Chapter 1

Technical Administration

Topics

1.0.0 Maintenance Administration

2.0.0 Maintenance Support

To hear audio, click on the box.

Overview

The higher you ascend on the enlisted ladder, the more valuable you are to the Navy. Advancement brings both increased rewards and responsibilities. You must be able to perform various administrative duties within the Construction Mechanic rate, such as opening and closing OPNAV 4790/2K and OPNAV 4790/CK Completed Maintenance Action orders, maintaining history jackets, updating preventive maintenance record cards, and repair parts. The type of activity to which you are attached will determine the way you should carry out your administrative responsibilities.

Objectives

When you have completed this chapter, you will be able to do the following:

1. Identify the personnel and their functions, and the required paperwork associated with a Battalion Equipment Maintenance Program.
2. Recognize the principles and techniques of administering the Civil Engineering Support Equipment (CESE) maintenance program.
3. Recognize key items of maintenance support required for the Civil Engineering Support Equipment (CESE) maintenance program.

Prerequisites

None

This course map shows all of the chapters in Construction Mechanic Basic. The suggested training order begins at the bottom and proceeds up. Skill levels increase as you advance on the course map.

Automotive Chassis and Body	↑	
Brakes		
Construction Equipment Power Trains		C
Drive Lines, Differentials, Drive Axles, and Power Train Accessories		M
Automotive Clutches, Transmissions, and Transaxles		
Hydraulic and Pneumatic Systems		
Automotive Electrical Circuits and Wiring		B A
Basic Automotive Electricity		S
Cooling and Lubrication Systems		I
Diesel Fuel Systems		C
Gasoline Fuel Systems		
Construction of an Internal Combustion Engine		
Principles of an Internal Combustion Engine		
Technical Administration		

Features of this Manual

This manual has several features which make it easy to use online.

- Figure and table numbers in the text are italicized. The figure or table is either next to or below the text that refers to it.
- The first time a glossary term appears in the text, it is bold and italicized. When your cursor crosses over that word or phrase, a popup box displays with the appropriate definition.
- Audio and video clips are included in the text, with an italicized instruction telling you where to click to activate it.
- Review questions that apply to a section are listed under the Test Your Knowledge banner at the end of the section. Select the answer you choose. If the answer is correct, you will be taken to the next section heading. If the answer

is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

- Review questions are included at the end of this chapter. Select the answer you choose. If the answer is correct, you will be taken to the next question. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

1.0.0 MAINTENANCE ADMINISTRATION

Administrative guidelines concerning Civil Engineering Support Equipment (CESE) maintenance are contained in Naval Facilities Publication 300 (NAVFAC P-300), *Management of Civil Engineering Support Equipment* and the most current version of Commander, First Naval Construction Division 11200.2 (*COMFIRSTNCDINST 11200.2).*

1.1.0 Maintenance Organization

The organization of equipment maintenance work centers varies in the following aspects:

- Number and types of assigned equipment
- Number and experience of personnel
- Work hours
- Number of shifts
- Environmental conditions
- Mission of the activity

The typical Naval Mobile Construction Battalion's (NMCB's) maintenance organization is divided into several shops:

- The Light Shop is responsible for the planned maintenance and breakdown repair of all equipment assigned by the Maintenance Supervisor (generally all equipment codes beginning with 0). The number of crews is dictated by manpower and equipment quantity assigned. This shop conducts Preventive, Corrective, and Inactive Equipment Maintenance (IEM) per Naval Sea Systems Command Instruction 4790.8B (NAVSEAINST 4790.8B) on all Light Shop CESE assigned to IEM. This shop also maintains repair parts for assigned CESE.

