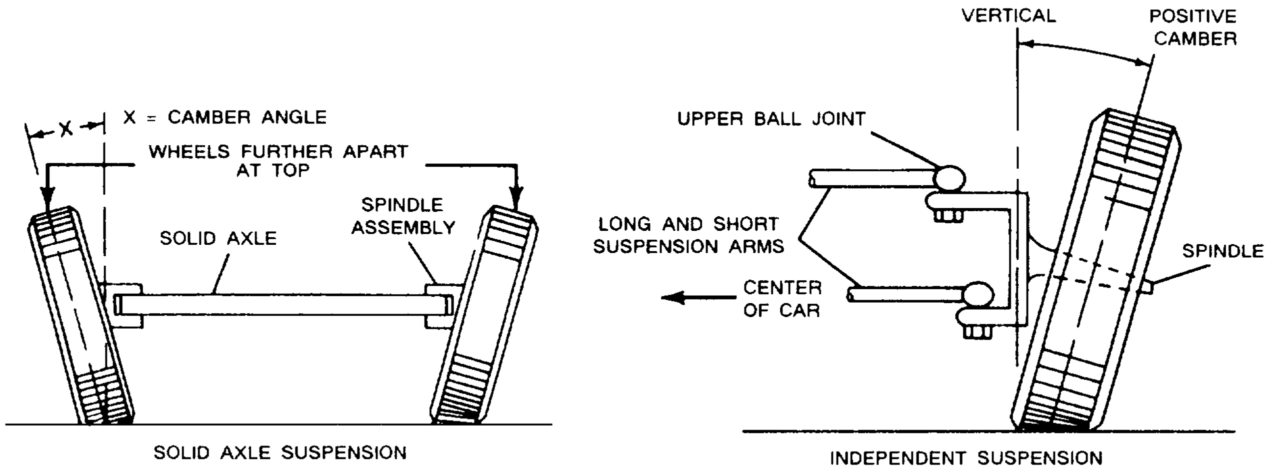


Figure 12-1.—Camber angle.

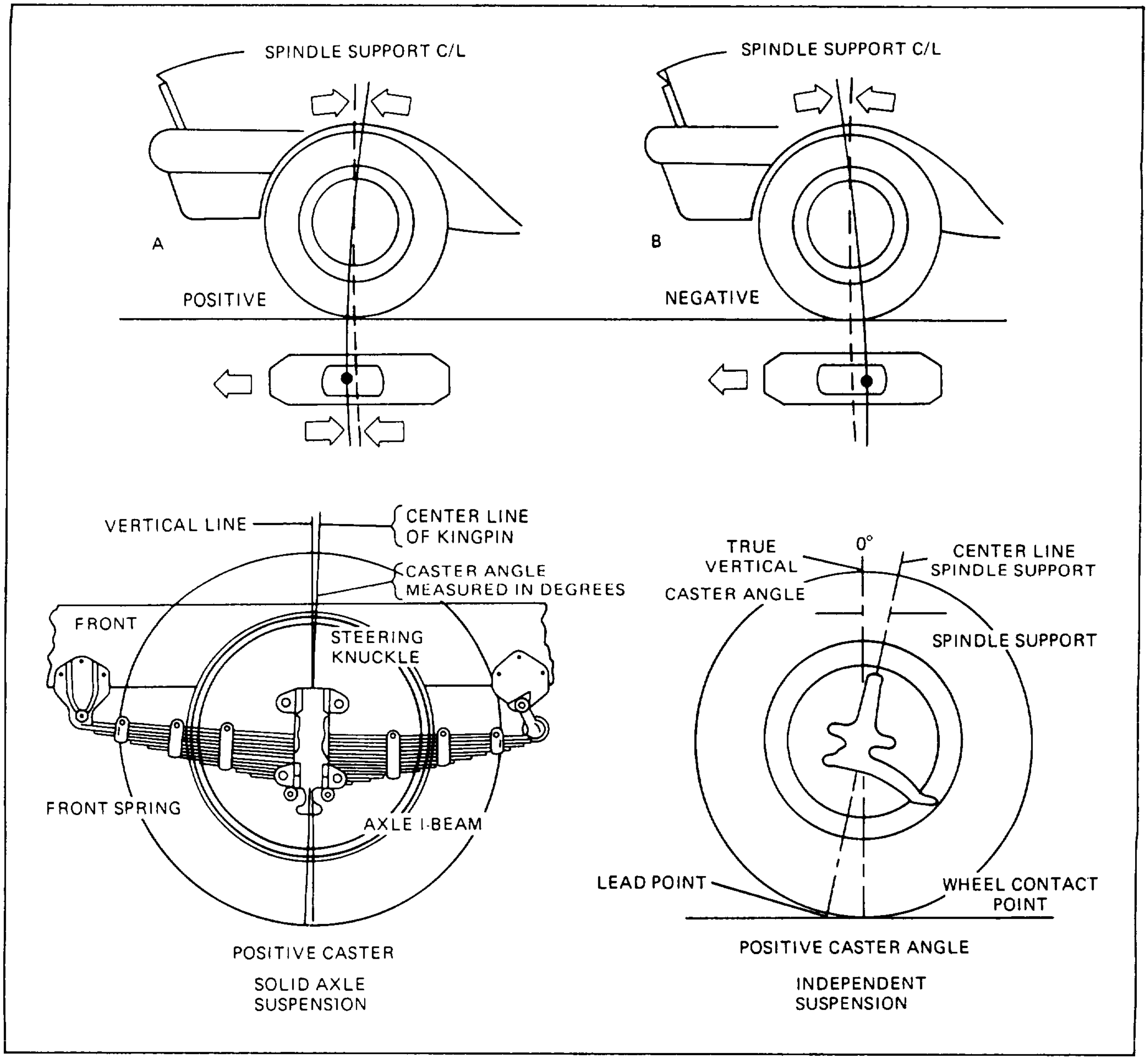


Figure 12-2.—Caster angle.

of excessive positive camber tries to pivot the wheels out on a vehicle.

2. **CASTER ANGLE.** When viewed from the side of the wheel, the caster angle is the degree to which the kingpin or ball joint tilts forward or rearward in relation to the frame (fig. 12-2). Like the camber angle, the caster angle is also measured in degrees. It is shown by a line drawn straight up and down, as in figure 12-2, and then a second line drawn through the center of the kingpin or pivot points. The caster angle is the angle formed at the point where the two lines cross, as viewed from the side of the vehicle.

A good example of caster is a bicycle. The fork is tilted backward at the top. A straight line drawn down through the front-wheel pivot or kingpin would strike the ground ahead of the point where the tire contacts the road. A wheel mounted in this fashion is said to have positive (+) caster or "just" caster. If the top of the kingpin is tilted forward so that a straight line drawn through it hits behind the point where the tire contacts the ground, the wheel is said to have negative (–) caster.

On a vehicle with axle suspension, caster is obtained by the axle being mounted so that the top of the steering knuckle or kingpin is tilted to the rear. On a vehicle with

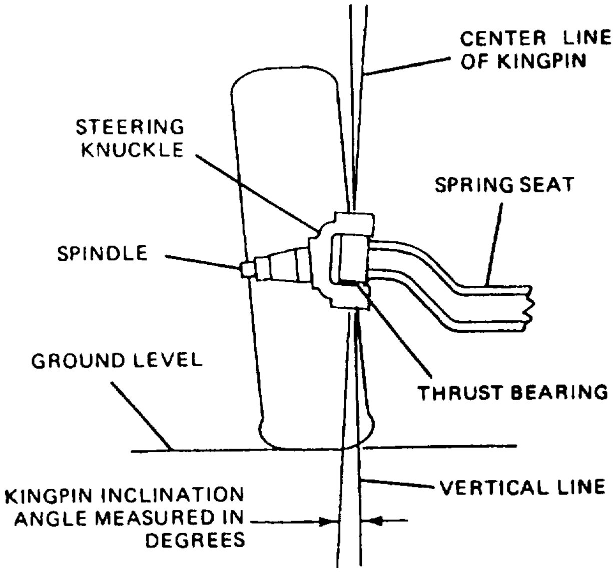


Figure 12-3.—Kingpin inclination.

independent suspension, the upper pivot point (ball joint) is set to the rear of the lower pivot point.

Caster is a directional control angle, but not a tire wearing angle. Positive caster causes the vehicle to steer in the direction in which it is moving. This is called an automatic steering effect; for instance, the forward momentum of a vehicle tends to keep wheels with positive caster in the straight-ahead position. After rounding a turn, this causes the wheels to return to a straight-ahead position when the driver releases the steering wheel. This automatic steering effect is also called self-righting or self-centering action.

Positive caster makes the turning of the steering wheel more difficult, whereas negative caster turns more easily, but will cause the vehicle to wander.

3. **KINGPIN INCLINATION.** The inward tilt of the kingpin at the top is known as kingpin inclination (KPI). KPI (fig. 12-3) is measured in degrees from the center line of the ball joint or kingpin to true vertical (0). It is a directional control angle with fixed relationship to camber settings. It is also nonadjustable. One purpose of this inclination is to reduce the need for excessive camber. Figure 12-4 shows a dead axle with fixed KPI. The angle of the kingpin and spindle is made extreme to clarify the principles involved.

Timing the wheels to the left or right revolves the spindles around the kingpin. As the spindle is moved to the left or right from the position shown in figure 12-4, B, its end moves down, as shown in figure 12-4, A and C. Thus, as the front wheels turn, the spindle will attempt to move down from the high point. Since the wheels and tires prevent the spindles from moving down, the axle is raised. This action tends to raise the front of the vehicle. As the turning force is removed from the wheels, the weight of the vehicle helps force the wheels back to the straight-ahead position.

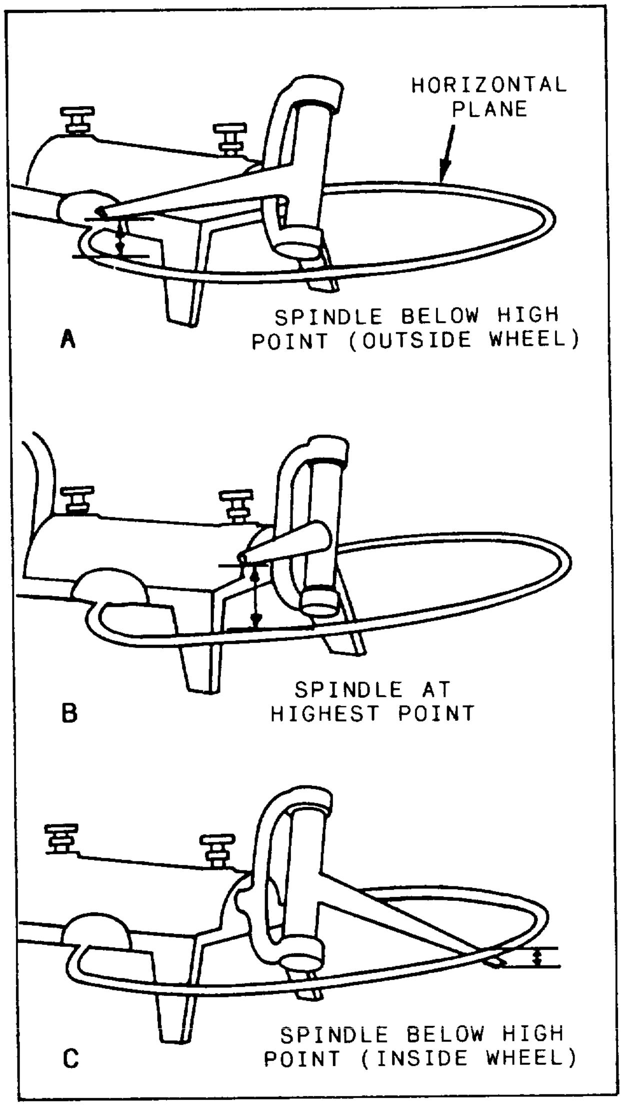


Figure 12-4.—Fixed KPI.

Vehicles with ball-joint suspension have what is known as steering axis inclination (SAI) which is defined as the inward tilt of the spindle support arm at the top. The spindle assembly is supported at the upper and lower control arms by ball joints. The pivoting axis of the wheel around the ball joints is the same as the kingpin axis of vehicles with dead axles.

4. **TOE-IN.** This is the distance between the front of the front wheels as compared to the distance at the

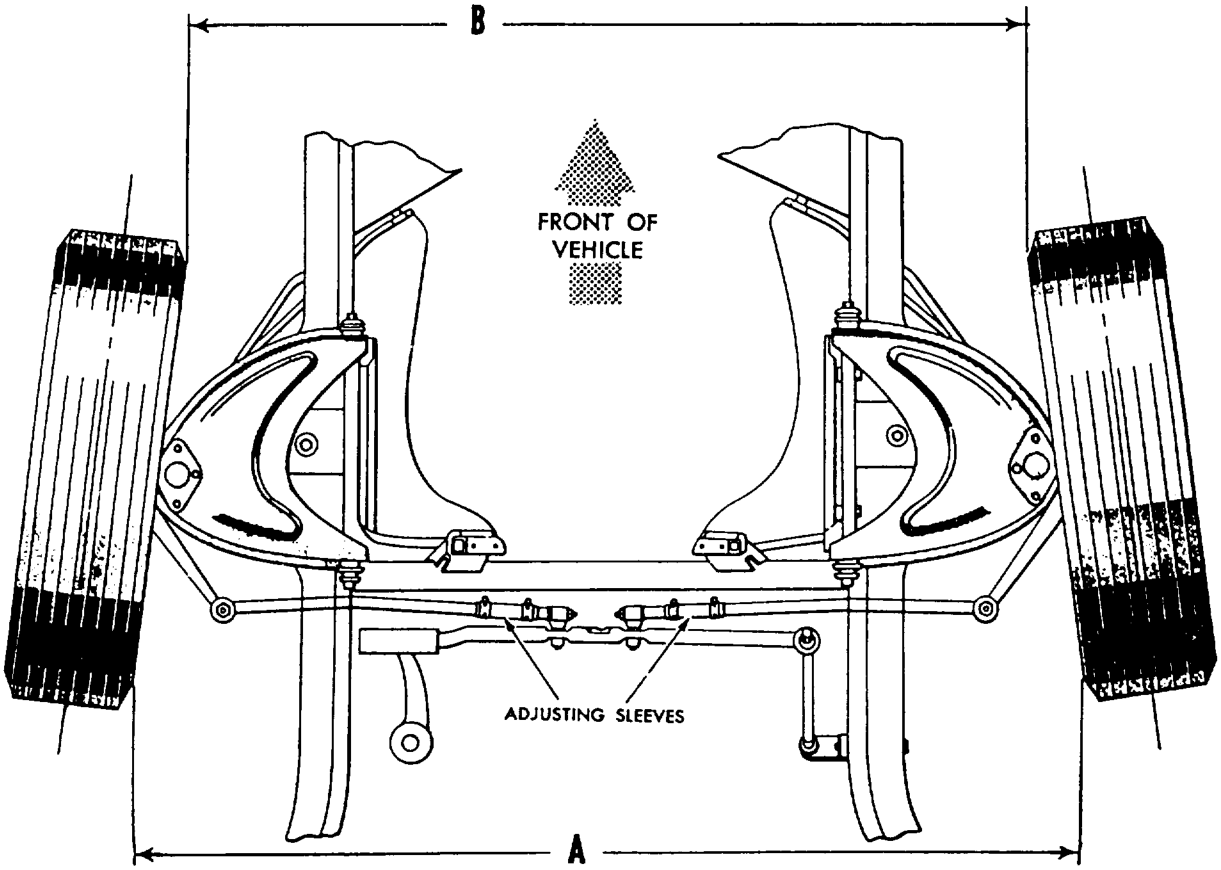


Figure 12-5.—Toe-in.

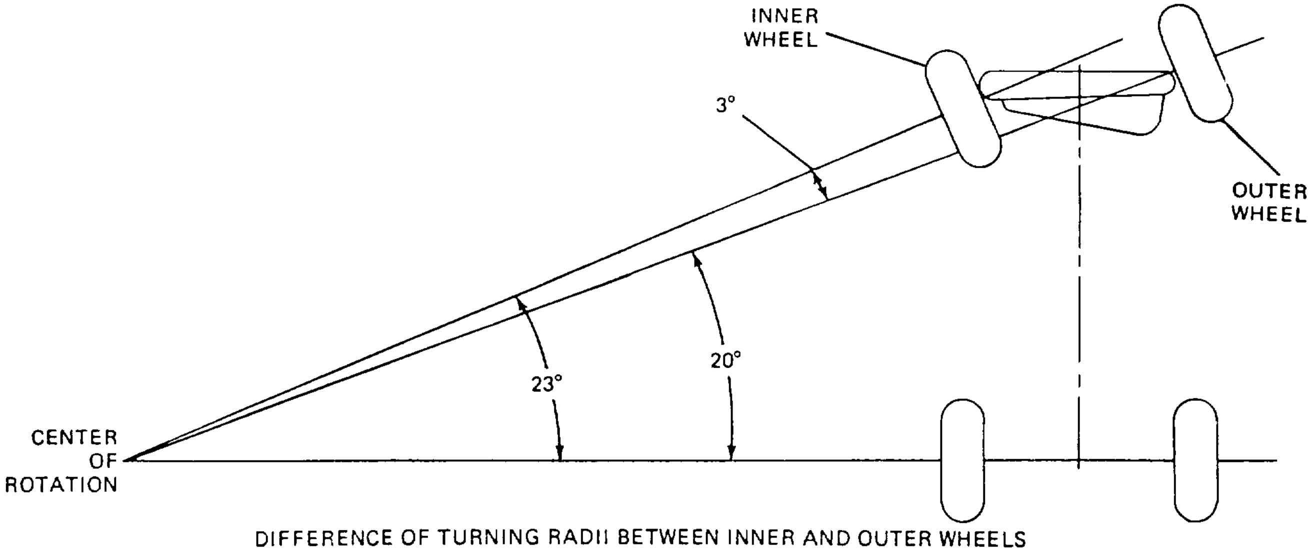


Figure 12-6.—Difference of radii between inner and outer wheels.

rear of the front wheels, as shown in figure 12-5. Note that line B is shorter than line A. The setting is taken at spindle height with the wheels in the straight-ahead position. Toe-in is measured in fractions of an inch. It is a tire wearing angle. The purpose of toe is to compensate for the normal looseness required in the steering linkage and to balance the effect of camber on the tires. The natural tendency of the wheel is to rotate like a cone around the point. If both front wheels are forced to follow a straight path by the motion of the vehicle, there is a continual tendency for the tires to slip away from each other. Toed-in wheels tend to travel toward each other and counteract this condition. By properly relating camber and toe-in, tire wear is reduced to a minimum. The motion of the wheel is balanced between two opposing forces, and pull on the steering mechanism is reduced.

Of all the alignment factors, toe-in is the most critical. A bent tie rod will change the amount of toe. Toe-in is adjusted last by your turning the tie rod sleeves.

5. **TURNING RADIUS.** The front-end assembly of the modern motor vehicle requires careful design and adjustment because each front wheel is pivoted separately on a steering knuckle. Because of this construction, the front wheels are not in the same radius line (drawn from the center of rotation [fig. 12-6]) when a vehicle is making a turn. Because each wheel should beat right angles to its radius line, it is necessary for the front wheels to assume a toed-out position when rounding curves. If they do not, the tires slip, which causes excessive tire wear. The inner wheel (the one closer to the center of rotation) turns more than the outer wheel, so it will travel in a smaller radius. This difference in the turning ratios of the two wheels is called toe-out. It is usually specified as the number of degrees over 20 that the inner wheel is turned when the outer wheel is turned 20 degrees. The-out on turns may be checked, but there is no provision made for its adjustment. The steering linkage must be examined carefully for bent or defective parts if this angle is not within the manufacturer's specifications.

6. **TRACKING.** Tracking (fig. 12-7) is the ability of the vehicle to maintain a right angle between the center line of the vehicle and both the front and rear axles or spindles. (The rear wheels should follow the front wheels.) If this angle is off, the vehicle will appear to be going sideways down a straight road. This problem could be caused by shifted or broken leaf springs or a bent or broken rear axle mount, bent frame, bent steering linkage, or misadjusted front-end alignment.

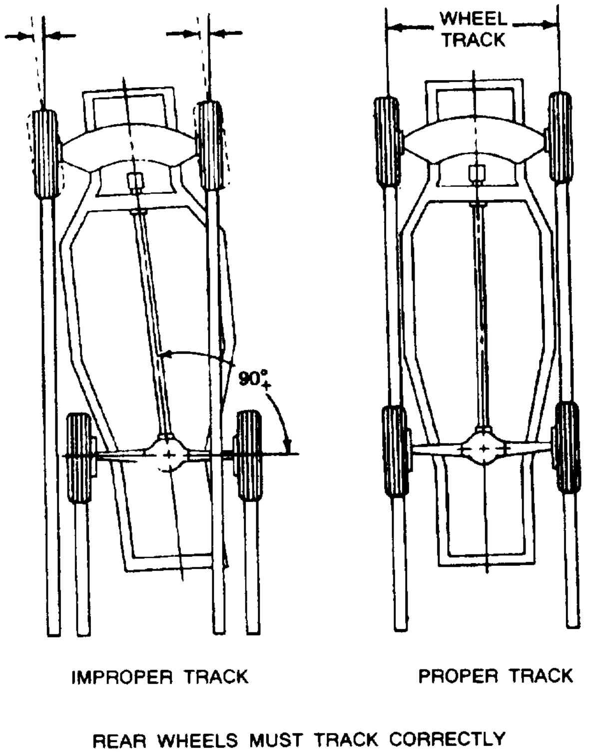


Figure 12-7.—Rear wheels must track correctly.

ADJUSTING WHEEL ALIGNMENT

In the preceding paragraphs, we covered the principles of the different angles involved in front-end alignment. In the following paragraphs, we will cover safety, tools, and alignment procedures.

SAFETY PRECAUTIONS

You should keep the following precautions in mind when you are working under a vehicle:

1. While repairing or adjusting the steering system and the wheel alignment, be sure the vehicle is and will remain stationary. At least one wheel should be blocked on both sides, even if the equipment is on a level surface.

2. Make yourself familiar with a suspension system before you work on it; know the “jack” points. You need to know which components bear the weight of the vehicle.