- The Heavy Shop is responsible for the planned maintenance and breakdown repair of all equipment assigned by the Maintenance Supervisor (generally all non-light shop equipment minus the 5000 shop equipment). The priority of this shop is generally in support of the battalion's construction effort. This shop conducts Preventive, Corrective, and IEM per NAVSEAINST 4790.8B on all Heavy Shop CESE assigned to IEM. This shop also maintains repair parts for assigned CESE.
- The Support Shops are normally comprised of the 5000 Shop (EC 5000-5999), Steel Shop, MR Shop, Tire Shop, and Paint Shop. These shops are specialty shops that are tasked with supporting the other shops with their particular expertise. These shops also maintain repair parts for assigned CESE.
- The Crane Shop is responsible for the planned maintenance and corrective repair of all cranes and ensuring all maintenance guidelines are adhered to per NAVFAC P-307.

NOTE

At no time will cranes be put in IEM Status I.

All cranes will be kept alive and cycled per *COMFIRSTNCDINST 11200.2.* Cranes on deadline are maintained in IEM Status II until removed from deadline.

The following personnel organization is based on a typical Naval Mobile Construction Battalion operation, but the functions are applicable to small shops where one person may perform several functions.

1.1.1 Maintenance Supervisor/Division Maintenance Chief

The Maintenance Supervisor/Division Maintenance Chief (A4) is usually the senior mechanic assigned to an activity, normally a Construction Mechanic Senior Chief (CMCS) who has successfully completed the Ship's Maintenance and Material Management (3-M) Personnel Qualifications Standards (PQS) up to Section 304. The A4 is tasked with ensuring proper 3-M maintenance and repair of all automotive, construction, and material and weight handling equipment assigned to the NMCB/Unit. Duties and responsibilities are described in *COMFIRSTNCDINST 11200.2* and Ships' Maintenance and Material Management (3M) Manual, NAVSEA Instruction 4790.8B.

1.1.2 Work Center Supervisor

The Work Center Supervisor (WCS) functions under the supervision of the Maintenance Supervisor/Division Maintenance Chief. The Supervisor is normally a Construction Mechanic Chief (CMC) who has successfully completed 3-M PQS up to Section 303. The WCS has all the administrative and military duties of a Platoon Commander in addition to the assigned functional responsibilities and Ships' Maintenance and Material Management (3M) Manual, NAVSEA Instruction 4790.8B.

The WCS uses SKED every week to develop the assigned shop's Weekly 13 Week Accountability Log. The A4/Division Maintenance Chief and WCS ensures that project critical equipment has priority in the shop. Responsibilities of the WCS are detailed in *COMFIRSTNCDINST 11200.2*.

1.1.2.1 Light Shop Work Center Supervisor

The Light Shop WCS is responsible to the Maintenance Supervisor/Division Maintenance Chief for scheduled Preventive, Corrective, and IEM maintenance requirements for over the road, material handling equipment (MHE) and personnel carrying CESE.

1.1.2.2 Heavy Shop Work Center Supervisor

The Heavy Shop WCS is responsible to the Maintenance Supervisor/Division Maintenance Chief for scheduled Preventive, Corrective, IEM, and field service maintenance on ALL CONSTRUCTION CESE.

1.1.2.3 Crane Crew Work Center Supervisor

The Crane Crew WCS ensures that preventive and corrective maintenance are performed on all cranes assigned. All scheduled preventive maintenance is performed as per Maintenance Requirement Card (MRC).

1.1.2.4 Support Shop Work Center Supervisor

The Support Shop WCS is responsible to the Maintenance Supervisor for the maintenance and repair of CESE starting with an Equipment Code (EC) of “5” and/or as directed by the Maintenance Supervisor. The WCS identifies and coordinates all maintenance requirements through the shop that necessitate the CM/EO/CE/SW/HT/MR skill for completion with Dispatcher on Project and “C” assigned CESE. Responsibilities of the various shops are detailed in *COMFIRSTNCDINST 11200.2* and include the following shops:

- Machine Shop
- Steel and Radiator Shop
- Electrical Shop
- Battery Shop
- Paint Shop
- Tire Shop

1.1.3 Inspector

Work Center Inspectors examine the equipment for additional required repairs when the CESE is scheduled for planned or corrective maintenance. Inspectors work directly for and are responsible to the Maintenance Supervisor/Division Maintenance Chief. They should be senior mechanics, knowledgeable and proficient in their rating, and should be able to clearly describe each repair action on the MRC. Each piece of equipment is inspected after repairs are completed on the 2-Kilo by each work center Inspector to ensure that work is correctly completed.