3. Make use of jack stands!

4. When using alignment equipment, follow the manufacturer's instructions.

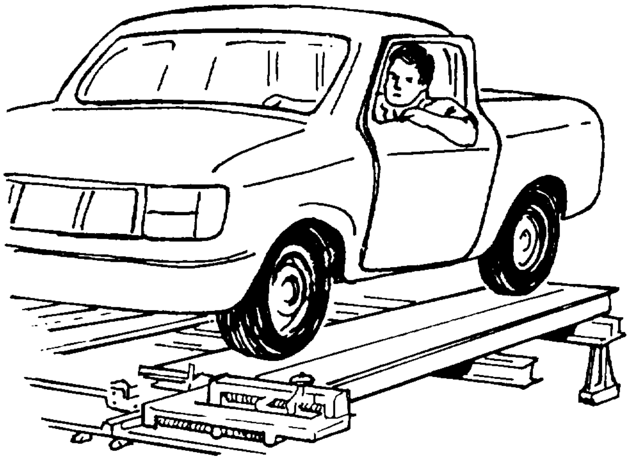


Figure 12-8.—Wheel alignment rack.

TOOLS FOR FRONT-END ALIGNMENT

To measure alignment angles, you will need special equipment, A wheel alignment rack (fig. 12-8) would be ideal. It positions a vehicle so that you can take measurements accurately and easily. However, it is doubtful that you will find such a setup in the battalions. You most likely will find the magnetic caster-camber gauge (fig. 12-9), a set of turntables (fig. 12-10), and a toe-measuring gauge (fig. 12-1 1). These three tools are the essentials. There are a large variety of tools on the market to aid you in making the actual caster, camber, and toe adjustments. Some are necessary; others can be substituted from your kit 13.

ALIGNMENT PROCEDURES

Check suspension and steering systems before making any of the following alignment adjustments:

1. Inspect the tires for correct size and inflate them to correct the air pressure. If the front tires are worn from misalignment, rotate or replace them. A tire worn on one side or the other will tend to pull to the worn side, even after the vehicle has been correctly aligned.

2. Inspect the wheel bearings, and correct excessive end play before making any other inspections or adjustments.

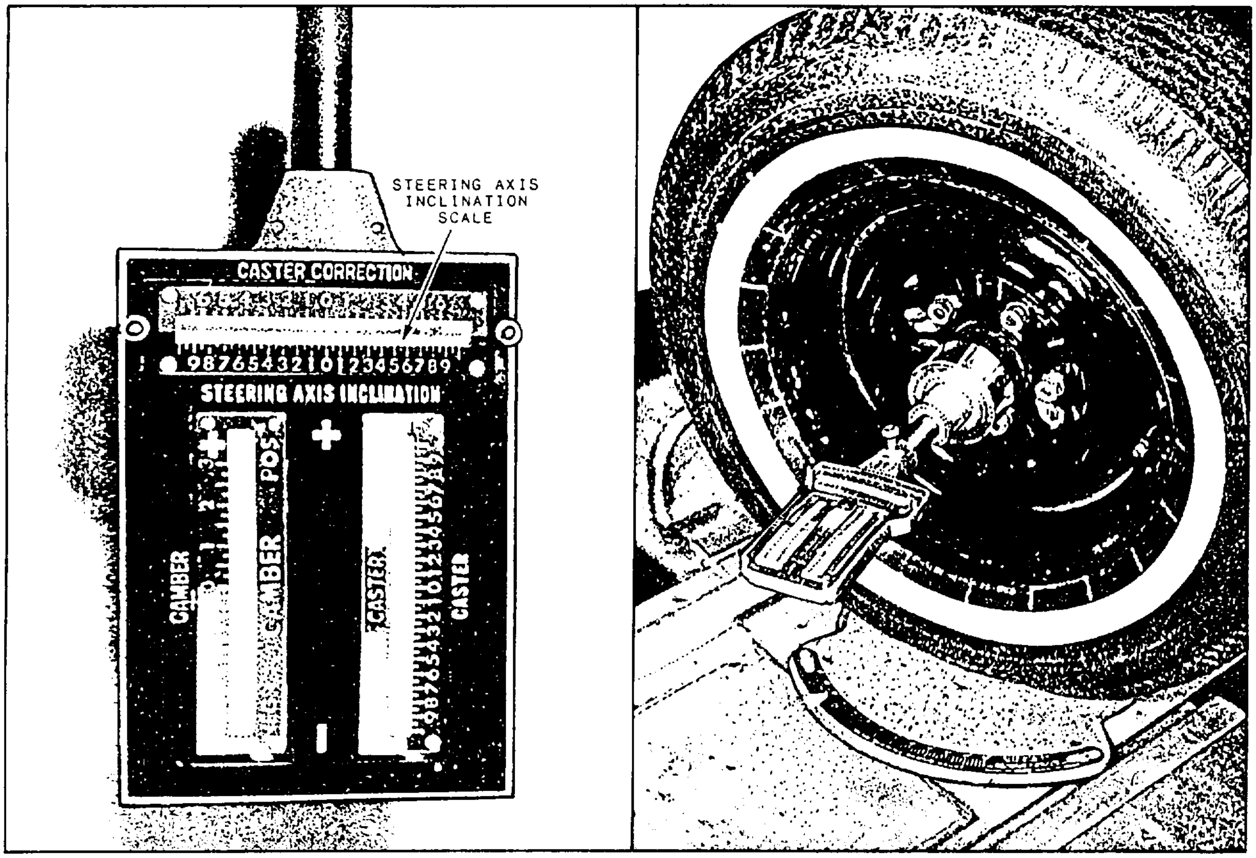


Figure 12-9.—Magnetic caster, camber gauge.

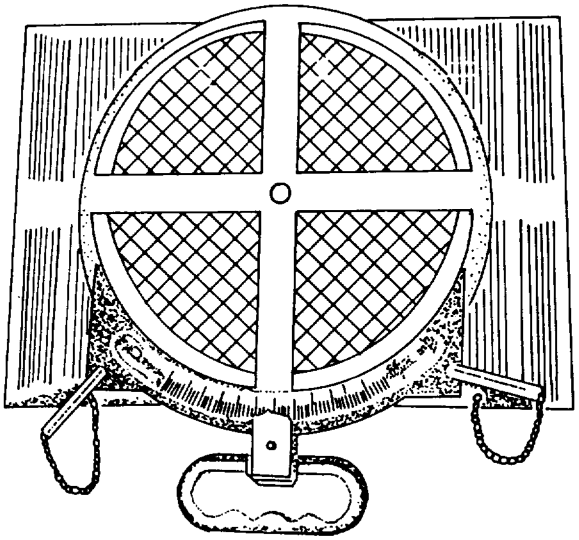


Figure 12-10.—Portable turntable.

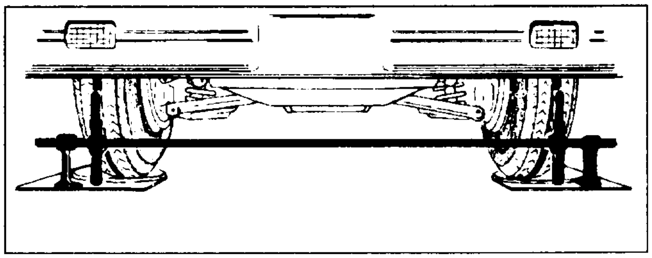


Figure 12-11.—Mechanical toe-measuring gauge.

3. Grasp the idler arm and try to work it up and down; then try to spread the tires apart while watching the steering linkage, (fig. 12-1 2). In either case, you should not see excessive movement. Inspect the tie rod ends for uncontrolled movement.

4. Check the upper and lower control arm bushing for wear or looseness. Either defect will contribute to improper alignment. Repair as needed.

5. Inspect the upper and lower ball joints. You are checking the axial and radial play. Make sure either does not exceed the manufacturer's specifications. Inspect one wheel at a time in the following manner: (A) If the lower ball joint carries the load (spring rides on the lower control arm) (fig. 12-13, A), place the jack under the lower control arm. If the upper ball joint carries the load (spring mounted on top of the upper control arm) (fig. 12-13, B), put the jack under the vehicle frame. (B) Using a pry bar under the tire, work it up and down while watching for movement at the ball joints. This is axial play. (C) While holding the wheel at the top and bottom, push in at the top and pullout on the bottom; then reverse the procedure. You are checking for radial play. Some ball joints have wear indicators. The nipple that the grease fitting is threaded into sticks out of the ball joint

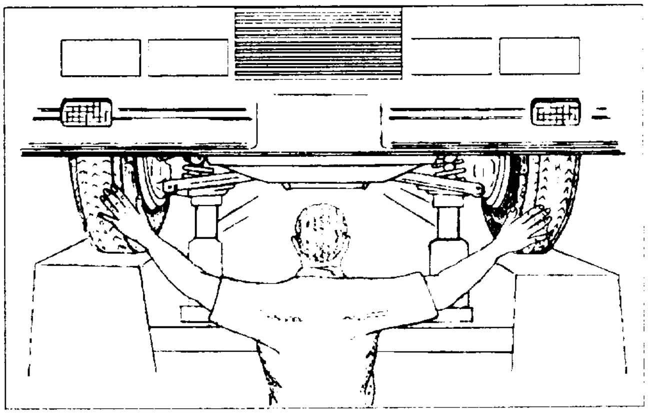


Figure 12-12.—Checking the steering linkage.

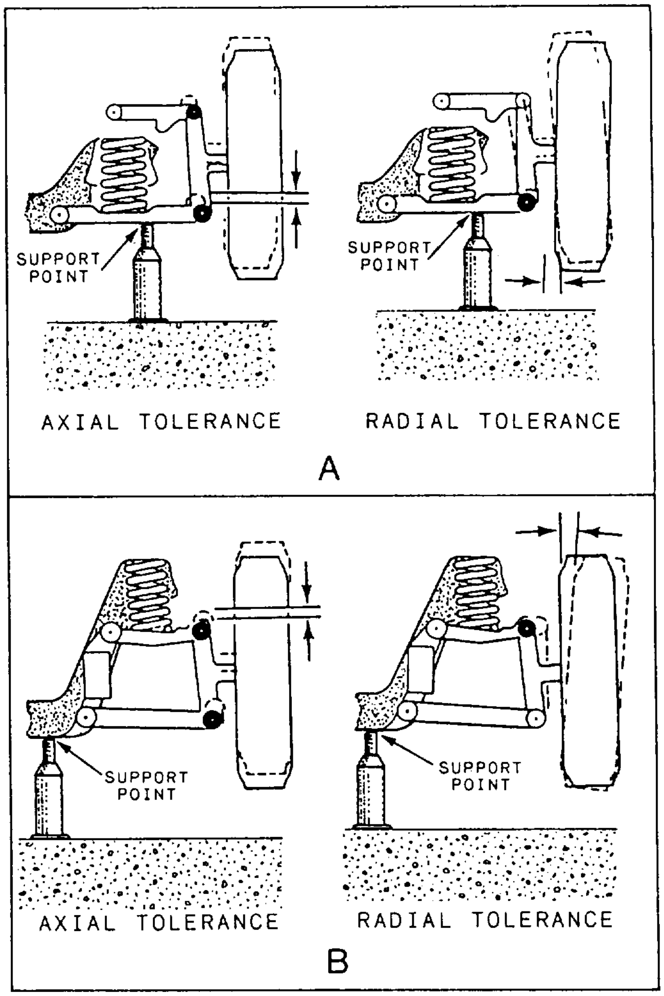


Figure 12-13.—Checking ball joints for wear.

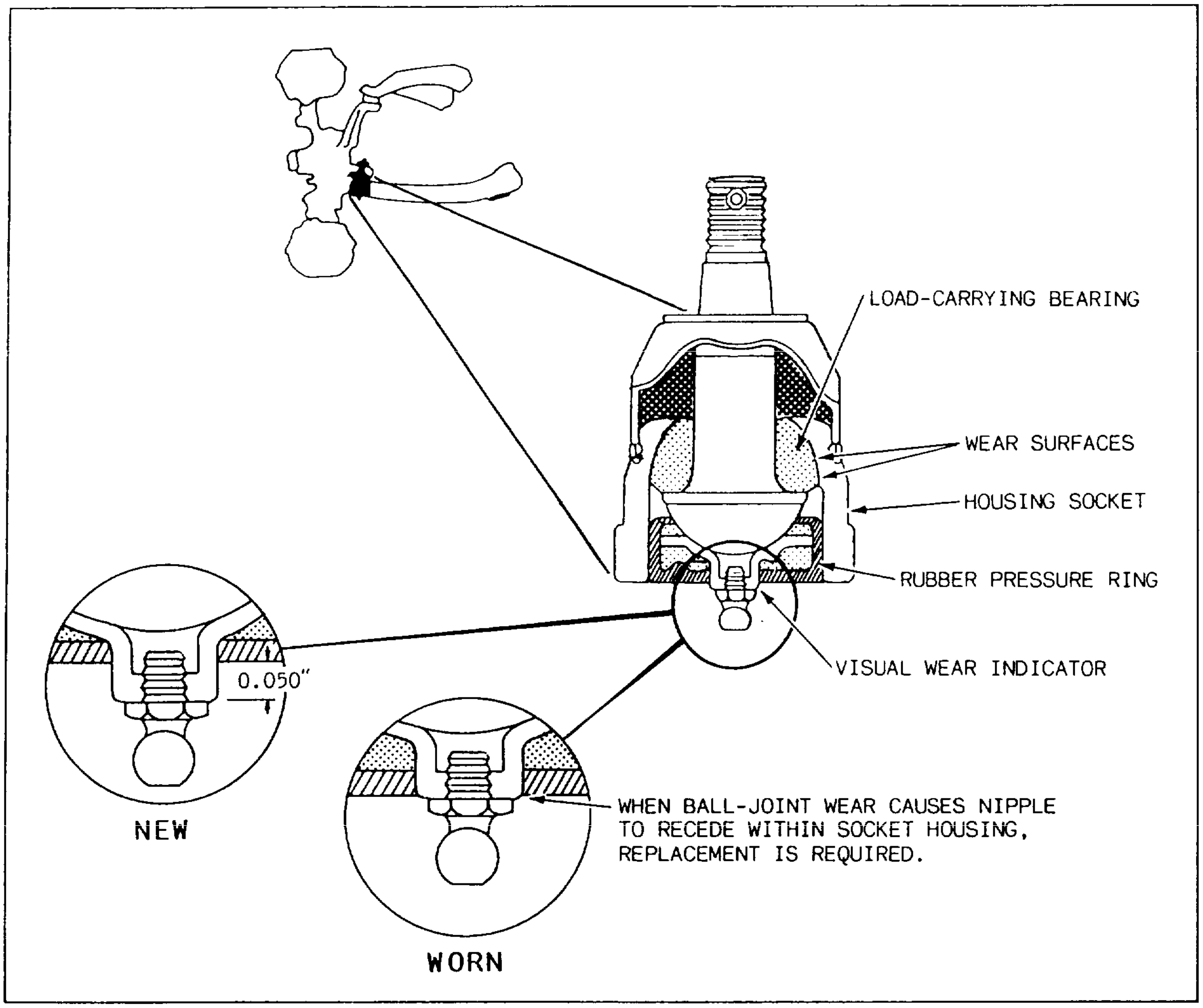


Figure 12-14.—Ball joint wear indication.

one-sixteenth inch (fig. 12-14). As the ballpoint wears, the nipple will move up into the balljoint housing. When the nipple is flush with the housing,replace the ball joint.

6. Check the shock absorber action and front springs for sagging or breakage.

7. Check the vehicle height. If the vehicle uses torsion bars vice coil springs, adjust the height by turning the adjusting bolt (fig. 12-15).

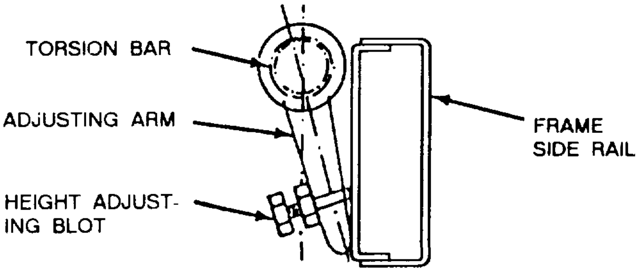


Figure 12-15.—Torsion bar adjusting bolt.

8. Inspect the steering wheel for excessive play and rough travel. The sector shaft (cross shaft) may require adjustment, which often cures steering looseness.

9. Vehicles should be aligned at curb height and weight. This means the vehicle should have no passengers, a full tank of fuel, and the proper amounts of coolant and lubricants. The spare tire and jack must be in the proper location.

ADJUSTABLE SUSPENSION ANGLES

Procedures for front-end alignment vary considerably with each make and model of vehicle. However, the basic principles do not change. Camber refers to the same angle in a Jeep as it does in a 15-ton stake truck Figure 12-16 shows some of the various adjustments for different model vehicles. Manufacturers have designed different ways of controlling front-end alignment adjustments. They are all a variation of one of the following:

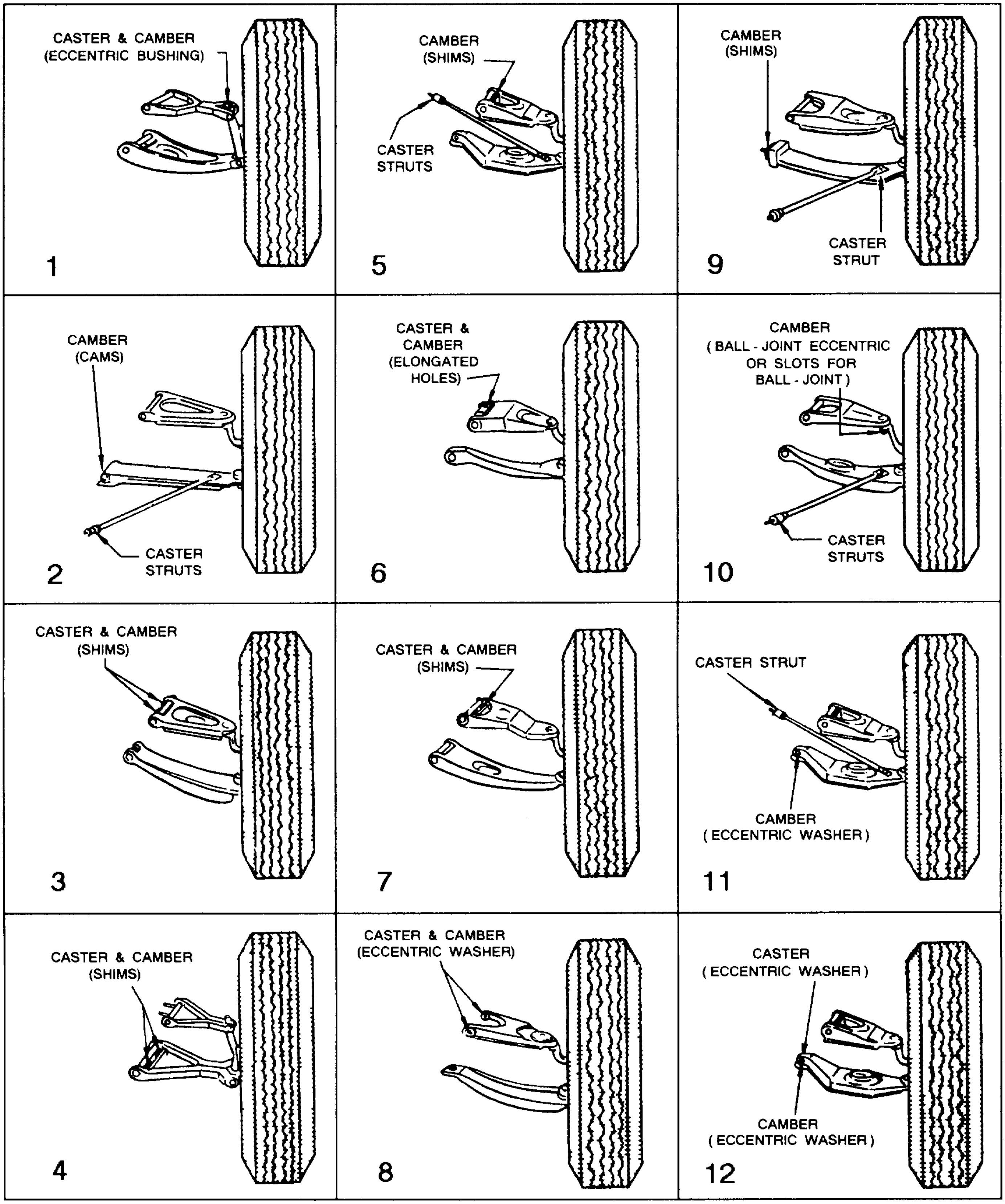


Figure 12-16.—Various locations of caster-camber adjustment points.

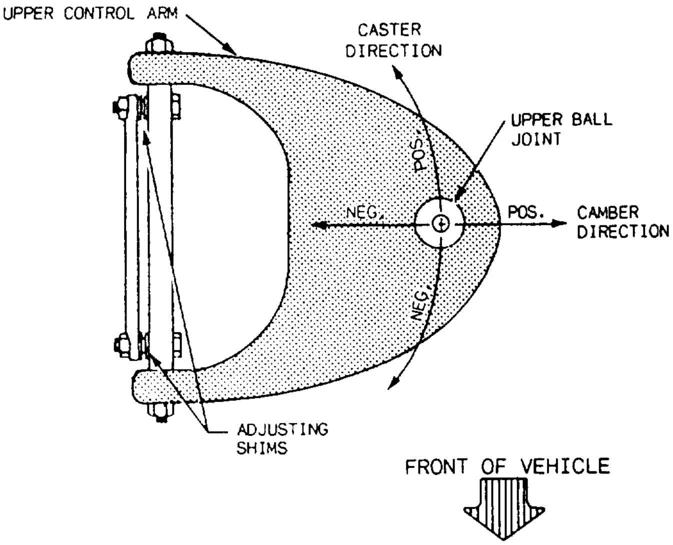


Figure 12-17.—Positive and negative directional movement of upper control arm.

1. Shims of various thickness at upper or lower control arm.

2. Eccentrics at upper or lower control arm and some use a strut rod for caster adjustment.

3. Elongated holes in the upper control arm or frame. The holes are serrated in the control arm and frame for a lock-tight fit.

Because all alignment angles are inter-related, one affecting the other, it is suggested you make your adjustments in the following order first-adjust caster, second-camber, third-center the steering wheel and adjust the tie rods so the wheels are straight ahead, and fourth-adjust toe-in.

Because of the variations in the different way each manufacturer designs a vehicle, you are advised to check the service manuals for specific adjustment locations and procedures.

CASTER/CAMBER ADJUSTMENTS

Regardless of the method or location of the adjustment, you should always consider the positioning of the upper control arm (specifically the ball joint) in relation to the lower. Whenever an adjustment is necessary, you must first consider in which direction you should move the upper control arm.

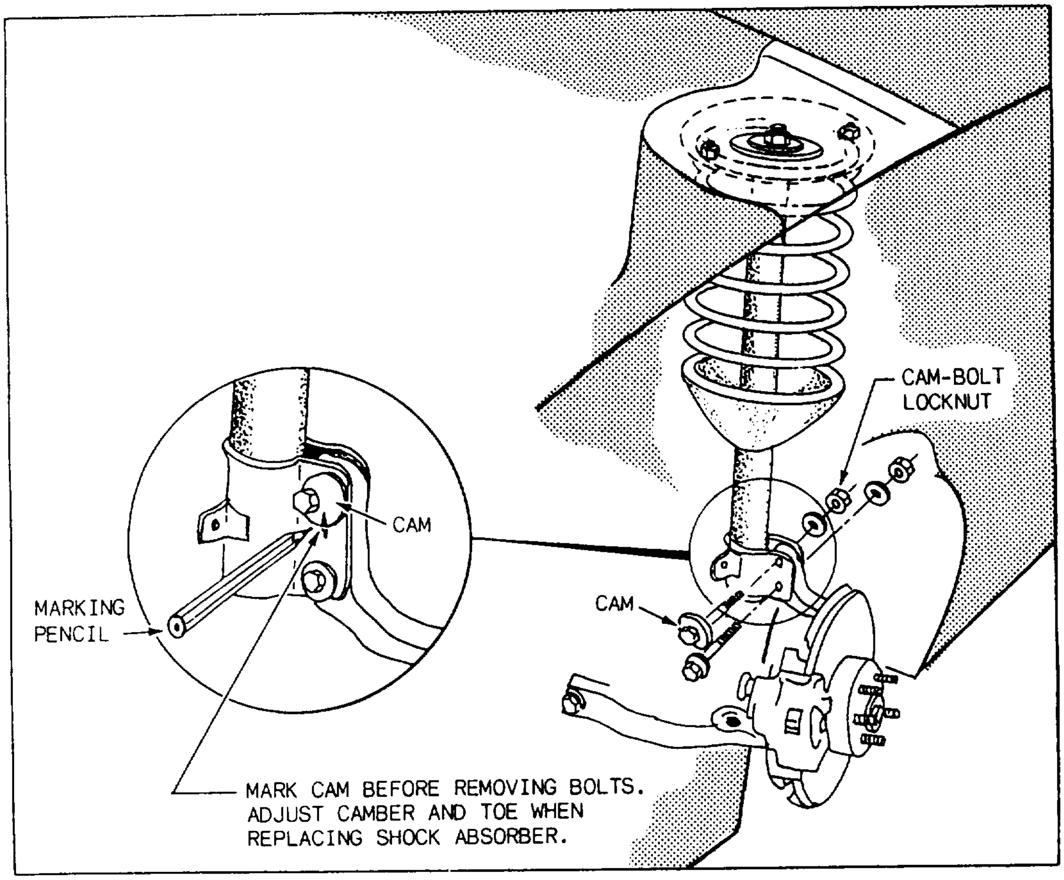


Figure 12-18.—MacPherson strut.

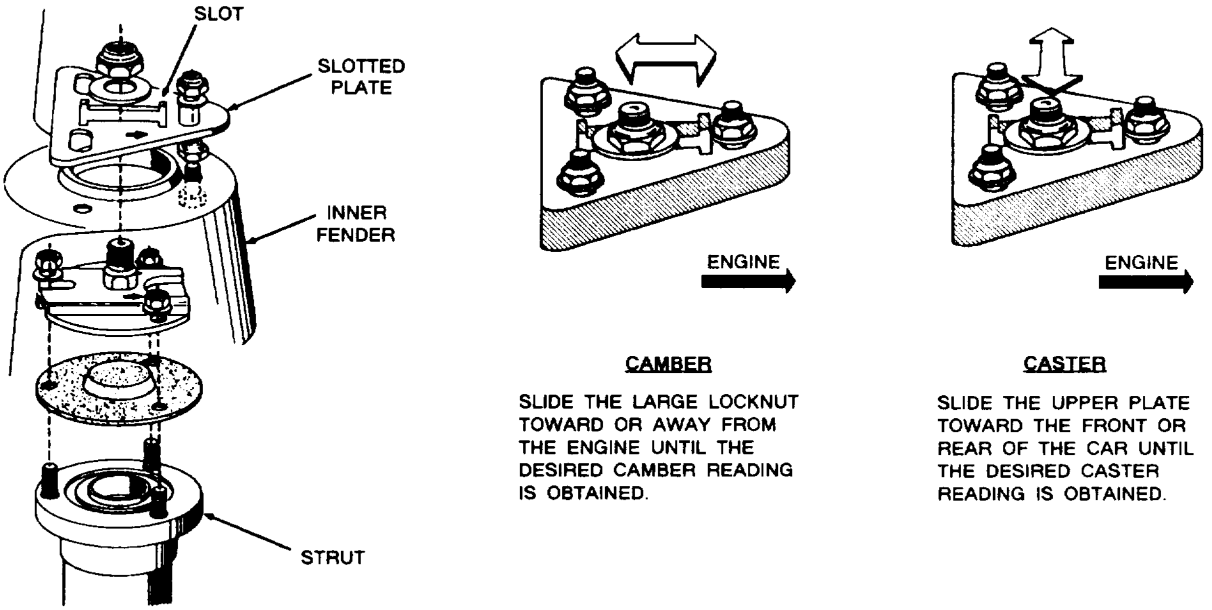


Figure 12-19.—Caster/camber adjustment kit for McPherson strut.

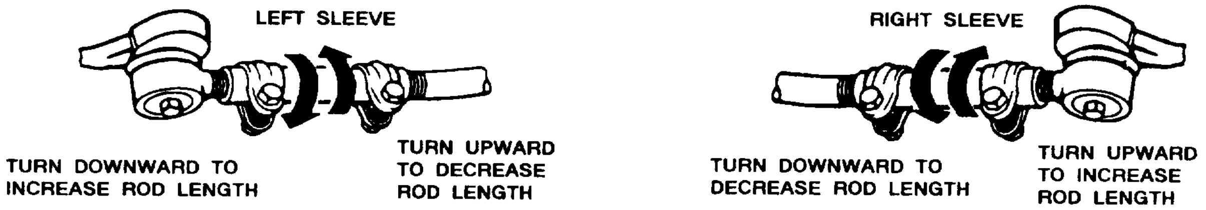


Figure 12-20.—Adjustments for toe-in and steering wheel alignment.

For example, if we move the upper ball joint to the rear of the vehicle, caster is changed in a positive direction (fig. 12-17). When you move the upper ball joint to the front of the vehicle, you change it in a negative direction.

It is the same when adjusting camber; you are still thinking of the top ball joint. Referring to figure 12-17, you see that by moving the top ball joint out, away from the vehicle, you change camber in a positive direction. Move it in, and you move it in a negative direction. Of course, when you move the ball joint, you are actually moving the entire upper control arm.

On vehicles with MacPherson-struts, (fig. 12-18), even though you are not dealing with upper and lower control arms, the principle is still the same. Some vehicles, from the manufacturer, do not provide a means for caster or camber adjustment. However, there is a kit (fig. 12- 19) available for those vehicles. Once the kit is installed, you will be able to make both adjustments. On other vehicles there is an adjustment for camber at the lower end of the strut, as shown in figure 12-18. You loosen the cam bolt locknut and route the cam bolt left or right. This moves the wheel in or out. Be sure to mark the location of all bolts when replacing these struts.

TOE-IN AND STEERING WHEEL ADJUSTMENT

After you have adjusted caster and camber, you should now adjust toe-in. It is the last angle to be adjusted, because caster and camber are so closely related. The adjustment of either will affect toe-in. It is adjusted in the same way on all vehicles-by turning the sleeves on the tie rod ends (fig. 12-20). This shortens or lengthens the steering linkage connecting the wheels.

Before you take the toe reading, it is important for you to make sure the front wheels are straight and the steering wheel is centered. You must center the steering wheel so that the steering gear is positioned on the high

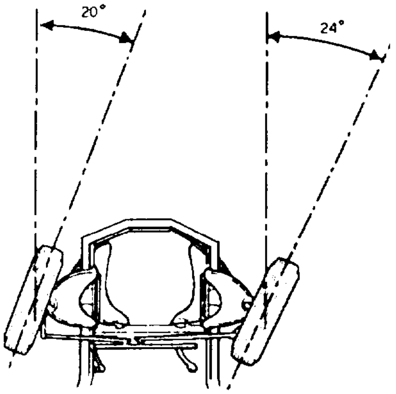


Figure 12-21.—Checking the turning radius.

point. This will cause less wear on the steering gears. A suggested procedure is as follows:

1. Position the wheels straight ahead; check the position of the steering wheel. It should be centered; if it is not, center it now. To find center, turn the steering wheel all the way to the left and count the number of turns while turning it all the way to the right. Now, turn the steering wheel back half the number of turns. Now check the front wheels; one may be turned in more or less than the other; adjust them so that they are parallel with the frame of the vehicle.

2. At this point, your toe reading should be zero (0). Now, adjust the toe by turning the tie rod end sleeves. They should be adjusted in equal amounts. If the setting is 1/4-inch toe-in, you take 1/8th off the right and 1/8th off the left wheel.

NONADJUSTABLE ANGLES

Now that we have covered the angles you can adjust, it is equally important that you understand the nonadjustable angles and how they can be checked as presented in the following section.

TURNING RADIUS

Turning radius is nonadjustable, but it can be checked (fig 12-21). Using turntable pads calibrated in degrees, turn the right wheel 20 degrees and read the setting on the left wheel. Then turn the left wheel 20 degrees and read the setting on the right wheel. Check your readings against the manufacturer's specifications. If all other adjustments are correct (caster, camber, toe-in), and the turning is incorrect, replacement of the steering arm is the only method of correction.

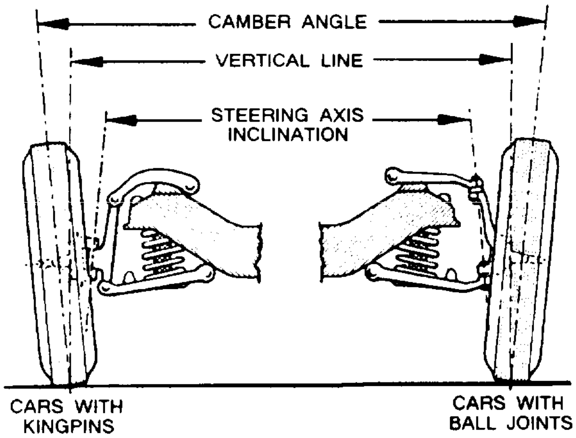


Figure 12-22.—Steering axis inclination.

STEERING AXIS INCLINATION (SAI)

Steering axis inclination is nonadjustable; it is the angle formed by the true vertical centerline of the ball joints or kingpin (fig. 12-22). SAI and camber are closely related. If you change the camber by tilting the top of the wheel in or out, you change SAI an equal amount. As previously stated, SAI is nonadjustable; therefore, the angle built into the steering knuckle does not change unless it is bent.

To check the spindle or spindle support, measure both camber and SAI. If camber is positive, add the two measurements. If camber is negative, subtract the camber measurement from the SAI measurement. The resulting figure is the angle built into the spindle support. Check the manufacturer's specifications. If your readings differ from the manufacturers, then the only corrective action is to replace the bent spindle.

STEERING AND ALIGNMENT TROUBLE

The driver can sense steering and alignment trouble. He or she can detect hard steering or play in the steering system and will call you to find the trouble and remedy it. The following are some complaints and their possible causes;

1. When breaking, vehicle pulls to one side:

    a. Uneven tire pressure

    b. Brakes grab

    c. Caster incorrect or uneven

    d. Wheel bearing too tight

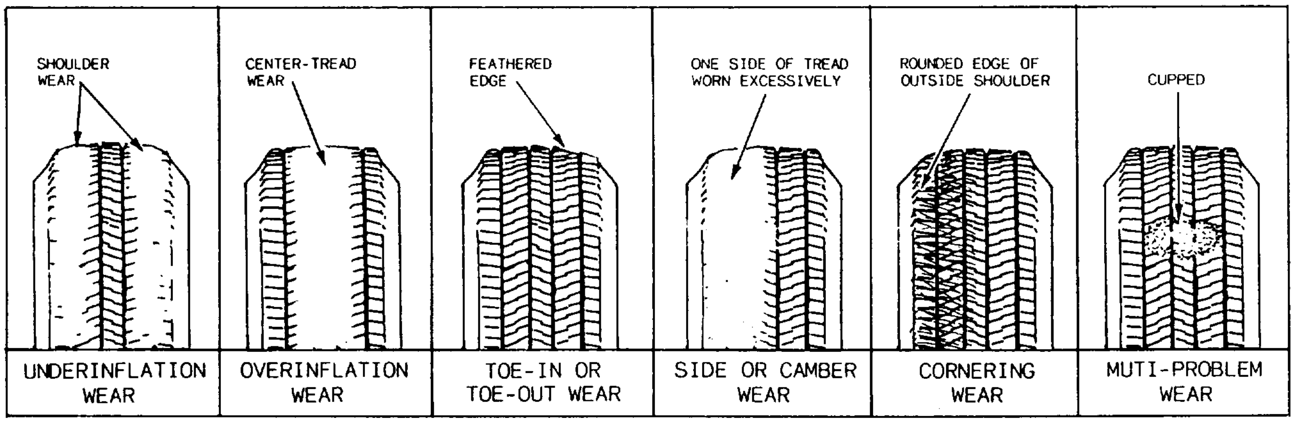


Figure 12-23.—Patterns of tire wear.

2. Shimmy at low speeds:
   - a. Low or uneven tire pressure
   - b. Loose linkage
   - c. Worn ball joints
   - d. Caster incorrect or uneven
3. Vehicle wanders:
   - a. Tire pressure incorrect or unequal
   - b. Caster or toe incorrect
   - c. Suspension components excessively worn or damaged
4. Steering wheel not centered:
   - a. Toe-in out of adjustment
   - b. Steering components bent
   - c. Steering wheel not properly placed on steering shaft
5. Steers hard:
   - a. Low tire pressure
   - b. Binding steering assembly or misadjusted
   - c. Excessive caster
   - d. Steering and suspension units not properly lubricated
6. Tire wear (fig. 12-23):
   - a. Underinflation causes wear at tread sides
   - b. Overinflation causes wear at tread center
   - c. Excessive camber causes wear at one tread side
   - d. Excessive toe-in or toe-out on turns causes tread to featheredge

TRACK ALIGNMENT

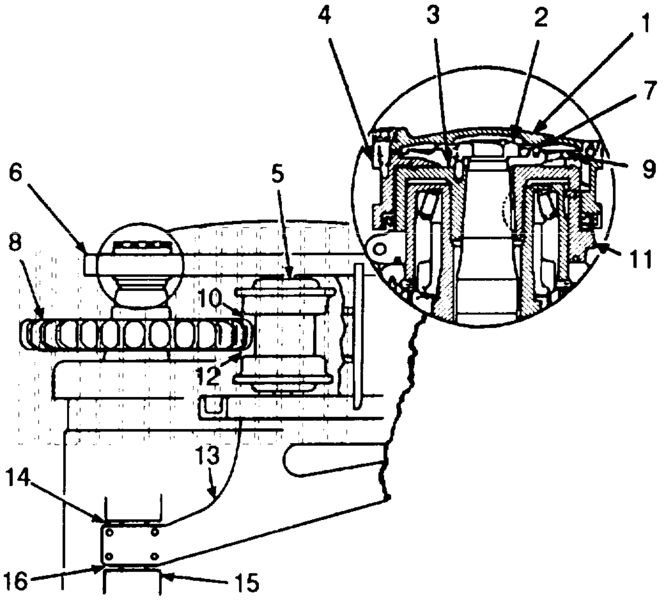
A misaligned front idler or track frame will cause many hours of project lost time and could cost several hundred dollars to replace worn-out components. You must know what components will be affected and what is involved in the proper alignment process. So, when this condition does arise, you will be able to diagnose it properly and take the corrective action needed to keep your equipment in the field and on the job.

Track frame misalignment can allow tee-out. This could cause excessive end wear of track pins, rail side wear and sprocket tooth gouging of the inside of the links, side wear of the sprocket and sprocket teeth, off-center external wear of the bushings, and flange wear of rear rollers. Misalignment of the front idler can cause wear of the front idler flange, the front track roller flanges, and the link side rails.

The use of track guiding guards keeps the track in proper alignment. These are called wear bars and plates. They are shimmied to align the idler with the track rollers. The side wear plates guide the idler, as it recoils back and forth. These guards should be reconditioned or adjusted to proper thickness, so they will guide the track squarely into alignment with the track rollers.

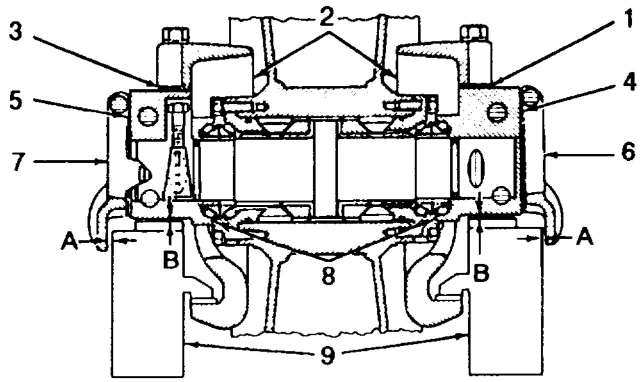
The front guiding guards receive the track from the idler and hold it in line for the first roller. The front roller then can be used fully for its intended purpose-that of carrying its share of the tractor load without having to climb the sides of the improperly aligned track.

The rear guiding guards hold the track in correct alignment with the driving sprocket, permitting a smooth, even flow of power from the sprocket to the track. With proper alignment, the gouging of link sides and sprocket teeth is eliminated.



1. Cap
2. Nut
3. Shims
4. Outer bearing assemble
5. Rear track roller
6. Track roller frame
7. Lock ring
8. Drive sprocket
9. Retainer assembly
10. Clearance
11. Holder assembly
12. Clearance
13. Diagonal brace
14. Clearance
15. Steering clutch case
16. Clearance

Figure 12-24.—Aligning track roller frame with sprocket.



1. Shims
2. Collars
3. Shims
4. Shims
5. Shims
6. Guide plate
7. Guide plate
8. End bearings
9. Frame. A: .03 ± .02 in. (0,76 ± 0,51 mm) dimension.
   B: .045 ± .015 in. (1,14 ± 0,38 mm) dimension.

Figure 12-25.—Aligning idler with track rollers.

The center guiding guards or track roller guards are available as attachments and are a continuation of the “hold the line” safeguard so important to extending track life. These center guards keep the track in line between the rollers when operating in rocky, uneven, or steep-sloped terrain, thereby reducing wear on the roller flanges and track links.

When aligning the track roller frame with the sprocket and adjusting the front idler, you must follow the manufacturer’s procedures. The following procedure is an example of what is involved in these adjustments.

TRACK ROLLER FRAME ALIGNMENT WITH SPROCKET

1. For the following example, refer to figure 12-24. For the track to lead straight off of the rear roller (5) onto the drive sprocket (8) and not rub against either the sides of the sprocket or the rims of the track roller, the center of the roller should be centered with the sprocket.

2. The drive sprocket (8) should be centered with the rear roller (5) so the area (10) and (12) between the outer face of the sprocket and the inner edge of the track roller rim are equal.

3. In the recess in the steering clutch case (15), check the clearance of the diagonal brace (13) at points (14) and (16).

4. To make this adjustment, remove the cap (1) from the outer bearing assembly (4) and take off the lock ring (7), nut (2), and retainer assembly (9).

5. To move the roller frame out, you add shims (3) between the retainer assembly (9) and the holder assembly (11). This will decrease the clearance (12) at the roller and at the diagonal brace (14) and increase the clearance at (10) and (16).

6. To move the roller frame closer to the tractor, you remove shims (3). This decreases the clearance at (10) and (16) and increases the clearance at (12) and (14).

ADJUSTMENT OF THE FRONT IDLER

For the adjustment of the front idler, refer to figure 12-25. To align the idler with the track rollers and keep the clearance between the yoke and the plate within specifications for dimension (B), you install shims (1) and (3) between collars (2) and bearings (8).

To shift the idler from side to side in order to align the idler and track properly, you add enough shims (4) and (5) between bearings (8) and guide plates (6) and (7) to provide clearance (A) between guide plates (6) and (7) and the frame (9).

This chapter stresses the importance of your understanding and following the principles of front-end alignment and track alignment in vehicle maintenance. Although these principles will remain the same, the make and year of the equipment assigned to your unit will change. Therefore, it is always recommended that you refer to the manufacturer's repair manual for specific adjustments for your particular equipment.

ASSIGNMENT 10

Textbook Assignment: "Troubleshooting Transmissions, Transfer Cases, Power Takeoffs, and Differentials," and "Wheel and Track Alignment," pages 11-1 through 12-5.

10-1. In the power train, where is the sprag unit located?

1. In the axle housing
2. In the transmission
3. In the transfer case
4. In the PJO assembly

10-2. On a Spicer-manufactured transmission, what does the third digit of the serial number indicate?

1. The number of forward speeds
2. The transmission gear ratio
3. The year of manufacture
4. The type of gear synchronizer used

10-3. Which of the following conditions produces torsional vibrations that sound like noises in the transmission?

1. Worn universal joints
2. Loose U-bolts
3. Unbalanced wheels
4. Each of the above

10-4. A transmission that slips out of gear could have which of the following problems?

1. Broken gear teeth
2. Excessive main shaft end play
3. Low fluid level
4. Loose engine-mount bolts

10-5. What is the most common cause of transmission failure?

1. Leaking seals
2. Low fluid level
3. Normal wear
4. Improper operation

10-6. Soap and soda added to transmission lubricant acts in what way?

1. As a cleaning agent
2. As a sealing agent
3. To retard discoloration of the oil
4. To stiffen the oil

10-7. When should you check the fluid level in a standard transmission?

1. Directly after use
2. One-half hour after use
3. After the vehicle has been parked for several hours

10-8. In a standard transmission, excessive pressure is avoided by what means?