Thorough final inspection increases reliability and, in turn, reduces the mechanic's workload. Inspectors may perform minor repair work that pertains to inspection procedures only. Inspectors should immediately notify the Maintenance Supervisor when suspected equipment abuse or recurring failures are discovered. The inspector reviews technical manuals, technical bulletins, maintenance bulletins, Advanced Change Notices (ACNs), and Feedback Report replies. Inspectors ensure required annual safety inspections and hourly/mileage repairs/adjustments are completed in accordance with MRCs. The Inspector ensures all collateral equipment is inspected for completeness, deterioration, preservation, shelf life, and proper stowage.

1.1.4 Technical Librarian

The Technical Librarian is responsible to the Maintenance Supervisor for the pre-packed library, which contains operational, maintenance, and parts manuals. The Librarian establishes and enforces checkout procedures for all manuals, and maintains all required reference materials needed to research and initiate part requisitions on Naval Supply (NAVSUP) Form 1250-2s. The Technical Librarian normally researches and prepares the NAVSUP Form 1250-2s to free floor mechanics to perform maintenance functions.

1.1.5 Work Center Supervisor (3-M)

Work Center Supervisors are qualified and designated in writing. They are responsible to the Division Officer via the Group Supervisor, if applicable, for the effective operation of the 3-M System within their respective Work Center. Work Center Supervisor responsibilities are the following:

- Maintain a detailed working knowledge of all equipment deficiencies within the Work Center. The Work Center Supervisor uses the Current Ship’s Maintenance Plan (CSMP) as a daily working document for the scheduling of any maintenance actions not included on the Preventive Maintenance Schedule (PMS) schedules.
- Schedule weekly Work Center maintenance and supervise its proper accomplishment.
- Ensure the status of Work Center planned maintenance is correctly reflected on the PMS schedules.
- Ensure the Division Officer or Group Supervisor, if applicable, is advised of all 3-M System activity within the Work Center.
- Maintain an adequate supply of 3-M System materials within the Work Center.
- Ensure prompt reporting of all material deficiencies and completed maintenance actions as required.
- Ensure all 3-M System documents submitted from the Work Center are correct, legible, and promptly prepared and submitted.
- Ensure maximum use of PMS as an aid for training personnel in maintenance procedures for equipment within the Work Center.
- Ensure 3-M System Work Center files, publications, MRC decks, Tag Guide Lists (TGLs), and EGLs are complete and current.
- Review MRCs and promptly submit a PMS Feedback Report (FBR) whenever maintenance requirements are not fully understood, errors are believed to exist, maintenance requirements appear inadequate or excessive, additional coverage is needed, or performance of the maintenance requirement would cause a hazardous condition to exist.
- Ensure PMS covers all equipment in the Work Center. Maintain an accurate and current List of Effective Pages (LOEP) by comparing the documentation with the actual equipment configuration. Submit PMS FBR when changes to the LOEP are required. Submit configuration change requests when appropriate.
- Ensure programmed Periodic Maintenance Requirements (PMRs) scheduled for ship's force accomplishment are completed and reported in strict accordance with the PMR, if applicable.
- Ensure proper testing and inspection of work done by outside activities prior to job acceptance.

- Ensure delivery of test and measurement equipment and other portable support equipment to testing and calibration Work Centers as indicated on scheduling reports.