1. By the use of special fluids
2. By the use of a vent valve
3. By allowing for fluid expansion
4. By totally sealing the transmission

10-9. What seal cannot be inspected with the transmission installed?

1. The shift-rail seal
2. The output shaft seal
3. The input shaft seal
4. The fill plug seal

10-10. When a thin oil-type liquid is found beneath the flywheel housing, what is the most likely source?

1. Differential fluid
2. Transmission fluid
3. Engine oil
4. Transfer case fluid

10-11. When oil leaks from the front seal of the transmission, it may ruin the clutch.

1. True
2. False

10-12. For you to locate the mechanical problems of a transmission, what method is best?

1. Road testing
2. Component disassembly
3. Discussing the problem with the operator

10-13. When you hear a noise that only occurs when the clutch is disengaged, what is most likely the problem?

1. A mainshaft bearing
2. The input shaft
3. The clutch release bearing
4. A countershaft bearing

10-14. The incorrect alignment of a power train may cause sounds similar to a defective transmission.

1. True
2. False

10-15. A first and reverse gear in a standard transmission is usually of what design?

1. Helical
2. Herringbone
3. Spur
4. Hypoid

10-16. When is a standard transmission most likely to slip or jump out of gear?

1. During steady acceleration
2. During rapid acceleration
3. During steady deceleration
4. During rapid deceleration

10-17. If flushing is required, you should flush the transmission case with what type of liquid?

1. A special oil
2. Transmission lubricant
3. Solvent
4. Detergent

10-18. When determining whether or not to use an old transmission part, which of the following factors should you consider?

1. Serviceability of the old part
2. Cost of replacing the part
3. Availability of a new part
4. All of the above

10-19. You should coat transmission parts that are ready for reassembly with what type of liquid?

1. A light coating of clean transmission fluid
2. A medium-grade preservative lubricating oil
3. A rust-preventive compound
4. A fiber grease

10-20. In the transfer case, worn or broken gears, worn bearings, and excessive end play in the propeller shaft will cause what problem?

1. Clashing gears
2. Hard shifting
3. An unbalanced propeller shaft
4. Noisy operation

10-21. In an automotive vehicle, the power takeoff that supplies power to the auxiliary accessories can be attached to which of the following units of the power train?

1. Transmission
2. Auxiliary transmission
3. Transfer case
4. Each of the above

10-22. Within the power takeoff attachment, the shifter shaft is held in position by what means?

1. A shift lock
2. A fork
3. A spring-loaded ball
4. A sliding spur gear

10-23. Some vehicle power takeoff units have two speeds forward and one in reverse, whereas some have several forward speeds and a reverse gear. The power takeoff units with the several forward speeds are used to operate what units?

1. Power trains
2. Winches
3. Tracklayers
4. Front-wheel drives

10-24. A power takeoff assembly that slips out of gear could be caused by which of the following problems?

1. Bent or broken linkage
2. Faulty bearings
3. Broken gear teeth
4. Leaking shaft gears

10-25. Which component of a drive train is used to allow changes in the angle of the propeller shaft?

1. Support bearing
2. Companion flange
3. Slip joint
4. Universal joint

10-26. Lubricating universal joints with a low-pressure grease gun will prevent which of the following problems?

1. Bearing damage
2. Seal damage
3. Bearing seizure
4. Overlubrication

10-27. Which of the following is one purpose of the differential in the rear axle assembly of a wheeled vehicle?

1. To serve as a torque member
2. To make sure the rear wheels always turn at the same speed
3. To boost engine power transmitted to the wheels
4. To enable the axles to be driven as a single unit although turning at different speeds

10-28. What causes the pinions side gears and axle shafts to rotate as one unit?

1. Unequal wheel resistance
2. Equal wheel resistance
3. High-axle torque
4. Relative motion between the pinions

10-29. The average speed of the two differentials side gears is always equal to the speed of what components?

1. The drive shaft
2. The pinion gear
3. The wheels
4. The bevel drive gear

10-30. What is the name of the device that locks both axles together as a single unit?

1. A trunnion lock
2. The dog clutch
3. The side gears
4. The cone clutch

10-31. Compared to a standard differential, the high-traction differential for automotive vehicles combines pinions and side gears that have

1. fewer teeth but the same tooth form
2. more teeth but the same tooth form
3. fewer teeth and a modified tooth form
4. more teeth and a modified tooth form

10-32. In a no-spin differential, the wheel speed of the wheel with the least traction is controlled by what means?

1. The ring gear
2. The driver
3. The speed of the propeller shaft
4. The speed of the wheel applying the tractive effort

10-33. Which parts of the standard differential distinguish it from the no-spin differential?

1. Ring gear and spider
2. Pinions and side gears
3. Two driven clutch members with side teeth
4. Spring retainer and trunnions

10-34. In a differential, an improperly adjusted ring and pinion set would initially make what kind of sound?

1. Squealing
2. Humming
3. Clicking
4. Thumping

IN ANSWERING QUESTIONS 10-35 THROUGH 10-37, SELECT FROM COLUMN B THE TYPE OF AXLE THAT BEST FITS THE DESCRIPTION GIVEN IN COLUMN A. RESPONSES IN COLUMN B MAY BE USED ONCE, MORE THAN ONCE, OR NOT AT ALL.

	A. DESCRIPTIONS	B. TYPES OF AXLES
10-35.	The axle housing carries the weight of the vehicle because the wheels are supported by the bearings on the outer ends of the housing	1. Semi-floating axle 2. Three-quarter floating axle
10-36.	Each wheel is carried on the end of the axle tube on two ball bearings or roller bearings and the axle shafts are bolted to the wheel hub	3. Full-floating axle
10-37.	The wheels are keyed or bolted to outer ends of the axle shafts and the outer bearings are between the shafts and housing	

10-38. At what level should the lubricant be maintained in the gear cases of vehicle power trains?

1. One inch below the inspection hole
2. Two inches below the inspection hole
3. Three inches below the inspection hole
4. Even with the bottom of the inspection hole

10-39. Overfilling the differential with fluid could cause the brakes to slip or grab.

1. True
2. False

10-40. When inspecting the power train of a vehicle, which of the following faults should mechanics look for?

1. Missing transmission bolts
2. Bent propeller shaft
3. Loose U-bolts
4. All of the above

10-41. Positive camber is the tilt of the top of the wheel in which direction?

1. In toward the engine
2. Outward away from the engine
3. To the rear of the vehicle
4. To the front of the vehicle

10-42. In what increments is camber measured?

1. Degrees
2. Fraction of an inch
3. Centimeters

10-43. What is one of the reasons camber is built into a vehicle?

1. To make cornering easier
2. To compensate for the loading effect on wheels
3. To relieve (partially) the pressure on springs
4. To assist in directional control

10-44. Primarily, camber is what kind of an angle?

1. Tracking angle
2. Toe-in angle
3. Tire-wearing angle
4. Nonadjustable angle

10-45. The forward or backward tilt of the kingpin or ball joint from the vertical line is termed as what angle?

1. Camber
2. Caster
3. Toe-in
4. Steering axis inclination

10-46. Caster is primarily what type of angle?

1. A toe-in angle
2. A tire-wearing angle
3. A turning angle
4. A direction control angle

10-47. In what increments is caster measured?

1. Degrees
2. Fractions of an inch
3. Centimeters

10-48. Positive caster is the tilt of the king pin or ball joint at the top in which direction?

1. In toward the engine
2. Away from the engine
3. Toward the front of the vehicle
4. Toward the rear of the vehicle

10-49. A tendency of a vehicle to maintain a straight-ahead course is due to what angle?

1. Positive camber
2. Positive caster
3. Negative camber
4. Negative caster

10-50. Negative caster tends to yield which of the following results?

1. Makes it easier for you to recover a vehicle from a turn
2. Decreases tire wear on the outside of tire tread
3. Makes the vehicle wander and weave
4. Makes the steering wheel more difficult for you to turn

10-51. Which of the following is true of caster?

1. It is nonadjustable
2. It is fixed
3. It is adjustable
4. It is automatically established

10-52. The inward tilt of the kingpin or ball joint from the true vertical line is known by what terminology?

1. Camber
2. Caster
3. SAI or KPI
4. Toe–in

10-53. In what increments is SAI or KPI measured?

1. Centimeters
2. Degrees
3. Fractions of an inch

10-54. What is one of the purposes of SAI or KPI?

1. To offset road crown
2. To prevent tire wear
3. To reduce the need for excessive camber
4. To prevent shimmy of the front wheels

10-55. Why is a vehicle closer to the road when the wheels are in a straight-ahead position than when they are turned?

1. Because of the angle of the spindle support arms
2. Because of the camber angle
3. Because of SAI or KAI
4. Because of toe-in

10-56. The difference in the distance between the wheel centers at the rear of the front tires and the wheel centers at the front of the tires is known by what terminology?

1. Steering axis inclination
2. Toe-in or toe-out
3. Caster
4. Camber

10-57. What is the purpose of toe-in?

1. To make sure the front wheels are turning about a common point
2. To make sure the inside wheel turns at a greater angle than the outside wheel
3. To allow or compensate for the normal looseness in steering linkage
4. To make sure the outside wheel turns at a greater angle than the inside wheel

10-58. How is toe-in adjusted?

1. By shortening or lengthening the tie rods
2. By shortening or lengthening the relay rod
3. By shimming the control arms
4. By shortening or lengthening the drag link

CHAPTER 13

AIR-CONDITIONING SYSTEMS

Air conditioning is the treatment of air to ensure control of temperature, humidity, and dust (or foreign particles) at levels most suitable to personal comfort. A good example is the air-conditioning system used by astronauts; their air-conditioning units must supply all life-sustaining conditions to support their existence. In this chapter, we examine the basic principles of refrigeration, system components, troubleshooting, and the repair of these systems. Furthermore, in closing, the changes to automotive air systems and how they may affect you as a mechanic are also examined.

PRINCIPLES OF REFRIGERATION

Refrigeration is the process of producing low temperatures. It is usually associated with refrigerators or freezers rather than with vehicles. An understanding of heat transfer, basic refrigeration, pressure-temperature relationship, and the qualities of refrigerants is essential for a working knowledge of the air-conditioning system.

HEAT TRANSFER

It may seem a bit silly to cover heat transfer in connection with air conditioning. Keep in mind, however, that heat, like light, is a form of energy. As you remove light, a room grows darker. Likewise, when you remove heat, an area becomes colder. The process of transferring heat is the basis for air conditioning. Generally, when two objects of different temperatures are close to each other, heat energy will leave the warmer object and travel to the cooler. This is quite clearly illustrated in North America each fall and winter. As the rays of the sun become less direct and consequently give off less heat, we experience a drop in temperature. Cooler weather (refrigeration) results from this removal of heat.

Refrigeration applies a physical principle that is known to most of us through our everyday experiences. We have experienced the application of rubbing alcohol and its cooling effect. This example illustrates that an evaporating liquid absorbs heat. The evaporating moisture in the air on a hot day soaks up heat like a sponge. This removal of heat is exactly the same process used in automotive air conditioning. Heat is removed from the vehicle by an evaporating refrigerant and transferred into the atmosphere.

PRESSURE TEMPERATURE RELATIONSHIP

Different liquids have different boiling evaporating points; however, the boiling pint of any liquid increases when pressure is increased. When pressure is decreased, the boiling point is then decreased. This process of removing the pressure and allowing the coolant to boil is a vital part of any refrigeration system.

REFRIGERANT

With the exception of changes in state, gases used in refrigeration are recycled much like engine coolant. Different pressures and temperatures cause the gas to change state from liquid togas and back to a liquid again. The boiling point of the refrigerant changes with system pressure. High pressure raises the boiling point and low pressure reduces it. These gases also provide good heat transfer qualities and do not deteriorate system components. Two gases commonly used in the refrigeration process are Refrigerant-12 and Refrigerant-22. Use extreme caution when handling them. Refrigerant-12, otherwise known as R-12, Freon-12, or F-12, boils at –21.7°F (–29.8°C) when at sea level. Because of this low boiling point and its ability to pass through the system endlessly, R- 12 is almost the ideal refrigerant. (R-12 is currently being replaced by a refrigerant that is less harmful to our environment).

WARNING

> When you are working with R-22, keep in mind that this refrigerant contains methyl alcohol which can be a fire hazard. For this reason, automotive air-conditioning systems contain R-12.

HANDLING REFRIGERANT

R-12 is classified as a safe refrigerant because it is nonexplosive, nonflammable, and noncorrosive; however, you must observe certain precautions when

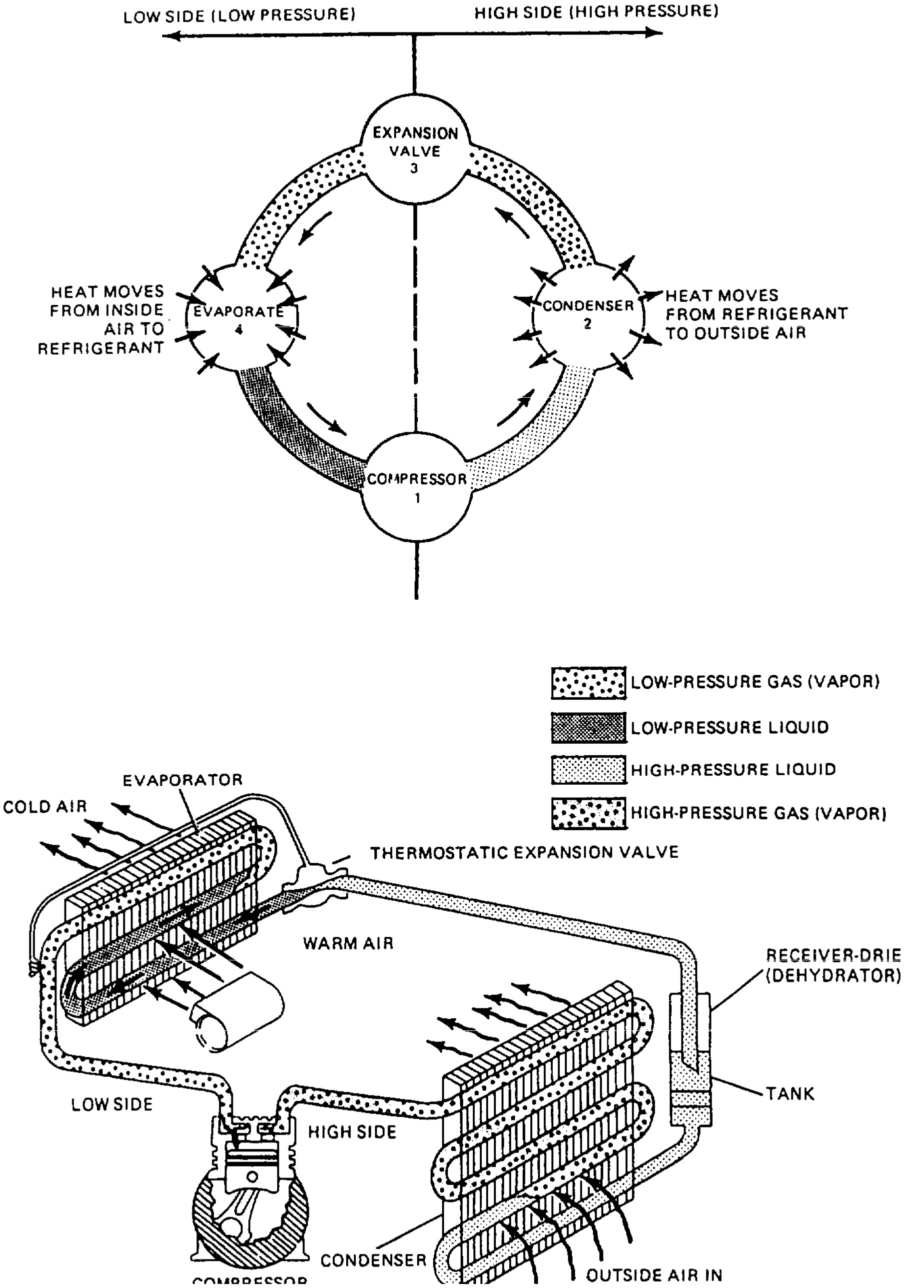


Figure 13-1.—The closed circuit refrigeration cycle.

using and handling it. At normal atmospheric temperatures, R-12 evaporates so rapidly that it freezes anything it contacts. For this reason, always wear rubber gloves and safety goggles when servicing a charged refrigeration system. Good ventilation in the working area must be ensured. Any sizable quantity of R-12 escaping into the atmosphere will displace the surrounding air and could result in suffocation. R-12 discharged near an open flame could produce a poisonous gas. Do not weld or use excessive heat of any kind near the air-conditioning system or refrigerant supply tanks. The heat will cause increased pressure inside the system and could result in an explosion. You should exercise great care to maintain the refrigerant under pressure in the supply tanks, in the air-conditioning system, and during servicing procedures.

The refrigerant must evaporate to provide a cooling effect, yet cannot be allowed to escape into the atmosphere. R-12 must circulate through a closed system (fig. 13-1), just as coolant circulates through the engine cooling system. R-12 is available in tanks and cans. The disposable can is the most convenient refrigerant container and it is widely used for servicing

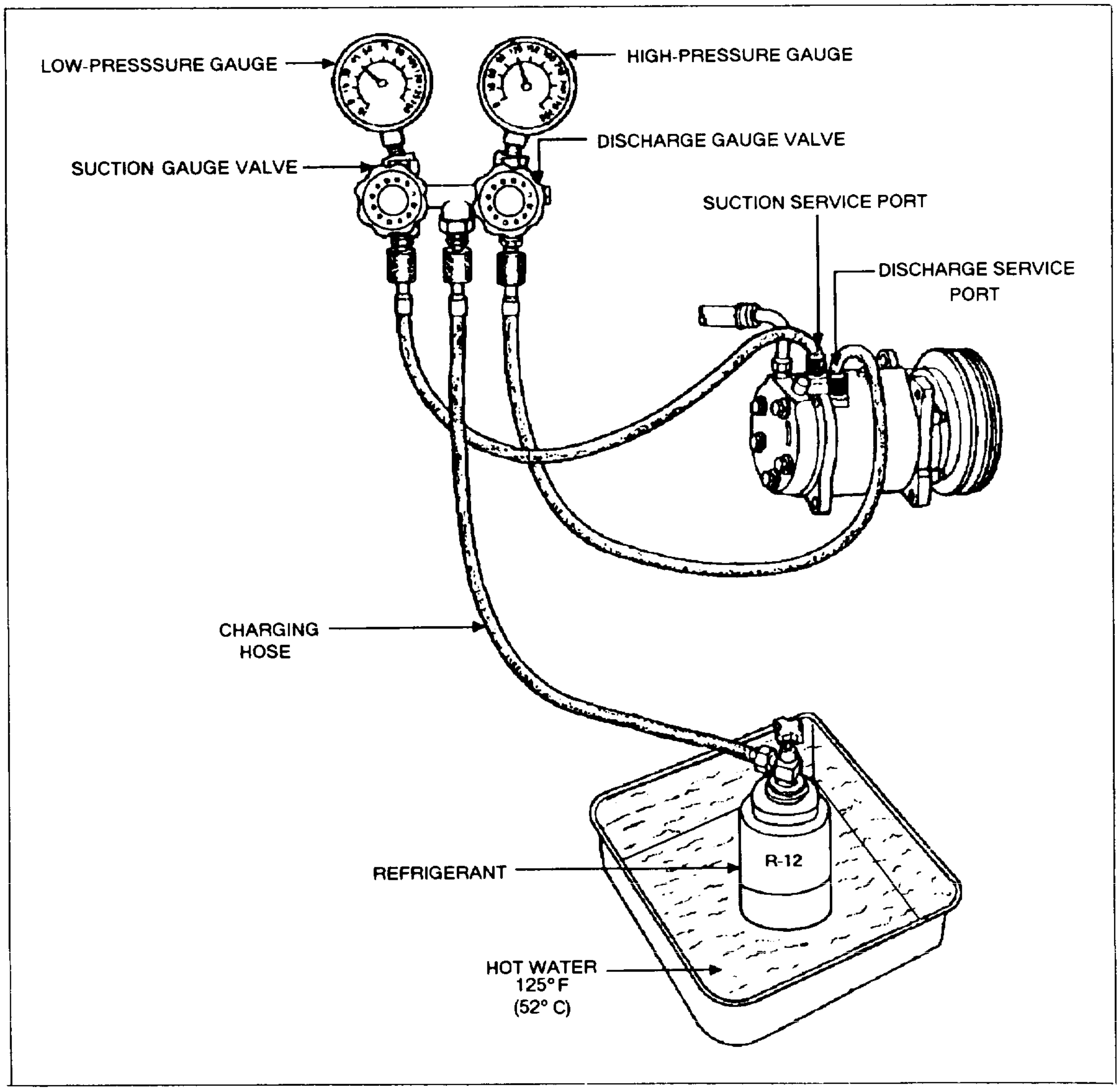


Figure 13-2.—Warming the refrigerant by using hot water.

and charging the system. Although R-12 is considered the safest refrigerant for automotive air-conditioning systems, the containers are under considerable pressure at ordinary temperatures. To prevent accidents or damage to the system, you must observe the following precautions:

- Do not subject the containers to excessive heat and do not store them in direct sunlight or near a shop heater.
- Use hot water (fig. 13-2) or rags saturated with water at temperatures not to exceed 125°F when refrigerant containers must be warmed for system charges.
- Never use a direct flame or a heater to warm containers or cans.
- Do not subject refrigerant containers to rough handling.
- Do not drop or strike containers.
- Keep refrigerant tanks upright, and be sure the metal cap is installed to protect the valve and safety plug when the tank is not in use.
- Do not transport refrigerant tanks or cans in vehicle passenger compartments.
- Cover the containers to protect them from direct sunlight when they are carried in an open truck.
- When you dispense refrigerant from cans, use the specified can valve that has provisions for puncturing the can only after the valve is installed.

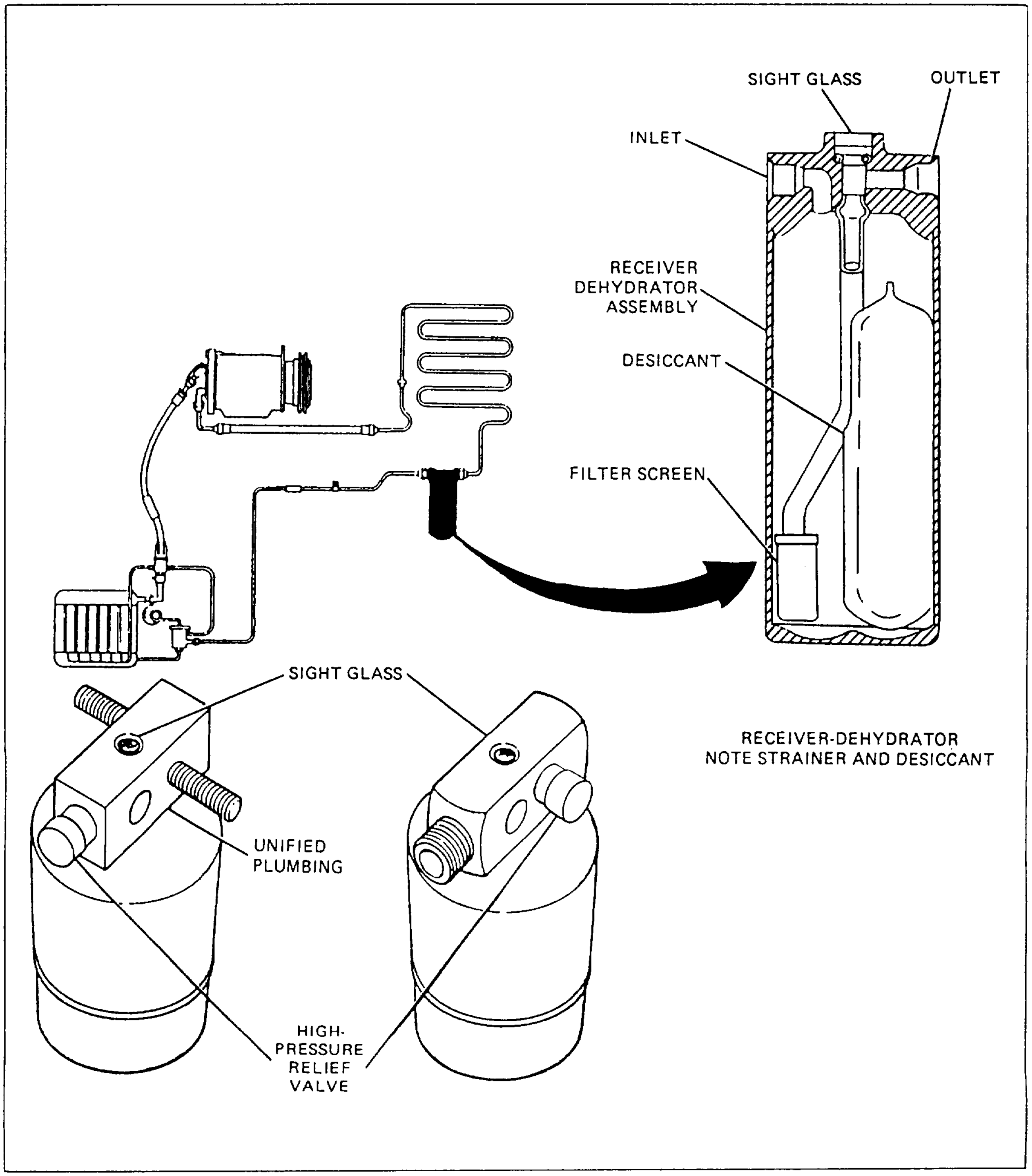


Figure 13-3.—Receiver and components.

REFRIGERATION CYCLE

The refrigeration cycle is a continuous closed-loop system. The refrigerant is pumped constantly through the components in the system. By changing the refrigerant pressure and by removing and adding heat, the refrigeration cycle is completed. The refrigeration cycle operates as follows:

1. The receiver/drier collects high-pressure refrigerant in a liquid form. Also, moisture and impurities are removed at this point.

2. The refrigerant is routed to the expansion valve through high-pressure lines and hoses.

3. The expansion valve reduces refrigerant pressure to the evaporator by allowing a controlled amount of liquid refrigerant to enter it.

4. A stream of air is passed over the coils in the evaporator as refrigerant enters.

5. As the low-pressure refrigerant moves through the coils in the evaporator, it absorbs heat from the airstream, which produces a cooling effect.

6. As the refrigerant nears the end of the coils in the evaporator, greater amounts of heat are absorbed. This causes the low-pressure liquid refrigerant to boil and change to a gas as it exits the evaporator.

7. As the refrigerant enters the compressor, the pumping action increases refrigerant pressure, which also causes a rise in temperature.

8. The high-pressure, high-temperature gas enters the condenser, where heat is removed by an outside ambient airstream moving over the coils. This causes the gas to condense and return to a liquid form again.

9. The high-pressure liquid refrigerant now enters the receiver again to begin another cycle. This continuous cycle, along with the dehumidifying and filtering effect, produces a comfortable atmosphere on hot days.

Figure 13-1 shows the refrigeration cycle. You should trace the order of the cycle to understand it fully.

COMPONENTS OF THE AIR-CONDITIONING SYSTEM

Each air-conditioning system must have a receiver/drier, an expansion valve or metering device, an evaporator, a compressor, and a condenser. Without these components, an air-conditioning system will not function. Additionally, the system must have some means of control. The following information briefly covers each air-conditioning component and the controls involved.

THE RECEIVER/DRIER

The receiver (fig. 13-3), otherwise known as a filter-drier or accumulator-drier, is a cylindrical-shaped metal tank. The tank is hollow with an inlet to the top of the hollow cylinder. The outlet port has a tube attached to it that extends to the bottom of the receiver. This tube assures that only liquid refrigerant will exit the receiver, because any gas entering will tend to float above the liquid.

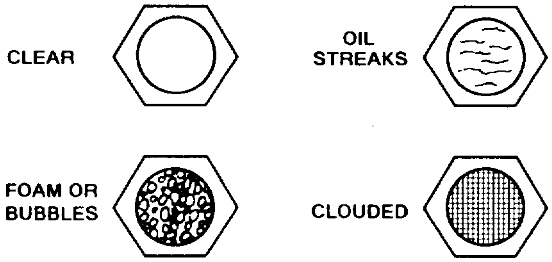


Figure 13-4.—Possible sight glass conditions.

- Filter–The filter is mounted inside the receiver on the end of the outlet pipe. This filter removes any impurities from the refrigerant by straining it.

- Desiccant–A special desiccant or drying agent, also, is located inside the receiver. This agent removes any moisture from the system.

- Relief Valve–Some systems use a relief valve mounted near the top of the receiver. This valve is designed to open when system pressure exceeds approximately 450 to 500 psi. As the relief valve opens, it vents refrigerant into the atmosphere. As soon as excess pressure is released, the valve closes again so the system will not be evacuated completely.

- Sight Glass–A sight glass is a small, round, glass-covered hole, sometimes mounted on the outlet side of the receiver near the top. This observation hole is a visual aid you use in determining the condition and amount of refrigerant in the system. If bubbles or foam is observed in the sight glass while the system is operating (above 70°F [21°C]) (fig. 13-4), it may indicate that the system is low on refrigerant. Some systems have a moisture-sensitive element built into the sight glass. If excessive moisture is present, the element turns pink. If the system moisture content is within limits, the element remains blue. In many later automotive air-conditioning systems, the sight glass has been eliminated. In such applications, you must depend on the system pressures.

THE EXPANSION SYSTEM

The refrigerant expansion system is designed to regulate the amount of refrigerant entering the evaporator and to reduce its pressure.

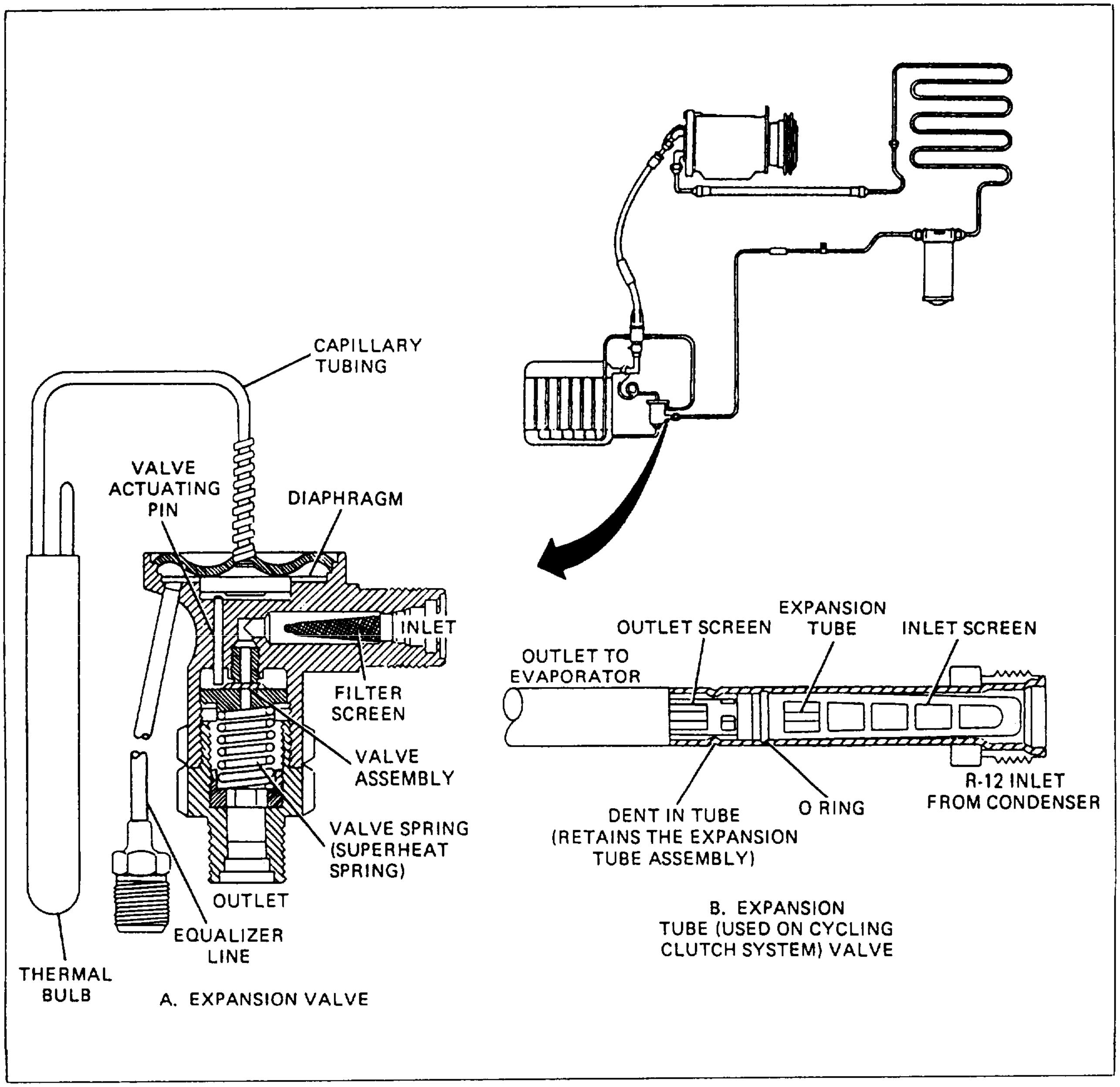


Figure 13-5.—Expansion valve and expansion tube.

Expansion Valve

One type of expansion system used on modem vehicles is the expansion valve (view A, fig. 13-5). The valve action is controlled by the valve spring, suction manifold, and pressure exerted on the diaphragm from the thermal bulb. Operation of the valve is as follows:

1. High-pressure liquid refrigerant flows into the valve and is stopped at the needle seat.

2. If the evaporator is warm, pressure is developed in the thermal bulb and transferred to the diaphragm through the capillary tube.

3. The diaphragm overcomes the pressure developed in the equalizer tube and valve spring pressure, causing it to move downward.

4. This movement forces the valve-actuating pin downward to open the valve.

As the refrigerant flows, it cools the evaporator and therefore reduces pressure in the thermal bulb. This allows the valve to close and stop refrigerant from flowing into the evaporator. By carefully metering the amount of refrigerant with the expansion valve, the evaporator cooling efficiency is increased greatly.

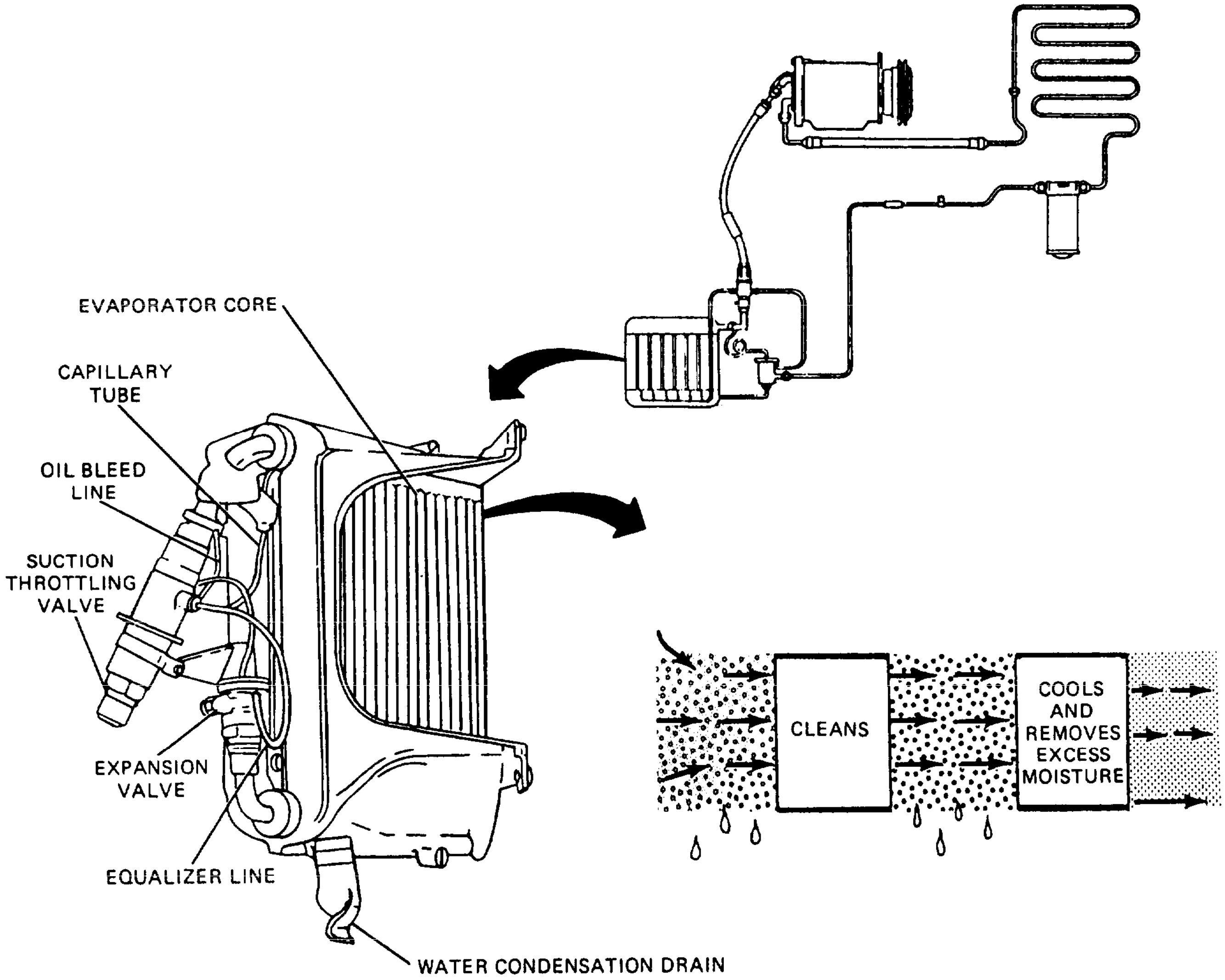


Figure 13-6.—Typical evaporator.

Expansion Tube

The expansion tube (view B, fig. 13-5) provides the same functions as the expansion valve. A calibrated orifice is built into the expansion tube. The tube retards the refrigerant flow through the orifice to provide the metered amount of refrigerant to the evaporator. The tube, also, has a fine screen built in for additional filtration.

THE EVAPORATOR

The evaporator is designed to absorb heat from the airstream directed into the driver's compartment. It is a continuous tube looped back and forth through many cooling fins firmly attached to the tube. The evaporator dehumidifies the air by passing an airstream over the cooling fins. As this happens, the moisture condenses on the fins and drips down to collect and exit under the vehicle. Also, dust and dirt are collected on the moist fins and are drained with the moisture. The temperature of the evaporator must be kept above 32°F. Should the temperature fall below 32°F, moisture condensing on the evaporator would freeze and prevent air from passing through the fins. A typical evaporator is shown in figure 13-6. There are basically three methods of regulating evaporator temperature; each is examined below.

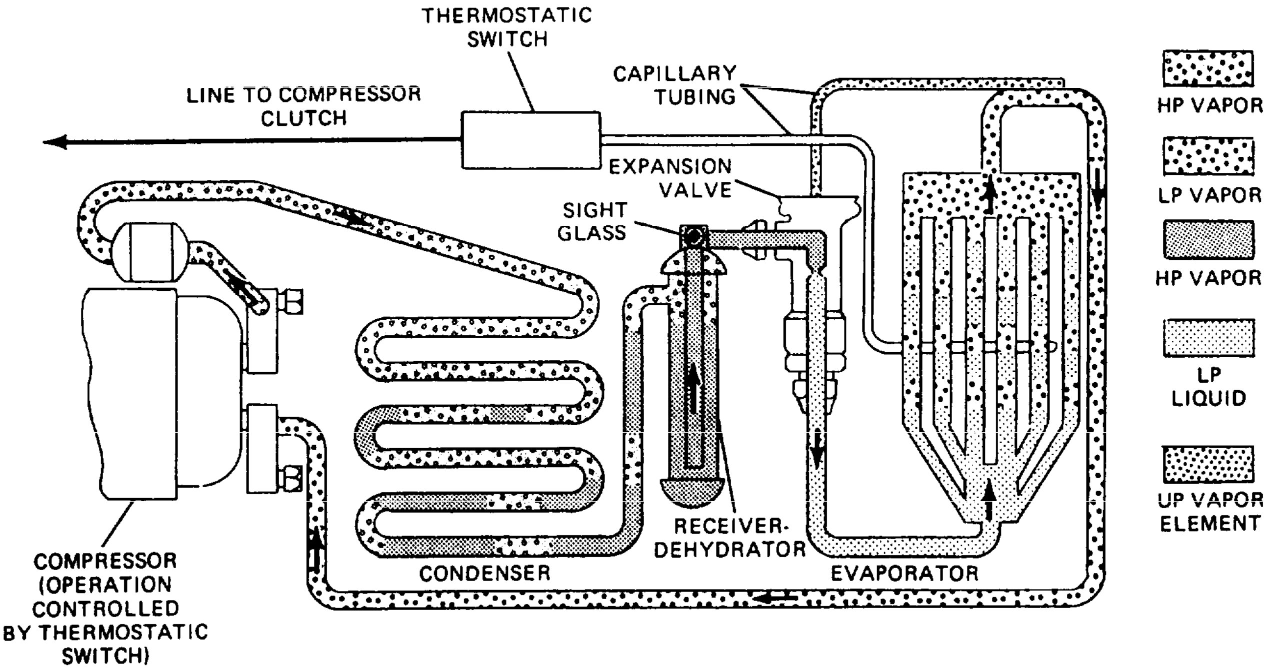


Figure 13-7.—Thermostatic switch.

Thermostatic Switch

This system uses an electrically operated switch (fig. 13-7) to engage and disengage the compressor. The switch is operated by a sensing bulb placed in the airstream after the evaporator. As the evaporator temperature falls, the thermostatic switch opens to disengage the magnetic clutch in the compressor. When the coil temperature reaches the proper level, the switch again closes to engage the clutch and drive the compressor.

Hot Gas Bypass Valve

The hot gas bypass valve was used on some older models to control evaporator icing (fig. 13-8). The valve is mounted on the outlet side of the evaporator. The high-pressure gas from the compressor joins with the low-pressure gas exiting the evaporator. These two gases mix, causing a pressure increase. Also, the boiling point increases which results in a loss of cooling efficiency. This, in turn, causes the evaporator temperature to increase, thus eliminating freeze-up. The compressor is designed to run constantly (when it is activated) in the hot gas bypass valve system.

Suction Throttling Valve

The suction throttling valve (fig. 13-9) is used now in place of the hot gas bypass valve system. It is placed

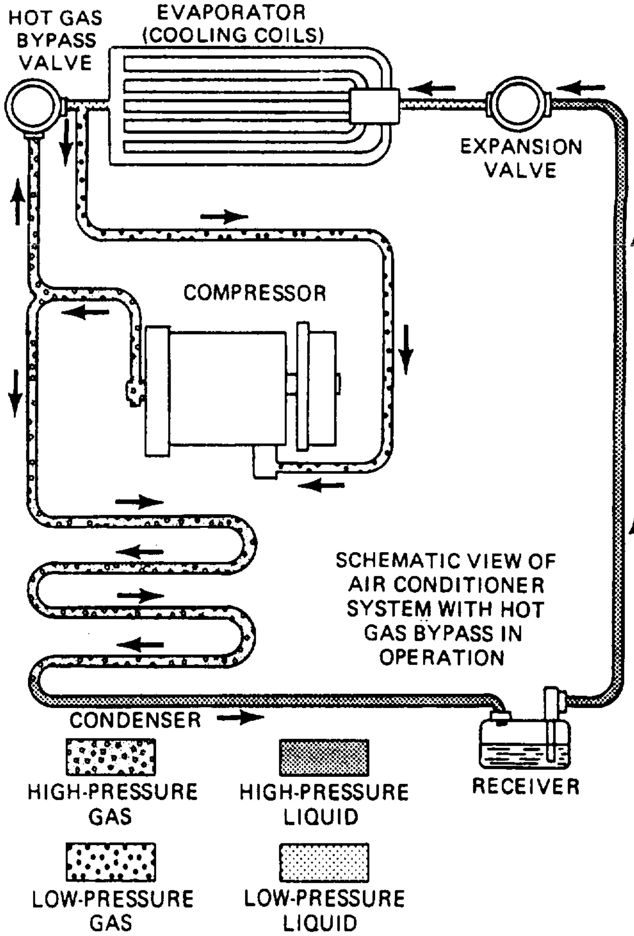


Figure 13-8.—Hot gas bypass valve.