1.2.0 Maintenance Categories

The goal of maintenance is to keep equipment in a safe and serviceable condition at all times at reasonable costs, and to detect minor deficiencies before they develop into costly repairs. The Maintenance System of the Naval Construction Force (NCF) is predicated on three categories or levels of maintenance and 3-M: Organizational, Intermediate, and Depot. The category of repairs performed is determined by the following:

- Nature of the repair
- Level of repair parts, support, tools, equipment, and time available
- Personnel capabilities
- Tactical situation

An activity's range of repair parts support is keyed to the authorized level of maintenance.

1.2.1 Organizational Maintenance

Organizational maintenance is that maintenance which is the responsibility of and performed by the operator, and scheduled preventive maintenance services performed by trained personnel. Organizational maintenance consists of proper equipment operation, safety and serviceability inspections, lubrication, minor adjustments and services in accordance with the MRC. Organizational maintenance is divided into operator and preventive maintenance as specified below:

1.2.1.1 Operator Maintenance

Each operator is required to perform work needed to maintain his or her vehicle in a clean, safe, and serviceable condition. Operator maintenance includes the daily inspections before, during, and after operation. It also includes periodic lubrication and adjustments. These requirements are completed utilizing the pertinent MRC. Operator maintenance is performed to ensure early detection of deficiencies.

1.2.1.2 Preventive Maintenance

Preventive maintenance is that maintenance which is scheduled for the purpose of maximizing equipment availability and minimizing repair costs. Preventive maintenance consists of safety and mechanical inspections, lubrication, and services and adjustments beyond an operator's responsibility. Operators should assist with this work unless directed otherwise. Maintenance support requiring more extensive services is categorized as Corrective level maintenance.

1.2.2 Corrective Maintenance

Corrective maintenance is that maintenance which is the responsibility of and performed in any designated maintenance shop. The extent of corrective maintenance encompasses the removal, replacement, repair, alteration, ***calibration***, modification, and the rebuild and overhaul of individual assemblies, subassemblies, and components. Although the rebuild and overhaul of major assemblies are included, only essential repairs should be accomplished to ensure safe and serviceable equipment. Equipment that requires extensive repairs or numerous assembly rebuilds will not be repaired without prior approval by higher authority. Corrective maintenance requires a higher degree of skill than organizational maintenance, and a larger assortment of repair parts and more precision tools and test equipment.

To preclude the possibility of the installation of expensive components on equipment which may be scheduled for excess, survey, or overhaul, field units must request authority from the respective Regimental (R43) Equipment Office representative, prior to the purchase of component parts costing in excess of $1,000 or a total repair cost in excess of $2,500.

1.2.3 Depot Maintenance

Depot maintenance is that maintenance performed on equipment that requires major overhaul or comprehensive restoration to a degree necessary to restore the entire unit to a like-new condition.

1.3.0 Maintenance Scheduling

1.3.1 Scheduling and Shop Control

An effective and efficient maintenance program requires the establishment and upkeep of a preventive maintenance scheduling system and a sound shop control procedure. Vehicles and equipment should be scheduled for inspection and servicing in accordance with the time, mileage, and operating hours prescribed in NAVFAC P-300, *Management of Civil Engineering Support Equipment* and the Material Maintenance Management Program (3M). As a minimum, the schedule should 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 as follows:

1. Determine the number of service intervals per year per vehicle by determining each vehicle's estimated annual miles, and then dividing by the manufacturer's recommended service interval.
2. Develop the number of working days between each inspection (designated inspection group) for each vehicle by dividing the number of working days per year (250) by the number of service intervals per year.
3. Establish a schedule from this determination that provides a quota of vehicles for inspection daily and a balanced shop workload.

Use an electronic record to track service intervals and service performed. The record should include the following:

- USN
- EC
- Make
- Model

- Year
- Estimated annual miles/hours
- Type of service
- Date
- Cumulative mileage or hours
- Miles or hours of operation
- Miles or hours operated or a specified interval

1.3.2 Shop Workload

The best method for accomplishing positive direction of shop workload is to identify and keep the following information current:

- Available work force by work center.
- Vehicles/equipment awaiting input by work center.
- Vehicles/equipment in process by work center.
- Vehicles/equipment deadlined for parts; cannibalization is not a normal acceptable business practice; replacement parts, whether new, rebuilt, or refurbished or reconditioned, will equal or exceed OEM standards.
- Vehicles/equipment awaiting outgoing inspection.
- Vehicles/equipment awaiting customer pickup.
- Work performed by outside contractor.

1.3.3 Non NCF Maintenance Program Shop Repair Order (SRO) Flow Procedures

Figure 1-1 illustrates recommended SRO flow procedures. See NAVFAC P-300, *Management of Civil Engineering Support Equipment* for details on preparing SROs.

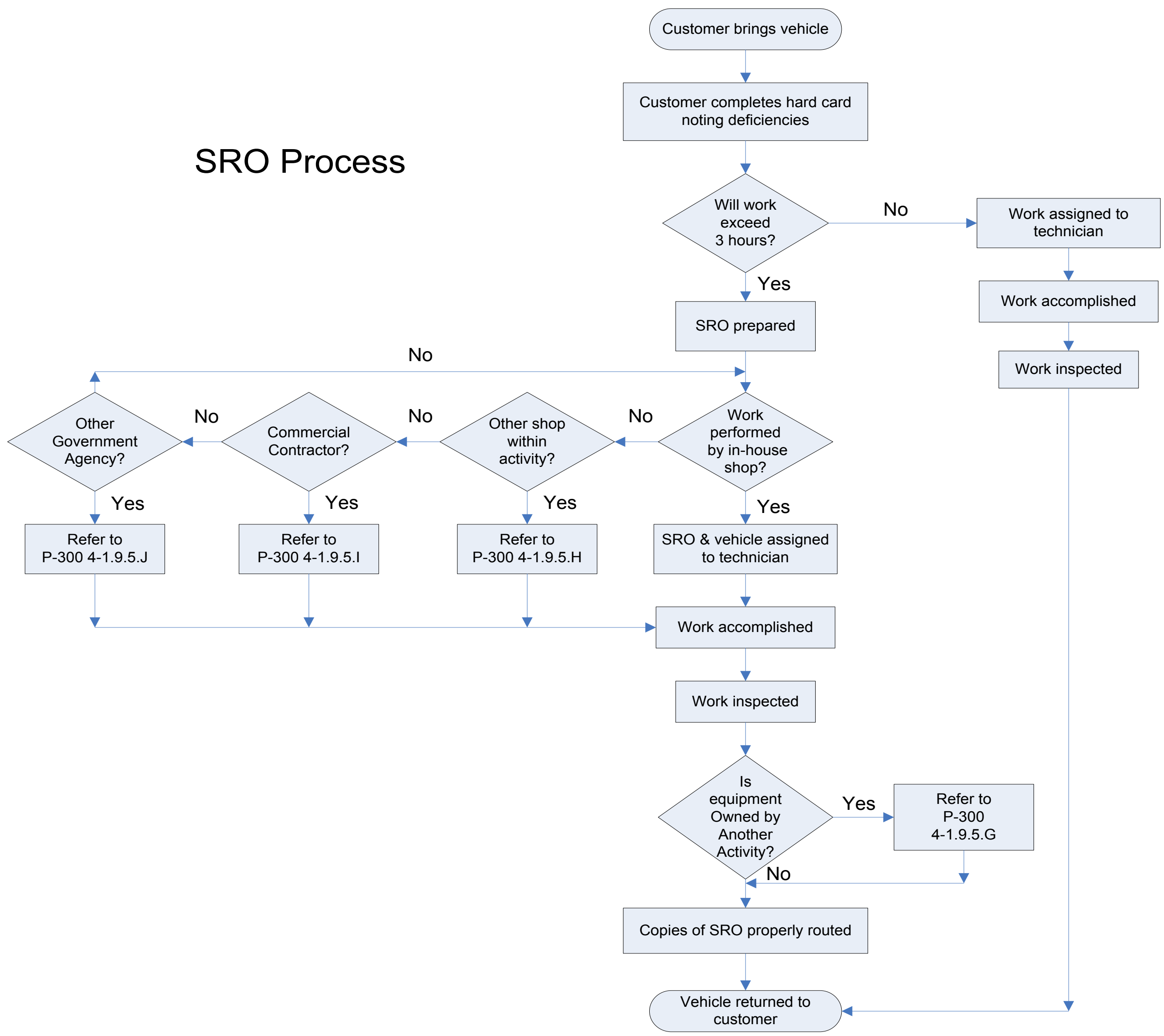

Figure 1-1 - Flow chart for Shop Repair Orders.

1.3.4 Supply Support

For a maintenance organization to perform effectively, it must receive responsive repair parts support. This support requires a high degree of cooperation and communication between the management and staff of the shop and the shop store, and between the Public Works Officer and the Supply Officer.

The responsibilities involved must be understood and fulfilled. Commander Naval Facilities Engineering Command (COMNAVFACENGCOM) and Commander Naval Supply Systems Command (COMNAVSUPSYSCOM) have recognized these understandings and promulgated them as policy outlined in NAVFAC P-300, *Management of Civil Engineering Support Equipment*.

1.3.4.1 Public Works Responsibility to the Supply Department

- Ensure that all initial support repair parts received in Public Works are turned over to the Supply Department for inventory control and accountability. Initial support repair parts intended for activity stock should not be retained in the physical custody or records of the Supply Department once issued to the end user.

- Provide information regarding repair parts requirements needed to support vehicles/equipment on hand or for any new vehicle/equipment received. (Requirements would normally be generated from actual operational experience or through normal routine inspection of equipment.)