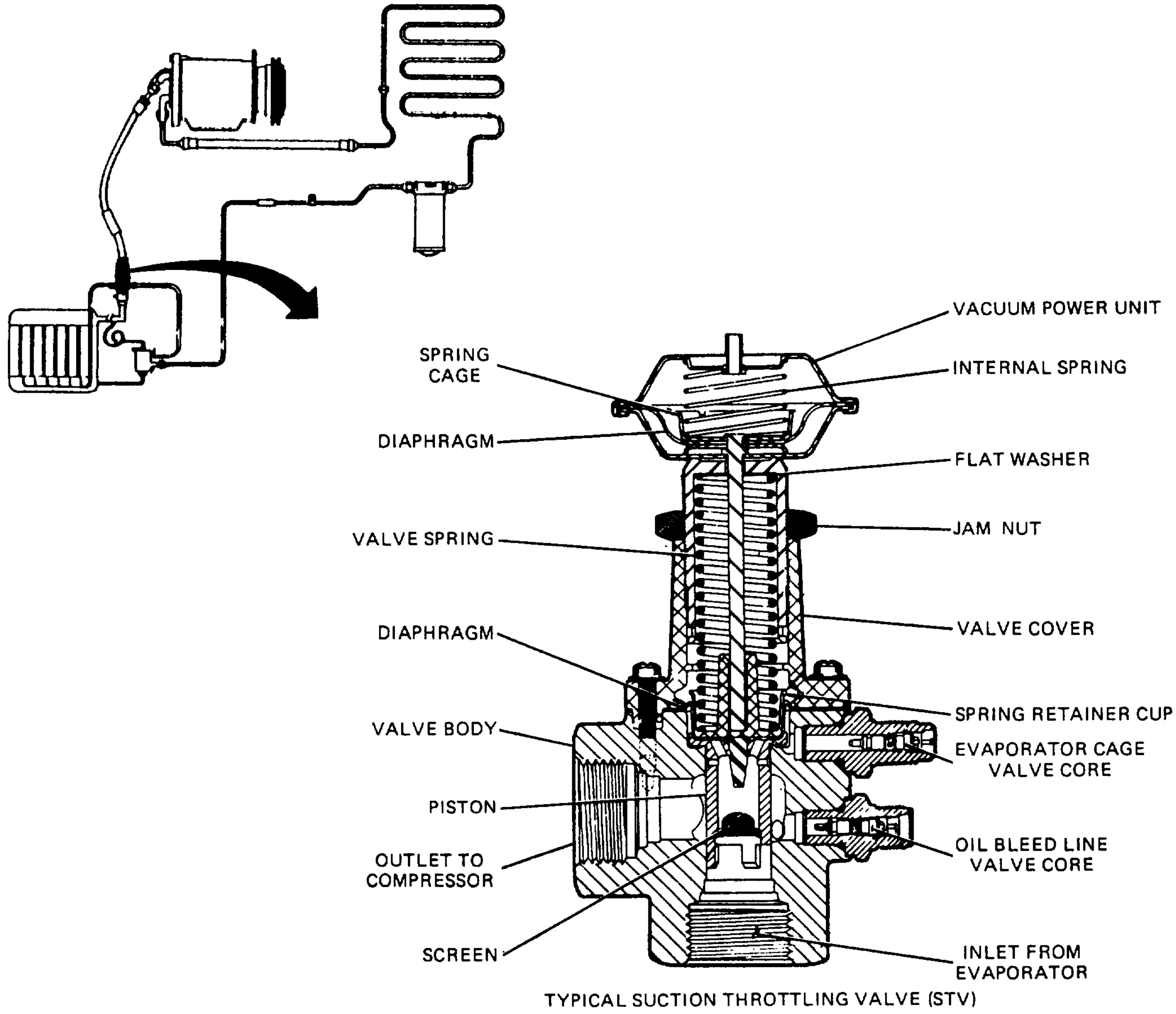


Figure 13-9.—Suction throttling valve.

in line with the outlet of the evaporator. This system is designed to limit the amount of low-pressure vapor entering the compressor. The suction throttling valve operates as follows:

1. The outlet pressure enters the valve on the bottom.

2. The gas pressure passes through a fine screen and small bleeder holes to act on a diaphragm.

3. The valve spring and atmospheric pressure oppose the gas pressure on the opposite side of the diaphragm.

4. As the outlet pressure of the evaporator overcomes the opposing forces, the diaphragm and piston move upward, allowing low-pressure gas to flow through the valve and flow to the inlet of the compressor.

As pressure again drops on the inlet side of the valve, atmospheric pressure and valve spring pressure close the valve again. A vacuum power unit is mounted to the top of the valve to help reduce valve spring pressure and prevent icing at high elevations.

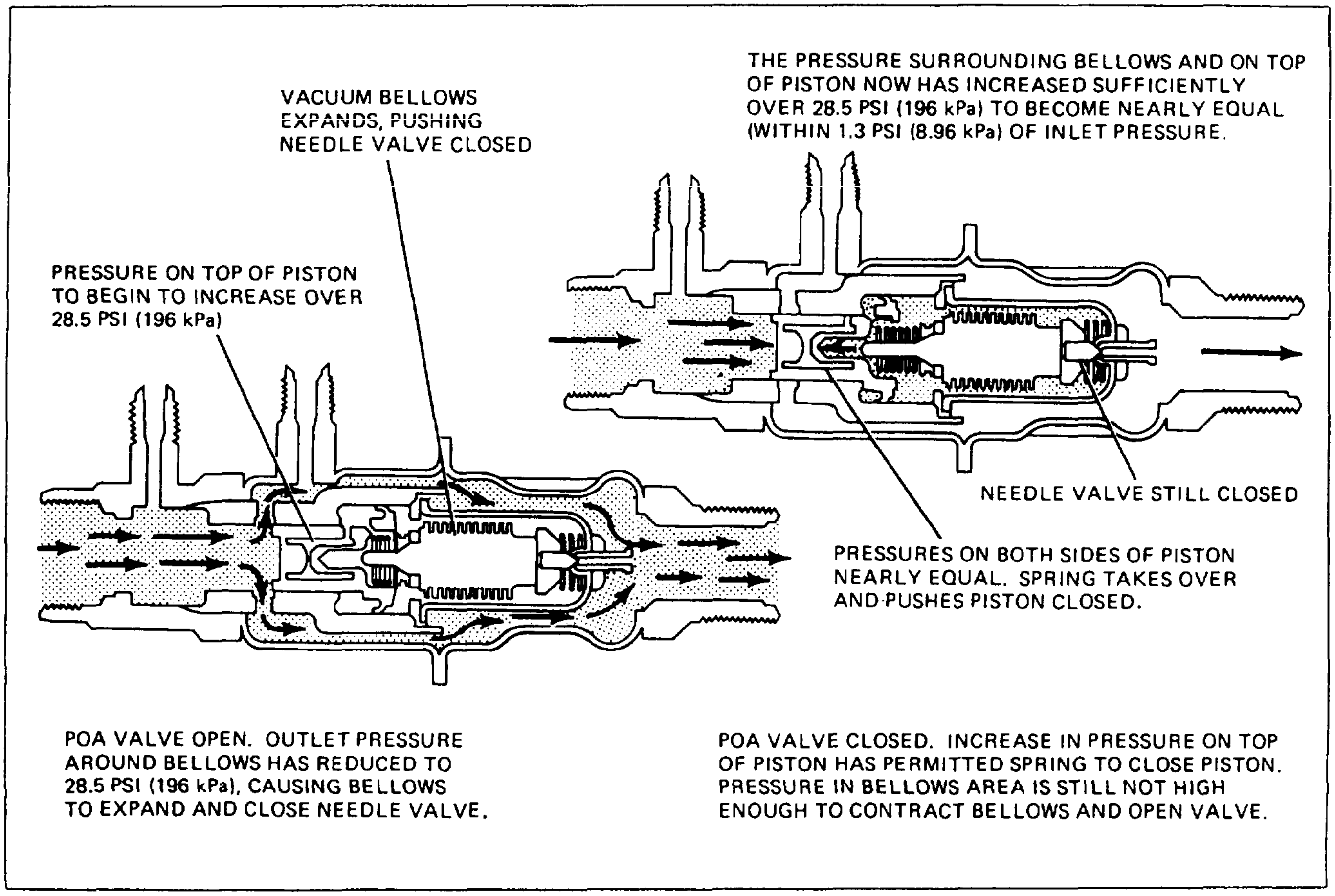


Figure 13-10.—Pilot-operated absolute (POA) suction throttling valve.

Pilot-Operated Absolute Suction Throttling Valve

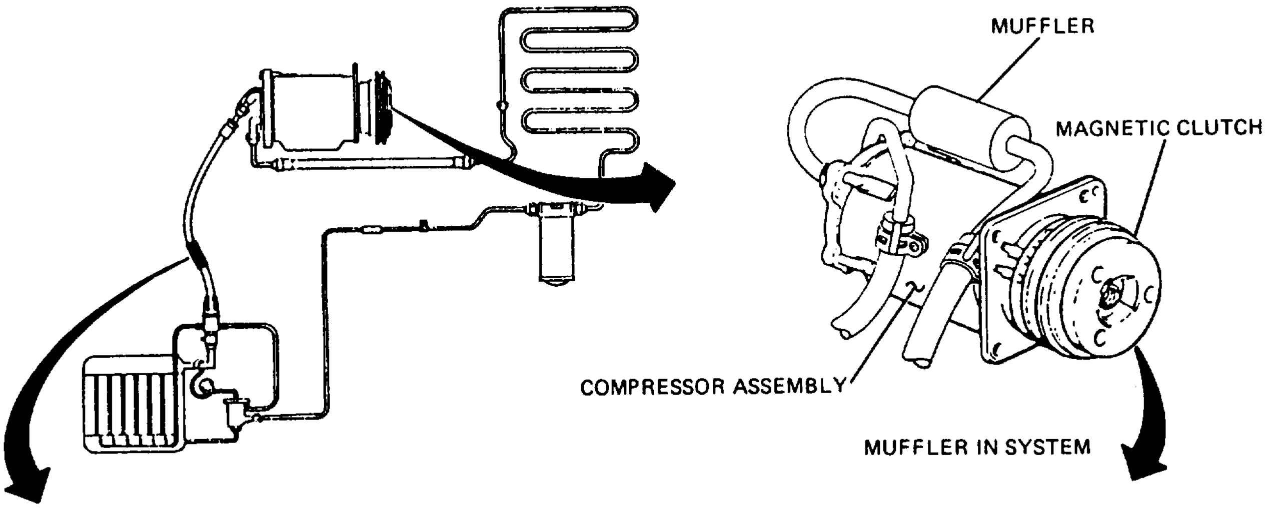
The pilot-operated absolute (POA) suction throttling valve (fig. 13-10) maintains the proper minimum evaprator pressure regardless of compressor speed, evaporator temperature, and changes in altitude. The POA suction throttling valve is operated by a bellows containing an almost perfect vacuum. The expanding and contracting action of the bellows operates a needle valve, regulating its surrounding pressure. As inlet and outlet pressure are equalized, spring pressure closes the valve. The pressure differential across the valve then forces the piston toward the lower pressure, therefore, opening the valve to allow refrigerant to flow.

THE COMPRESSOR

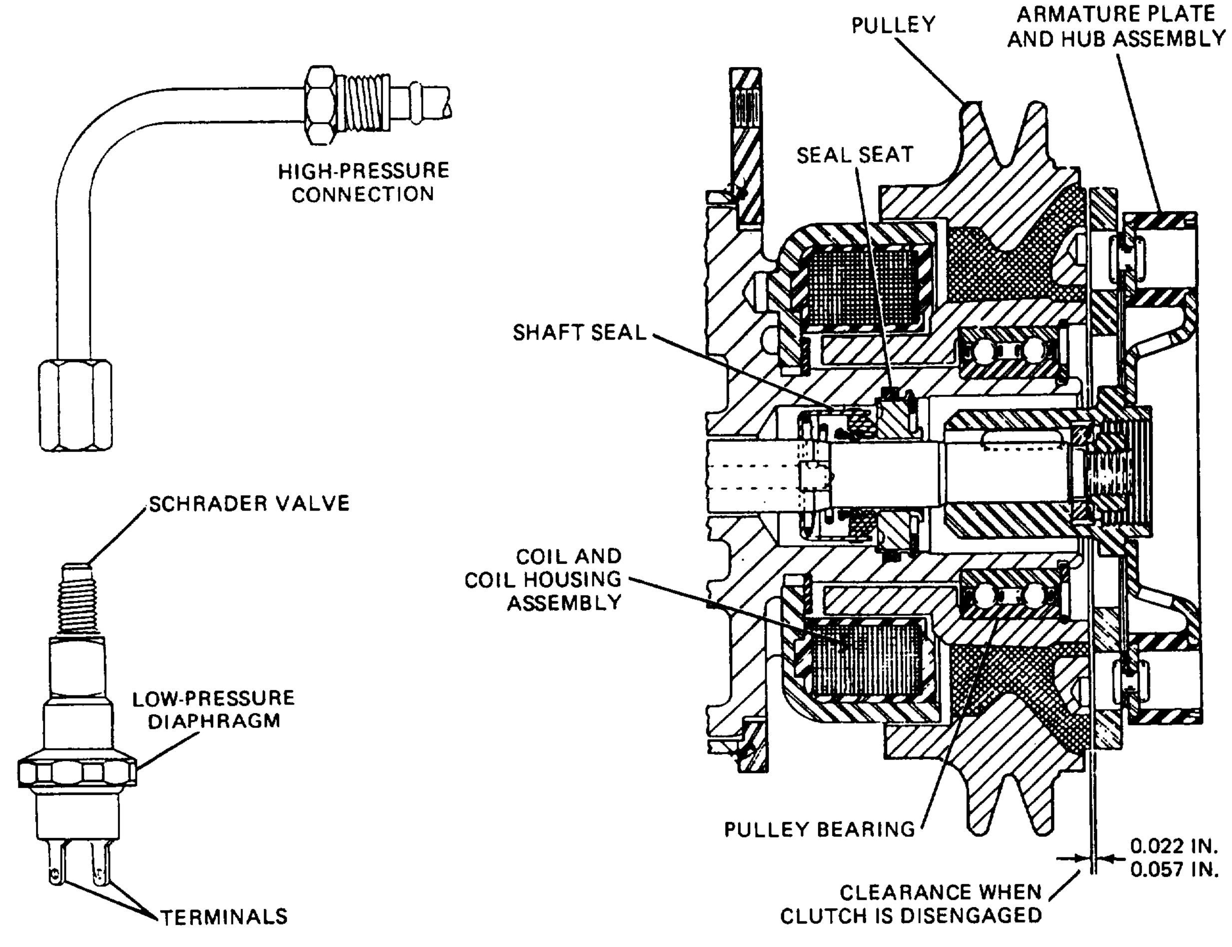
The compressor increases the pressure of vaporized refrigerant exiting the evaporator. When the system is activated, a coil produces a magnetic field that engages the drive pulley to operate the compressor (fig. 13-11). Some compressors tie protected from overheating by a superheat switch located inside the compressor (fig. 13-12). Should the compressor develop an excess amount of heat due to a loss of refrigerant or oil, the superheat switch disengages the compressor by completing a circuit and opening a thermal fuse. Sometimes a compressor discharge pressure switch is used to protect against a low refrigerant condition. (See fig. 13-10.) This switch disengages the compressor drive to protect the system when discharge pressure drops below approximately 35 psi (241 kPa). Often a muffler is used on the outlet side of the compressor (fig. 13-11). The muffler helps reduce compressor pumping noise and line vibrations.

Two-Cylinder Reciprocating Compressor

The two-cylinder reciprocating compressor (fig. 13-13) has two reciprocating pistons fitted into cylinders. A special valve plate, operated by differential pressures, is used to control gas flow.



MUFFLER IN SYSTEM



DISCHARGE PRESSURE SWITCH

COMPRESSOR CLUTCH - SECTION VIEW

Figure 13-11.—Compressor components.

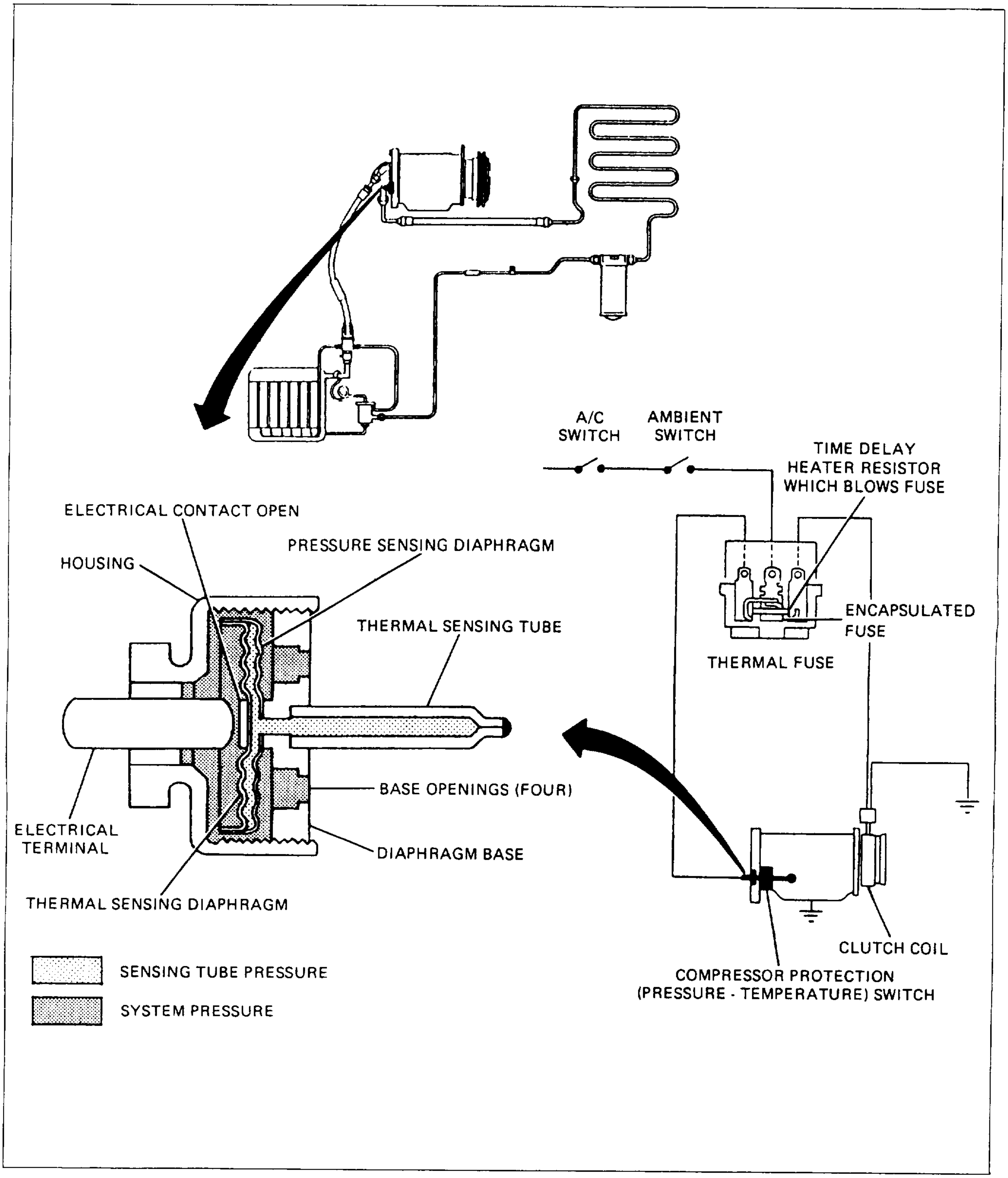


Figure 13-12.—Compressor superheat switch.

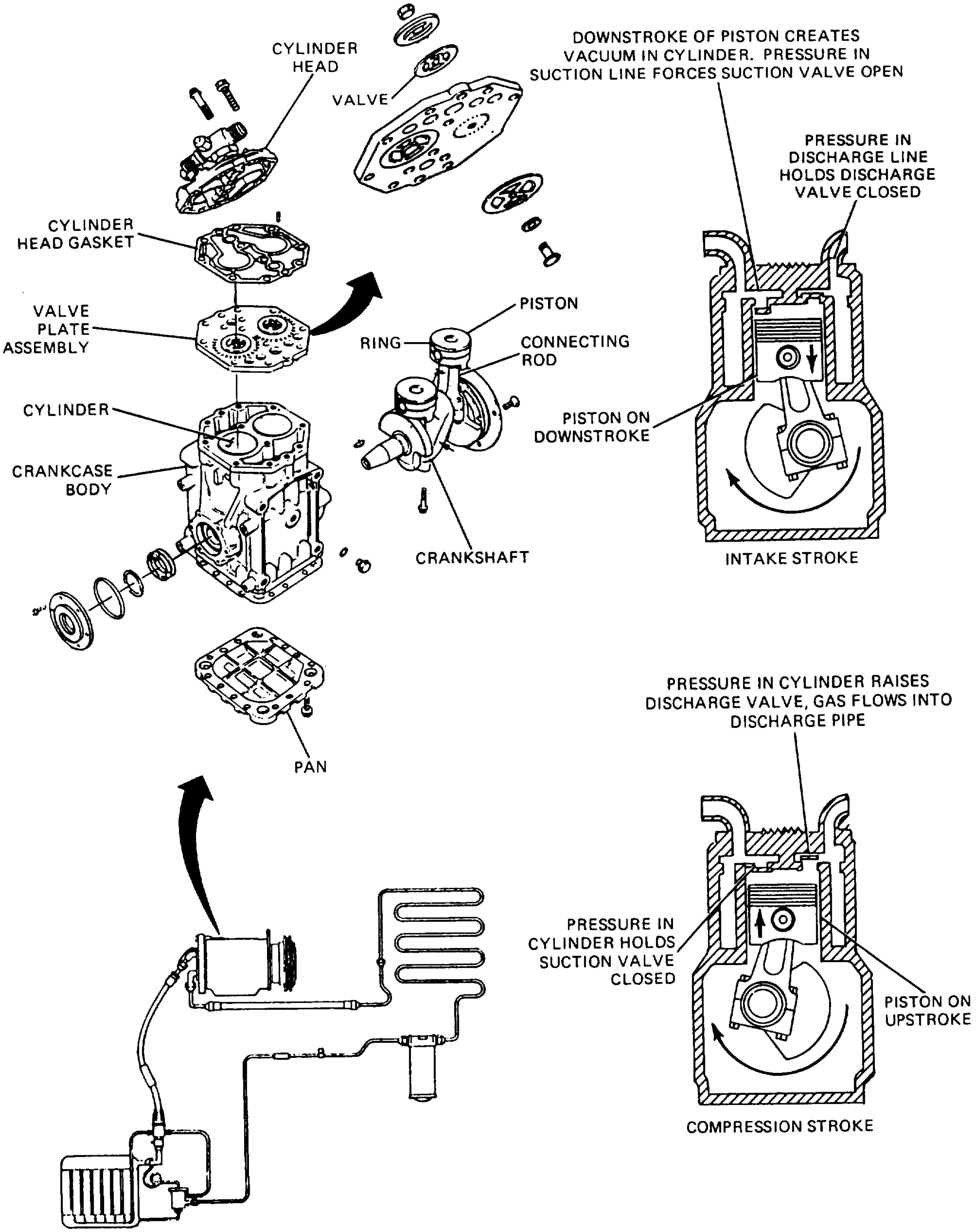


Figure 13-13.—Two-cylinder reciprocating compressor.