- Furnish advance information regarding repair parts requirements for scheduled overhauls. (Requirements would be generated in the same manner outlined in NAVFAC P-300, *Management of Civil Engineering Support Equipment*.)
- Provide technical assistance to the Transportation Shop store in identifying parts and insurance items, and in determining parts interchangeability.
- Advise shop store of equipment scheduled for disposal or phase out, and assist in identifying stocked items which should be eliminated from the shop store.
- In the absence of stock items, provide end use Operation and Maintenance, Navy (O&M, N) funds to permit procurement and delivery of repair parts required for work in progress, or for subsequent scheduled services and repair for which job orders have been issued.
- Conduct periodic follow-up of shop store parts orders (after required delivery date has passed) to ensure that appropriate action has been taken to reduce further delay.
- Encourage active coordination/communications between Public Works and Supply Department personnel.

1.3.4.2 Supply Department Responsibility to Public Works (Transportation)

- Provide for the timeliest method of repair parts support through the use of available stock, system stocks, or purchase action using imprest fund or blanket purchase authority and indefinite delivery parts contracts (IDTC) when practical.
- Perform technical research for parts identification and to determine part numbers, interchangeability, and cross-referenced parts numbers.
- Collaborate with Public Works in establishing stock levels in support of current and projected vehicle/equipment inventories.
- Record parts usage data for subsequent stock range and depth adjustments.
- Expedite local procurement action for immediate issue requirements when parts required are not readily available in the shop store or main supply department.
- Review outstanding requisitions regularly to ensure that status received indicates satisfactory supply action is in progress. Follow up as necessary to obtain delivery status.
- Advise Public Works personnel promptly, indicating delivery date(s) of requested repair parts.

- Assume responsibility for staging of material by segregating material receipts applicable to specific repair jobs and advising the shop maintenance supervisor of material status.
- Encourage active coordination/communications between Supply Department and Public Works personnel.