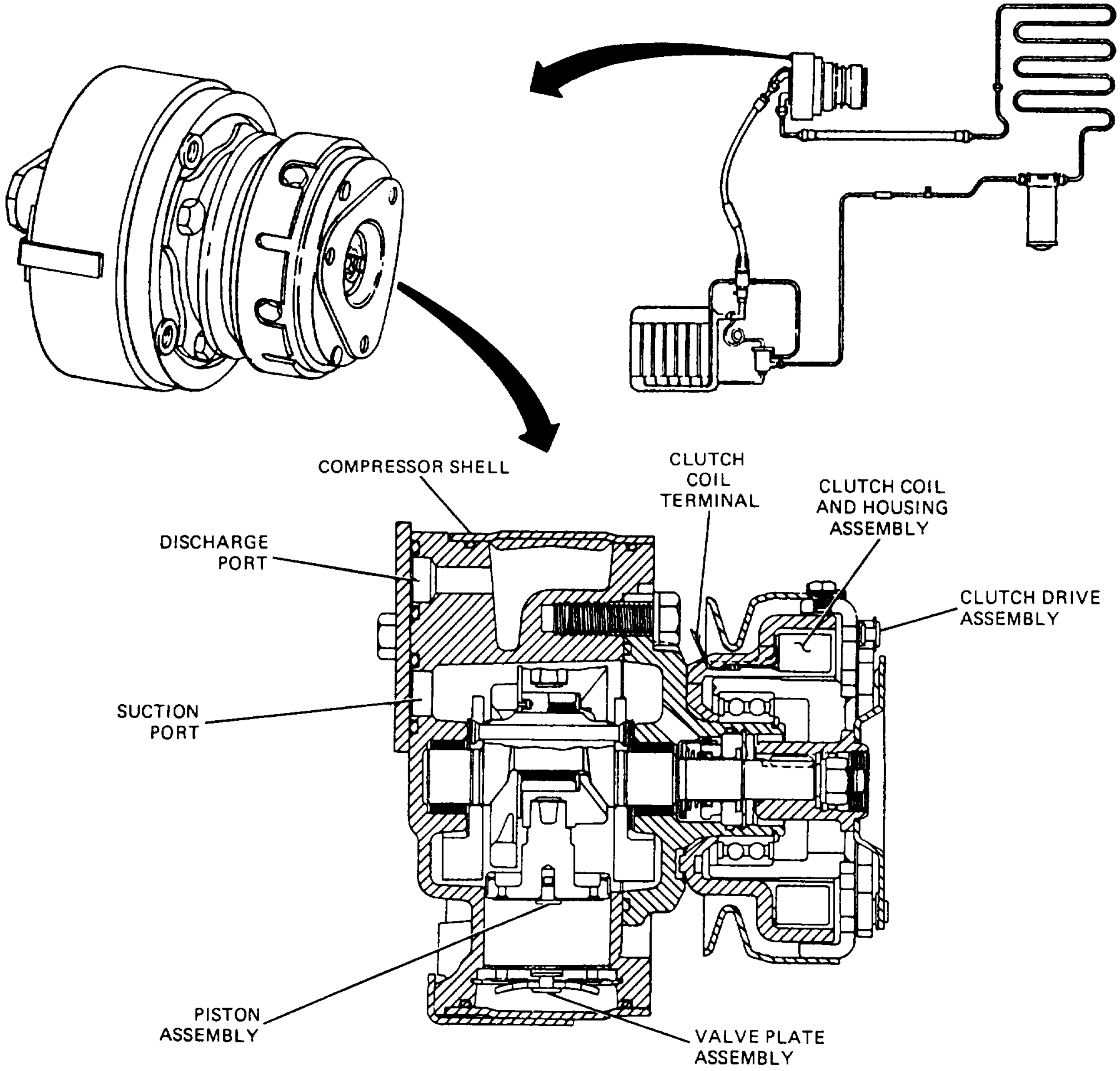


Figure 13-14.—Four-cylinder radial compressor.

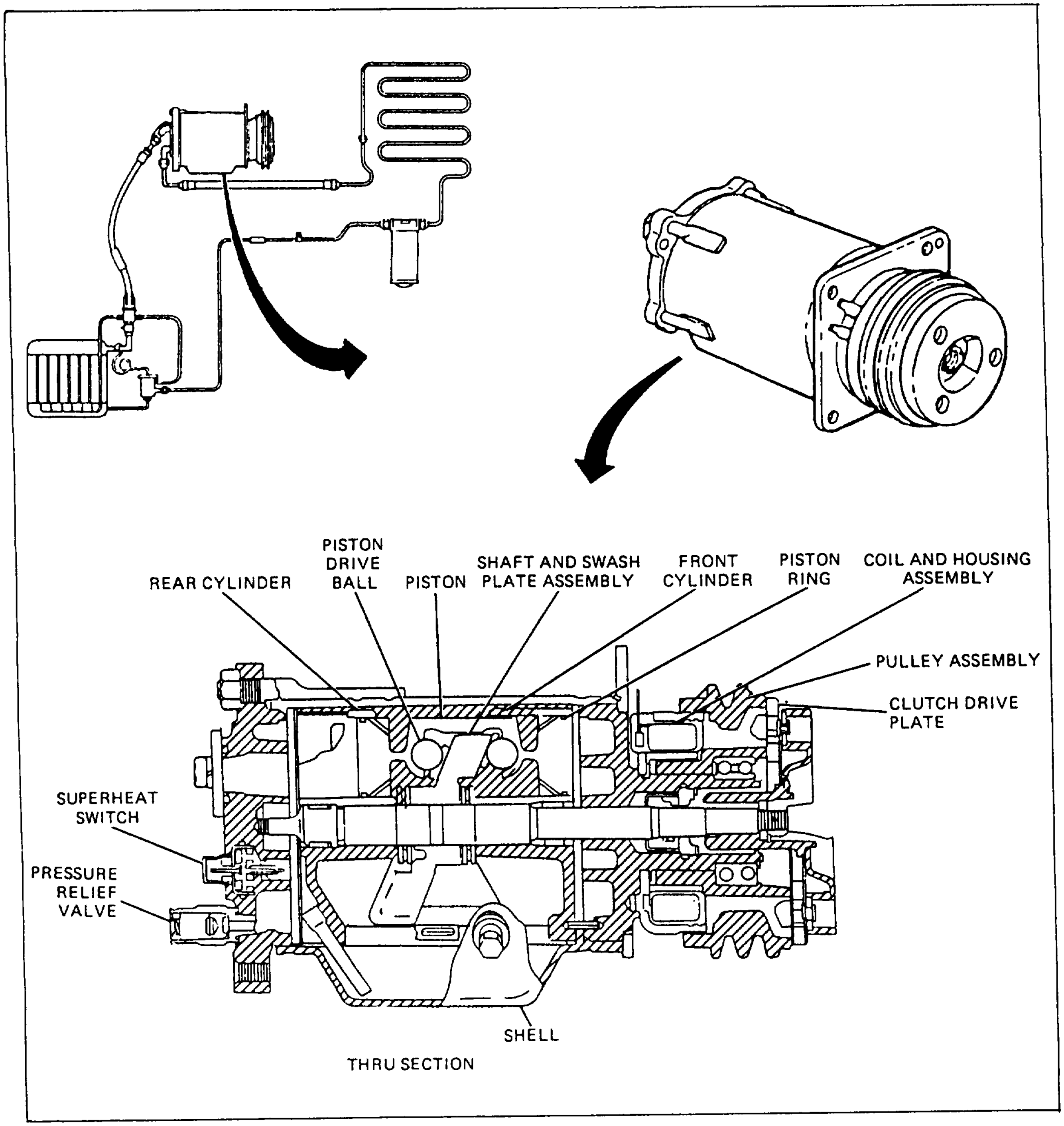


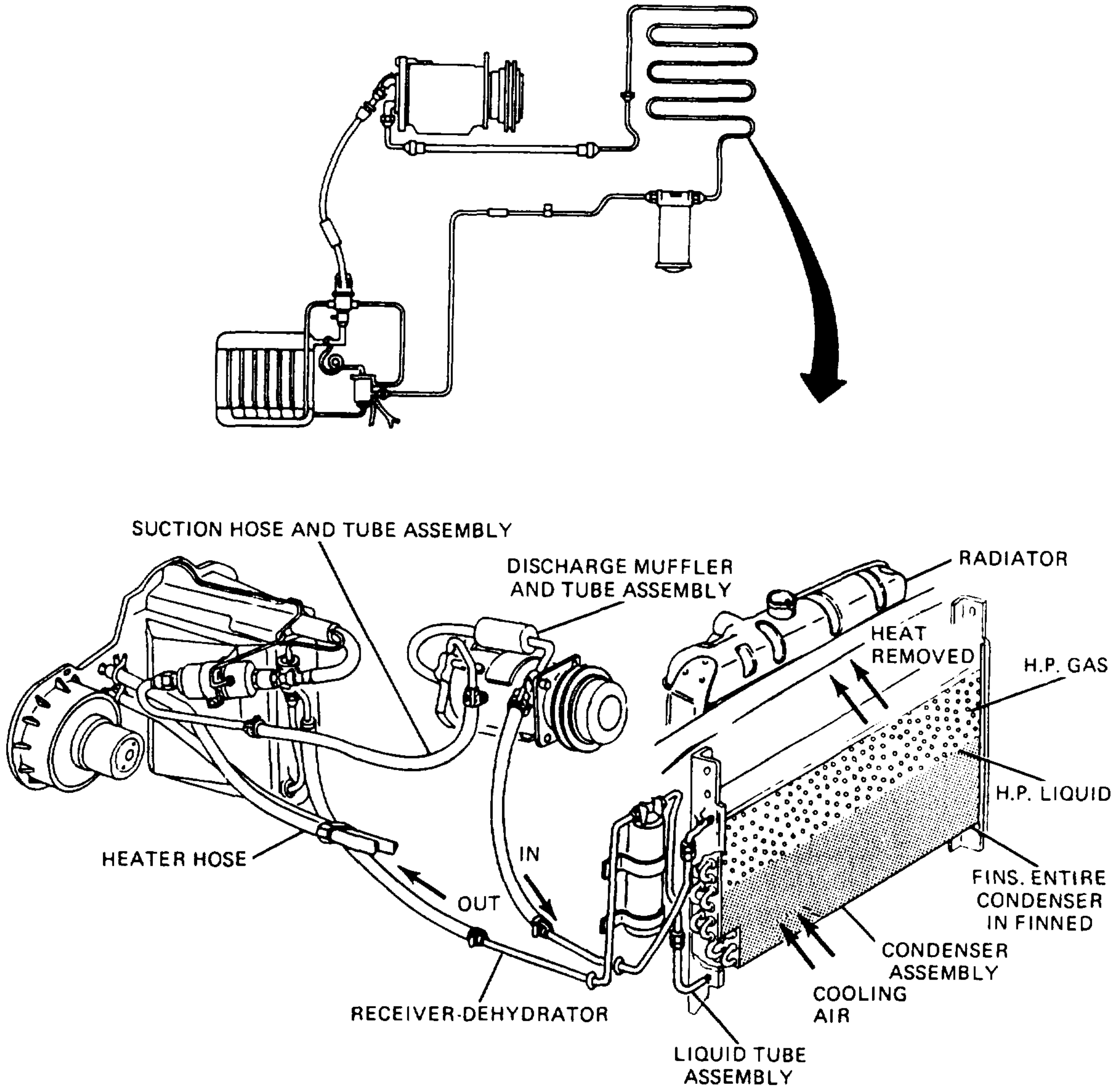
Figure 13-15.—Six-cylinder axial compressor.

Four-Cylinder Radial Compressor

The four-cylinder radial compressor (fig. 13-14) positions four pistons at right angles to each other. The pistons are driven by a central shaft connected to the engine by the electric clutch assembly and V-belt. The radial compact design of the compressor is very popular on the vehicles of today.

Six-Cylinder Axial Compressor

This design uses three double-ended pistons driven by a wobble plate (fig. 13-15). The three cylinders effectively produce a six-cylinder compressor. As the shaft rotates, the wobble plate displaces the pistons perpendicular to the shaft. Piston drive balls are used to cut down friction between the wobble plate and pistons. Piston rings, also, are used to aid in sealing.



TYPICAL CONDENSER.
UNIT MOUNTS IN FRONT OF RADIATOR.

Figure 13-16.—Condenser.

THE CONDENSER

The condenser (fig. 13- 16) is designed to remove heat from the compressed refrigerant, returning it to a liquid state. Generally, condensers are made from a continuous tube looped back and forth through rigidly mounted cooling fins. They are made of aluminum and can encounter pressures of approximately 150 to 300 psig and temperatures ranging from 120°F to 200°F (48°C to 93°C), Usually, the condenser is mounted in front of the radiator and subjected to a steady stream of cooling air.

Refrigeration oil provides lubrication for the compressor. Each system has a certain amount of refrigeration oil (usually approximately 6 to 10 oz (177 to 296 Ml)) added to the system initially. If the system stays sealed, the oil will not break down or need to be changed. Refrigeration oil is highly refined, must be free of moisture, and is designed for use in automotive air-conditioning systems.

MALFUNCTIONS OF COMPONENTS IN THE AIR-CONDITIONING SYSTEM

Problems in automotive air-conditioning systems are not uncommon. An ordinary industrial system does not have to contend with the vibration that a mobile unit does. What follows is a list of common problems and possible causes associated with each air-conditioning component. This is by no means a complete list, so you should have the manufacturer's vehicle repair manual handy.

COMPRESSOR

A thumping noise in the compressor or a cool and sweating compressor suction line accompanied by no cooling is usually caused by too much refrigerant in the system. If there is no moisture in the system, the excess refrigerant should be removed and stored for proper disposal. If moisture is present, you must discharge, evacuate, and recharge the system.

CONDENSER

The condenser unit could have clogged fins that limit the cooling ability of the unit. This could be caused by bugs, leaves, or other debris caught in the tins. This can be corrected by using air pressure to blow out the coils, Check for any icy or frosty spots on the condenser. An abnormally cold spot usually indicates partial restriction inside the condenser coils at that point. Restrictions are normally caused by foreign matter. Correct this condition by discharging and purging the system.

EVAPORATOR

The evapator is normally maintenance free for the life of a vehicle. If the evaporator does develop a leak, it will be necessary to remove the assembly for repair. An evaporator is repaired in the same manner as a radiator. If the evaporator does not get the right amount of refrigerant, the expansion valve is most likely at fault.

EXPANSION VALVE

The most common malfunction in the expansion valve is icing caused by moisture in the air-conditioning system. The system must be discharged and evacuated to remove all moisture. On occasion, the expansion valve may stick open or closed; in this case, you must replace the valve.

RECEIVER/DRIER

The receiver/drier may become saturated with moisture or the filter may become restricted. If the receiver/drier is saturated or restricted, replace it. For any of these repairs, comply with the appropriate maintenance manual.

INSPECTING THE AIR-CONDITIONING SYSTEM FOR LEAKS

Approximately 80 percent of all air-conditioning service work consists of your inspecting for and repairing leaks. Many leaks will be located at points of connection and are caused by vehicle vibration. They may only require the retightening of a flare connection or a clamp. Occasionally, a hose will rub on a structural part to create a leak, or a hose may deteriorate and require replacement. The compressor shaft seal may also require. occasional replacement. Anytime the system requires more than one-half pound of refrigerant after operating during one season, a serious leak is indicated that you must locate and repair. The following information covers a few of the various means of detecting leaks.

CAUTION

When any tests or repairs are being made on a charged air-conditioning system, always wear adequate eye protection.

INTERNALLY CHARGED DETECTOR

This detector is a specially colored leak detector available in a pressurized can and mixed with R-12. It can be introduced into the air-conditioning system with regular charging equipment. When a leak occurs in the system, a bright red-orange spot appears at the point of leakage and remains until it is wiped off. The internal leak detector remains in the system and will spot future leaks in the same manner. A sticker is usually placed under the vehicle hood to indicate that the system is charged with a leak detector.

BUBBLE DETECTOR

The bubble detector is a solution applied externally at suspected leak points. Leaking refrigerant will cause the detector to form bubbles and foam.

ELECTRONIC DETECTOR

This instrument indicates leaks electronically by flashing a light or sounding an alarm. There are several different types of electronic detectors. Directions for using the instruments are furnished by the manufacturer.

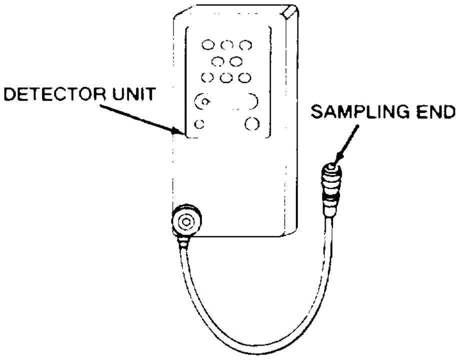


Figure 13-17.—Typical electronic leak detector.

This type of leak detector is the one most widely used today (fig. 13-17).

PROPANE TORCH DETECTOR

The propane torch detector shown in figure 13-18 is still used in the air conditioning field; however, it is rapidly being replaced by electronic devices.

CAUTION

The propane torch detector works by burning small amounts of R-12. In doing so, phosgene gas is produced. Phosgene gas can result in fatal injury; therefore, use this device in well-ventilated areas only.

The propane flame draws the leaking refrigerant over a hot copper alloy reactor plate, and a marked color change of the flame occurs if refrigerant is present.

CAUTION

The vehicle's engine must not be running when making this test.

To conduct this test, you should take the following actions:

1. Open the propane valve and light the torch.
2. Adjust the flame just high enough to heat the reaction to a cherry-red color.

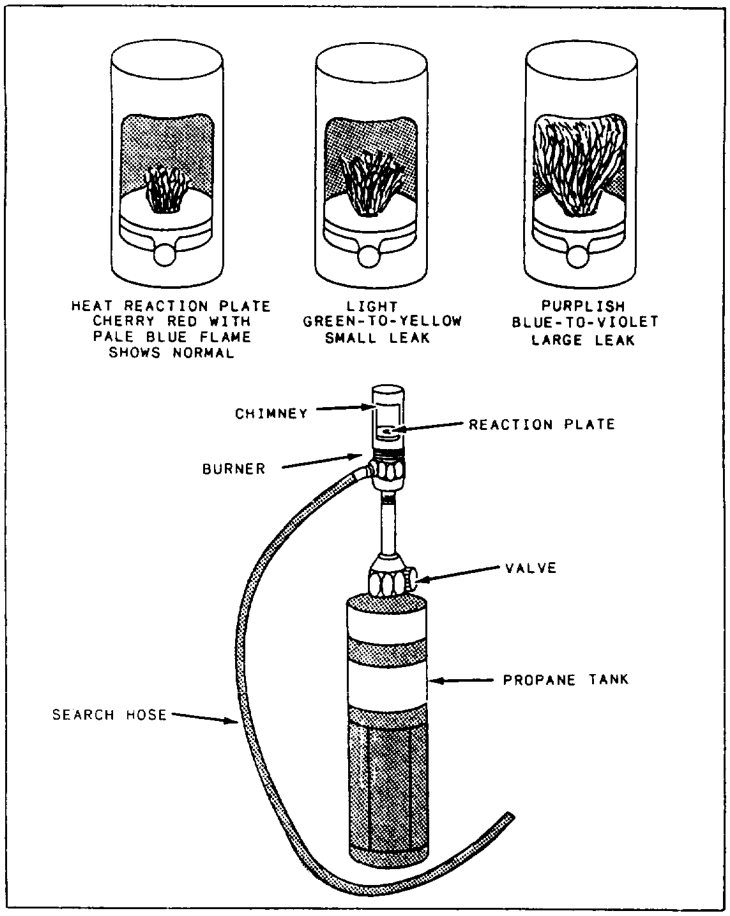


Figure 13-18.—Flame type of leak detector.

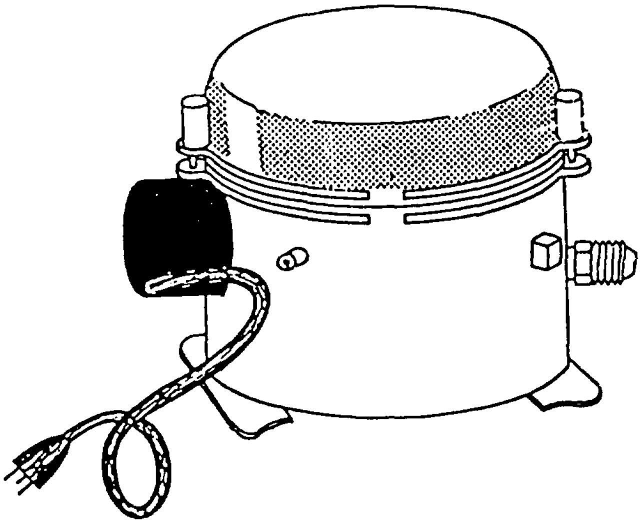


Figure 13-19.—Typical vacuum pump.

3. Reduce the flame when the reaction plate is red, and adjust the top of the flame even with, or slightly above, the reaction plate (just high enough to maintain the cherry-red color).

CAUTION

Too high a flame will soon burn out the reactor plate.