1.3.4.3 Technical Parts Ordering Data

Surveys conducted by COMNAVFACENGCOM into the breakdown of repair parts support have revealed that much delay and downtime are caused by the mechanic's failure to provide adequate technical data when requesting parts. It should be standard practice in all maintenance shops to provide shop stores with the following information for all but common hardware and bulk material.

- Description of Major Unit. Describe the vehicle or equipment unit for which the part is applicable, such as Truck, l/2 ton, 4 x 2, 5,000#GVW.
- Manufacturer of Major Unit. Give the make.
- Model of Major Unit. Give manufacturer's model designation.
- Year of Manufacture or Model Year. Determine from nameplate.
- Vehicle Identification Number (VIN). Determine from nameplate.
- Description of Component. Describe major component for which the part is required. For example: Engine V8 260 cubic inches; Transmission, Automatic, 5 speed, Allison, Model AT-545. Component identification can be determined from manufacturer's component line set lists provided with all new equipment. (Manufacturer's line set lists should be filed in the equipment history record jacket.)
- Manufacturer of Component. Give make of major component when other than make of major unit.
- Serial Number of Component. Give serial number from component nameplate where applicable.
- Description of Part. Give full description of part using standard nomenclature with noun name first followed by descriptive modifiers such as sprocket, camshaft; kit, carburetor. Provide the part name when available; however, the correct part name is the responsibility of the parts person and should be verified. Part numbers should be recorded on the SRO for future reference. This practice saves research time for the parts person.

1.3.5 Maintenance Forms

Proper use of appropriate forms is important to keep equipment maintained.

1.3.5.1 Operator's Inspection Guide and Trouble Report (NAVFAC 9-11240/13)

The Operator's Inspection Guide and Trouble Report is used by operators of motor vehicles to indicate the items they are required to inspect before and after operation. It also serves as a means of transmitting information regarding deficiencies detected during inspection or operation. *Figure 1-2* shows the form; the procedures for field application of the form follow the figure.

Operator's Inspection Guide and Trouble Report

Registration No.	Odometer Reading

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

	Damage (Exterior/Interior/Missing Components)
	Leaks (Oil, Gas, Water)
	Tires (Check inflation, abnormal wear)
	Fuel, Oil, Water supply (Antifreeze in season)
	Battery (Check water level, cables, etc.)
	Horn
	Lights/Reflectors/Mirrors/Turn signals
	Instruments (Oil, Air, Temperature, etc.)
	Windshield wiper
	Clean windshield/vehicle interior
	Cargo, mounted equipment
	Steering
	Safety Devices (Seat belts, flares, etc.)
	Drive Belts/Pulleys
	Brakes (Drain air tank when equipped)
	Other (Specify in Remarks)

Date	Operator's Signature

Remarks

NAVFAC 9-11240/13 (12-69)
A-33796

☆ U.S.G.P.O. 1989-627-001/80143

Supersedes DD Form 1358

S/N 0105-LF-004-1195

Figure 1-2 – Operator's Inspection Guide and Trouble Report (NAVFAC 9-11240/13).

1. Equipment dispatcher issues a form to the operator at the time of vehicle assignment.
2. Operator inspects each item on the form before and after operation.
3. Operator indicates by a check mark any item that does not function properly. The "Remarks" space may be used for items not listed, or for additional information concerning deficiencies indicated by a check mark.
4. Operator turns in the form to the dispatcher at the end of each day unless a deficiency requiring the immediate attention of a mechanic is discovered.
5. Equipment dispatcher forwards the forms to the maintenance branch for action when deficiencies are noted.
6. The work input section refers the NAVFAC 9-11240/13 (Operators Report) to the service writer or Maintenance Supervisor, who determines if the deficiencies noted require immediate attention, or if correction may be safely deferred until the next scheduled inspection. If the correction is deferred, the form is attached to the Service Record Card so that the deficiency may be described on the SRO when the next scheduled or unscheduled maintenance is done.