4. Move the search hose slowly around the system. Refrigerant R-12 is heavier than air, so move the search hose under all parts to ensure accurate detection and watch for the flame to change color. A pale blue color is normal and indicates that there is no refrigerant leak. Yellow or yellow-green indicates a small leak, purplish blue indicates a larger leak.

If you do not find a leak, increase the system charge by 50 percent. Add 1 pound to a 2-pound system; and 2 pounds to a 4-pound system. Repeat the detection check. It is often necessary for you to overcharge a system to locate a small or intermittent leak. If you find a leak discharge the refrigerant from the system, repair the damage, and recharge the system. Finally, recheck the system after completing repairs.

When searching for leaks in an air-conditioning system, you are looking very closely at all working parts. Do not waste this time. Check for cracked or worn hoses, loose electrical connections, broken wires, worn drive belts, and loose component mounts. When you detect any damage, make the needed repairs at the same time as the inspection.

PURGING THE AIR-CONDITIONING SYSTEM

Anytime an air-conditioning system is discharged and opened before it is returned to service, it must be evacuated and recharged. To perform this operation, you need certain tools, such as a vacuum pump (fig. 13-19), a gauge manifold set (fig. 13-20), and a leak detector.

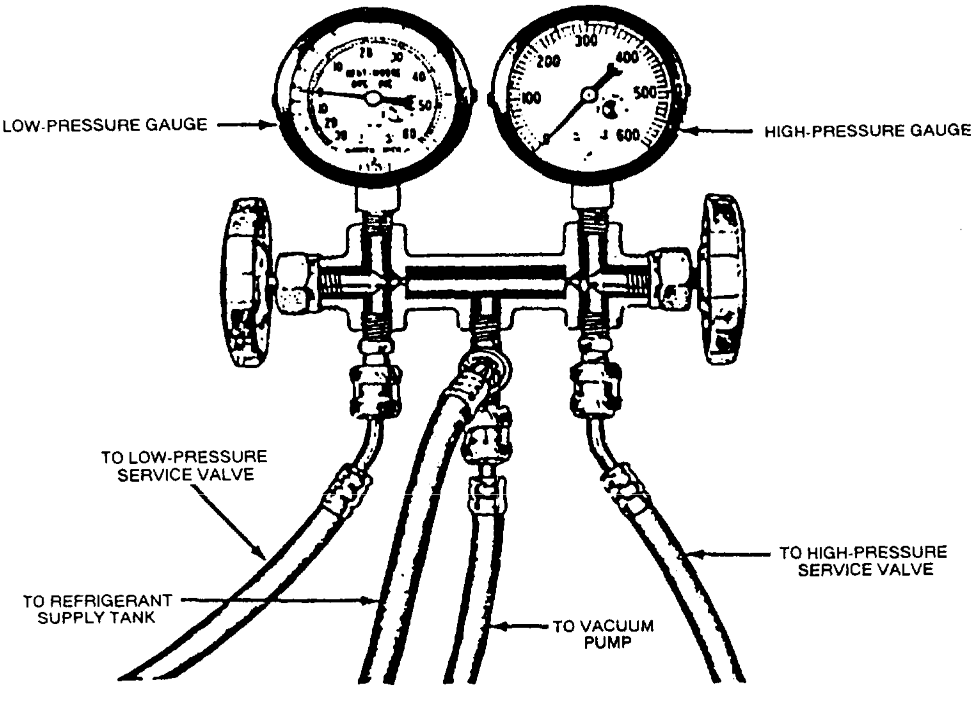


Figure 13-20.—Gauge manifold set.

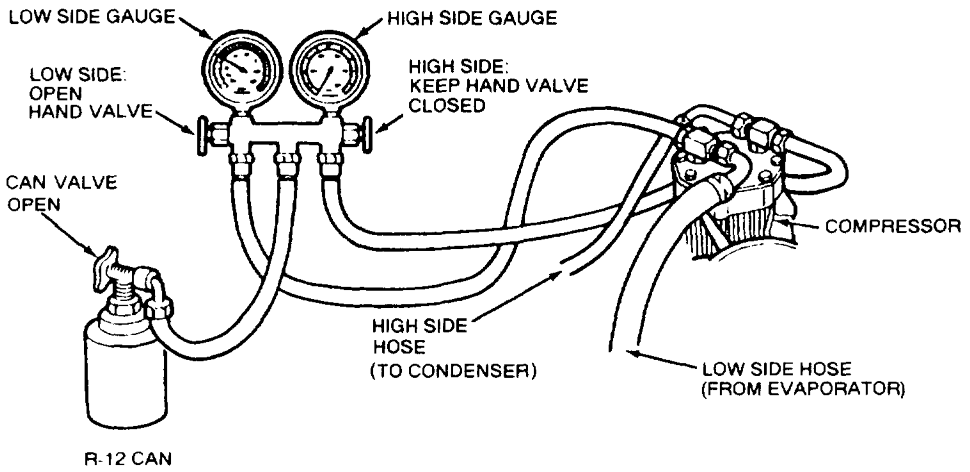


Figure 13-21.—Adding R-12 (low side) for system check.

Using the vacuum pump, draw the system down to at least 29 inches of mercury at sea level and hold it there for at least 30 to 45 minutes. This will remove all moisture from the system.

As the system is being pumped down, the vacuum should drop to the required inches of mercury. If it does not drop, this is an indication of a leak. In which case, you must recharge the system to detect the leak. After you detect the leak, repair the damage and re-evacuate the system.

Once the system is totally evacuated, again-close both valves on the gauge manifold set-disconnect the vacuum pump and connect the refrigerant source.

ATTENTION: Any oil lost during the discharge of refrigerant must be replaced or damage to the compressor will result.

ATTENTION: During discharge of an automotive air-conditioning system, the vehicle engine must NOT be running.

In the past, when a system was discharged before disassembly, the standard practice was to vent the refrigerant into the atmosphere. For environmental and legal reasons, this is no longer permissible. The proper procedure is to use a refrigerant recovery/recycling device (fig. 13-18) and reuse the refrigerant. You are to turn in excess used refrigerant to the defense recycling and management office (DRMO) for proper disposal.

ATTENTION: Disposal instructions for refrigerants may not be the same at different naval stations. Before you take any action concerning R-12 or any refrigerant, contact your supply department for proper disposal instructions.

ADDING REFRIGERANT TO THE AIR-CONDITIONING SYSTEM

Now that the system is pumped down, leave the gauge manifold set attached and attach your refrigerant source, as shown in figure 13-21. You are to take the following actions:

1. Loosen the center hose connection at the gauge manifold set.

2. Open the can valve for several seconds to purge air from the center hose.

3. Tighten the hose connection and close the can valve.

4. Start the vehicle engine and operate the air conditioner.

5. With the system operating, slowly open the low-side manifold hand valve to allow refrigerant to enter the system.

NOTE: The low side of the system is the suction side, and the compressor will pull the refrigerant from the can into the system.

6. With the container in an upright (vapor) position, add the refrigerant until the sight glass clears or the test set gauge readings are normal.

7. Rock the refrigerant can from side to side to increase the flow of refrigerant into the system.

CAUTION

Never turn a can into a position where liquid refrigerant will flow into the system.

Table 13-1.—Temperature pressure relationship

Readings–Low Side		Readings–High Side	
Evap. Temp. (°F)	Low Side Gage	Ambient Temp. (°F)	High Side Gage
10	2	60	95-115
12	6	65	105-125
14	10	70	115-135
16	14	75	130-150
18	18	80	150-170
20	20	85	165-185
22	22	90	175-195
24	24	95	185-205
26	27	100	210-230
28	29	105	230-250
30	32	110	250-270
35	36	115	265-285
40	42	120	280-310
45	48		
50	53		
55	58		
60	62		
65	66		
70	70		

Temperature Pressure Relationship

8. Close the low-side manifold valve and the refrigerant can valve.

9. Continue to stabilize the system, and check for normal refrigerant charge.

FUNCTIONAL TESTING OF THE AIR-CONDITIONING SYSTEM

Functional testing is required to establish the condition of all components in the system. The engine must be running and the air-conditioning system operating when performing this test. After the initial charge of refrigerant is installed into the system, watch the manifold gauge set. Correct pressure should be 15 to 30 psi for the low side and 175 to 195 psi for the high side. Evaluate the reading you receive against the standard chart in table 13-1. If the vehicle you are working on is equipped with a sight glass(fig. 13-4), the bubbles should disappear at the correct pressures. Close the low side gauge manifold set hand valve. Check the temperature of the air exiting the cooling duct. It should be close to 40°F with the blower running on low speed. Stop the engine and disconnect the gauge manifold set.

As you probably know, the refrigerant R-12 is no longer considered environmentally safe to use. As R-12 is being phased out, the new refrigerant R-134A is being brought on line, but not without a few problems.

Using anew refrigerant that works under higher pressure means changes in some of the components used with automotive air-conditioning systems. Some of the tools will no longer work with the new

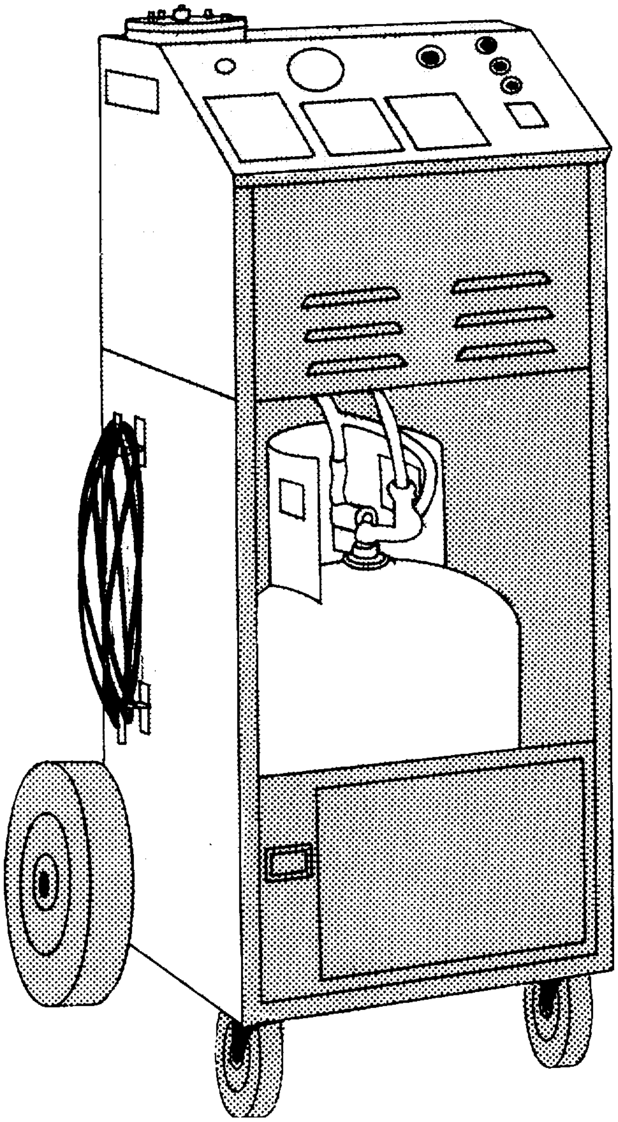


Figure 13-22.—Typical refrigerant recycling recovery device.

refrigerant; for example, the flame type of leak detector will not function, and your recovery, recycling systems (fig. 13-22) must be kept separate and not allowed to contaminate each other.

The components of the system also have some differences. Hoses of an R-12 system will not withstand the chemicals in a system using R-134A. Also, the lubrication oils are not compatible and must not be mixed.

Finally, to reduce the chances of a mix-up of parts, the threaded fittings of the new system components are purposely incompatible with the old.

The chance of a military shop having to convert an R-12 system to a R-134A system is slim. The information here is to make you aware of the changes only.

OTHER REFRIGERANTS

Now, we will simply say do not mix refrigerants, With all the changes in the air-conditioning industry, there are some refrigerants on the market that are not compatible with either system. These refrigerants are merely blends of existing refrigerants and, in some cases, are highly flammable. In other cases, these blend refrigerants may break down the desiccant in the receiver/drier and pass the debris into the rest of the system, clogging the expansion valve/orifice tube and possibly ruining the compressor.

DO NOT use any of these so-called blend refrigerants. For that matter, DO NOT manufacture your own adapters to cross match an R-12 to an R-134A system. You will only contaminate the system and cause damage to your equipment. Once again DO NOT mix refrigerants.

CERTIFICATION

Most states require or, before long, will require mechanic certification when working with automotive air-conditioning systems.

HAZARDOUS WASTE

When possible, recycle uncontaminated R-12 or R-134A for reuse. Return excess uncontaminated refrigerants to DRMO for disposition and disposal. Remember, any refrigerant blend is unusable and you should turn it in to DRMO, under applicable naval station instructions, as hazardous waste.

ASSIGNMENT 11

Textbook Assignment: "Wheel and Track Alignment and Air-Conditioning Systems," pages 12-5 through 13-21.

11-1. In what increments is toe-in measured?

1. Degrees
2. Fractions of an inch
3. Meters
4. Inches

11-2. Of all the alignment angles, Which is the most critical?

1. Caster
2. Camber
3. KPI
4. Toe-in

11-3. Toe-in is a tire-wearing angle.

1. T
2. F

11-4. If the front wheels do not assume a toed-out position when rounding a curve, what effect, if any, will this have on the tires?

1. Excessive tire wear
2. The tires will overheat
3. The tires will shimmy
4. None

11-5. At what point in the alignment process do you adjust toe-in?

1. Before camber
2. After camber
3. First adjustment
4. Last adjustment

11-6. If the upper ball joint carries the vehicle load, at what point should you place the jack to raise the vehicle?

1. On the outer end of the upper control arm
2. In the center of the upper control arm
3. Under the frame
4. In the center of the lower control arm

11-7. On ball joints with wear indicators, at what point should you replace the ball joint?

1. When the indicator is 1/16 of an inch out of the ball joint
2. When the indicator is flush with the ball joint
3. When the indicator recedes into the ball joint 1/16 of an inch
4. When the indicator recedes .25 of an inch into the ball joint

11-8. You should make the alignment adjustments in what order?

1. Toe–in, camber, caster
2. Camber, toe-in, caster
3. Caster, camber, toe-in
4. Caster, toe-in, camber

11-9. When you move the upper control arm out and to the rear, what adjustment have you made?

1. Decreased camber and increased caster
2. Increased camber and decreased caster
3. Decreased camber and decreased caster
4. Increased camber and increased caster

11-10. To adjust the toe-in of a vehicle, you must adjust which of the following components in equal amounts?

1. Upper control arms
2. Lower control arms
3. Tie rods
4. Steering knuckle arms

11-11. When turntables are used to check turning radius, the steering mechanism is correct, if when one wheel is turned 20 degrees, the other wheel turns about how many degrees?

1. 23
2. 22
3. 21
4. 20

11-12. When the driver complains that his vehicle “wanders,” you should check for which of the following probable causes?

1. Low tire pressure
2. Incorrect caster
3. Incorrect toe
4. All of the above

11-13. Excessive toe-in or toe-out will cause what type of tire wear?

1. Tread wear at both sides
2. Tread wear at the center
3. Tread wear that is featheredged
4. Tread wear only on one side

11-14. On a typical dozer, the use of track guiding guards keep the track in proper alignment. What are these guards called?

1. Spring plates
2. Wear bars and plates
3. Grouser plates
4. Equalizer bars

11-15. The front guiding guards receive the track from which component?

1. The roller
2. The chain
3. The idler
4. The sprocket

11-16. If two objects have different temperatures and are close to one another, heat energy travels in what direction, if any?

1. From the cooler object to the warmer object
2. From the warmer object to the cooler object
3. None; heat energy travels only when the objects actually touch one another

11-17. The boiling pressure of any liquid is increased in what way?

1. By raising the evaporation point
2. By decreasing the pressure on the liquid
3. By increasing the pressure on the liquid
4. By lowering the evaporation point

11-18. Refrigerant -12 boils at what temperature?

1. +21.7 F
2. -2.17 F
3. -2.17 C
4. -21.7 F

11-19. Refrigerant -22 is hazardous for what reason?

1. It is corrosive
2. It is a fire hazard
3. It has poor heat transfer qualities and must be used at higher pressures

11-20. A sizeable amount of refrigerant-12 in the atmosphere may cause what result?

1. Fire
2. Explosion
3. Suffocation

11-21. When warming a container of refrigerant-12, you should not exceed what temperature?

1. 90°F
2. 100°F
3. ll0°F
4. 125°F

11-22. In an air-conditioning system, what is the purpose of the receiver/dryer?

1. It collects high-pressure refrigerant
2. It lowers the pressure of the refrigerant
3. It raises the pressure of the refrigerant
4. It changes the refrigerant from a liquid to a gas

11-23. In what state is the refrigerant in as it exits the evaporator?

1. A liquid
2. A gas
3. Boiling
4. Condensing

11-24. What is the purpose of the desiccant located inside of the receiver?

1. It relieves pressure in the system
2. It acts as a filter
3. It acts as a bypass for the refrigerant
4. It removes moisture from the system

11-25. The relief valve opens between approximately what pressure range?

1. 200 to 300 psi
2. 300 to 400 psi
3. 400 to 450 psi
4. 450 to 500 psi

11-26. When you observe bubbles in the site glass of an air conditioning system, what does it indicate?

1. That no refrigerant is in the system
2. That the system is overcharged
3. That the system is undercharged
4. That too much oil is in the system

11-27. The refrigerant expansion system is designed to perform what function?

1. To increase refrigerant pressure
2. To reduce refrigerant pressure
3. To regulate refrigerant entering the evaporator
4. Both 2 and 3 above

11-28. The expansion tube retards refrigerant flow and performs what other function?

1. It acts as a filter
2. It raises refrigerant pressure
3. It regulates refrigerant entering the condenser
4. It opens the valve to allow the refrigerant to flow

11-29. The evaporator should be kept above what temperature in degrees?

1. 30°F
2. 32°F
3. 40°F
4. 45°F

11-30. In an air-conditioning system, where is the thermostatic switch sensing bulb located?

1. In the airstream after the evaporator
2. In the airstream before the evaporator
3. On the compressor clutch
4. In the airstream after the condenser

11-31. In an air-conditioning system that uses a hot gas bypass valve, where is the valve located?

1. On the compressor
2. On the inlet side of the evaporator
3. On the outlet side of the evaporator
4. On the condenser

11-32. In an air-conditioning system, what does the suction-throttling valve limit?

1. Condenser operation
2. Evaporator operation
3. The amount of high-pressure vapor entering the compressor
4. The amount of low-pressure vapor entering the compressor

11-33. By what means does the suction-throttling valve close as the pressure drops on the inlet side?

1. Oil pressure
2. Atmospheric pressure
3. Valve spring pressure
4. Both 2 and 3 above

11-34. In an air-conditioning system that uses a pilot-operated absolute suction-throttling valve, by what means does the valve close as the inlet and outlet pressures equalize?

1. Spring pressure
2. Outlet pressure
3. Inlet pressure
4. Oil pressure

11-35. A compressor discharge pressure switch is used to protect against what air-conditioning system problem?

1. Overcharging
2. Overspeeding
3. Low refrigerant
4. High-discharge pressure

11-36. The air-conditioning system compressor muffler reduces noise along with what other problem?

1. High-discharge pressure
2. Low-discharge pressure
3. Line vibrations

11-37. In a four-cylinder radial compressor, the pistons are driven by what means?

1. By a central shaft
2. By gears
3. By a wobble plate
4. By a special valve plate

11-38. In a six-cylinder axial compressor, what is the purpose of the piston drive balls?

1. To align the pistons
2. To assist in shaft rotation
3. To cut down friction
4. To aid in sealing

11-39. In an air-conditioning system, where is the condenser usually mounted?

1. Within the engine compartment
2. In front of the radiator
3. In back of the radiator
4. In the driver’s compartment

11-40. Approximately how much refrigeration oil is contained within each system?

1. 1 pint
2. 2 to 4 ounces
3. 4 to 6 ounces
4. 6 to 10 ounces

11-41. In an air-conditioning system, when the compressor produces a thumping noise and no cooling, it is an indication of what condition?

1. A clogged condenser
2. A faulty evaporator
3. Low oil level
4. Too much refrigerant

11-42. An abnormally cold spot on a condenser could indicate what condition?

1. A faulty compressor
2. A partially clogged condenser
3. A faulty evaporator
4. Too much refrigerant

11-43. When, if ever, should maintenance be performed on an evaporator?

1. Every six months
2. Each year
3. Every other A-type PM
4. Never; normally maintenance is not required

11-44. What causes most expansion valve problems?

1. Moisture
2. Lack of refrigerant
3. Too much refrigerant
4. A faulty thermal switch

11-45. What action must you take if the receiver/dryer is saturated?

1. Remove it and replace the desiccant
2. Evacuate the system and recharge it
3. Replace the receiver/dryer

11-46. A serious leak is indicated by the loss of how much refrigerant after a season of operation?

1. 1/4 lb
2. 1/2 lb
3. 3/4 lb
4. 1 lb

11-47. In an air-conditioning system that is internally charged with a leak detector, how is a leak indicated?

1. By a high-pitch alarm
2. By bubbles at the leak point
3. By foaming at the leak point
4. By a bright red-orange spot at the point of leak

11-48. Which of the following is the most widely used refrigerant leak detector in use today?

1. Flame type
2. Bubble
3. Electronic
4. Internal charge

11-49. A flame-type leak detector in operation will produce a poisonous gas that could be fatal in a closed working space.

1. True
2. False

11-50. When you are using a flame-type leak detector, a large leak is indicated by what color of flame?

1. A pale blue flame
2. A purplish blue flame
3. A yellow flame
4. A yellow-green flame

11-51. The air-conditioning system that is being evacuated must be drawn down to 29 inches and held for how many minutes?

1. 10 to 15
2. 15 to 30
3. 30 to 45
4. 45 to 60

11-52. During the discharge before evacuation, the air-conditioning system is in what operational state, if any?

1. Running on high
2. Running on low
3. None; it is not in operation

11-53. What is normally done with excess used refrigerant?

1. It is pumped into containers and turned into DRMO
2. It is turned into the local public works department
3. It is held in the shop for reuse

11-54. What is another name for the low side of the compressor?

1. High-pressure side
2. Low-pressure side
3. Fluid side
4. Suction side

11-55. During the functional testing of an air-conditioning system, what should be the temperature of the air exiting the cooling duct?

1. 32°F
2. 35°F
3. 40°F
4. 45°F

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