1.3.5.2 Shop Repair Order (SRO)

The NAVFAC 11200/3A (SRO) is no longer available. Activities should use a computer-generated SRO, such as PC Transport, NFTS, etc. Local procedures should be developed regarding SRO copy distribution. The SRO is used to do the following:

- Specifically authorize and control repair work on all types of CESE, including authorization to requisition necessary repair parts from shop stores.
- Furnish basic information for management analysis.
- Authorize work on equipment when work is performed in a shop other than the activity transportation shop.
- Authorize a specific job under a Work Request (NAVCOMPT Form 140) issued by the ordering activity.
- Support the Order for Supplies or Services (DD Form 1155) as source material for the preparation of reports at small activities wholly serviced by a commercial facility.

Information on the preparation and use of the SRO is detailed in NAVFAC P-300, *Management of Civil Engineering Support Equipment*.

1.3.5.3 Maintenance Inspection/Service Record

The Maintenance Inspection/Service Record, NAVFAC 11200/46 (*Figure 1-3*), is an adhesive-type sticker which is placed on the windshield, dash, or other conspicuous section of the equipment after each scheduled service. The purpose of the form is to remind the operator of the date the equipment is scheduled for the next service. It also provides information on the dates of the last ***oil*** and filter change and lubrication.

<table>
<tr><th colspan="6">Maintenance Inspection/Service Record</th></tr>
<tr><td colspan="4">Next Maintenance
Due Miles/Hours:</td><td colspan="2">Date</td></tr>
<tr><td colspan="6">→ * When NO service is performed, post data from prior sticker.</td></tr>
<tr><td colspan="4">Services Performed</td><td>* Miles/Hours</td><td>* Date</td></tr>
<tr><td colspan="4">□ Oil Change</td><td></td><td></td></tr>
<tr><td colspan="4">□ Filter Change</td><td></td><td></td></tr>
<tr><td colspan="4">□ Lubricate Chassis</td><td></td><td></td></tr>
<tr><td colspan="4">□ Service Air Cleaner</td><td></td><td></td></tr>
<tr><td colspan="4">□ Engine Tune-Up</td><td></td><td></td></tr>
<tr><td colspan="4">□ Smog Control Device</td><td></td><td></td></tr>
<tr><td colspan="4">□ Safety Inspection</td><td></td><td></td></tr>
<tr><td>Last PM (circle type)</td><td>A</td><td>B</td><td>C</td><td colspan="2">NAVFAC 11200/46 (8-70)
Supersedes NavDocks 9-11200/5</td></tr>
</table>

Figure 1-3 – Maintenance Inspection/Service Record.

1.3.5.4 Operator's Daily PM Report (Construction and Allied Equipment)

The Operator's Daily PM Report, Construction and Allied Equipment, NAVFAC 11260/4 (*Figure 1-4*) is used by operators of construction and allied equipment (except weight handling equipment) as a guide when performing daily PM services, and when reporting equipment deficiencies, hours operated, and ***fuel*** issued. See NAVFAC P-307 for Operator's Daily Check List of weight handling equipment. The following procedures are prescribed for field application of NAVFAC 11260/4:

1. Equipment dispatcher issues a form to the operator when the equipment is assigned.
2. Equipment operator performs pre-service maintenance checks and indicates findings on the form.
3. Equipment operator records malfunctions of other items requiring attention as observed during the working day.
4. Equipment operator records the number of gallons of fuel issued to the equipment while in his or her custody and enters hours operated at the end of the day. Hour readings should be taken from the equipment hour meter. Actual operating hours should be estimated for those units not equipped with hour meters.
5. At the close of business each day, the form is turned in to the equipment dispatcher, who reviews the form to ensure that the entries are valid and to take

note of any deficiencies reported. The form is then forwarded to the maintenance dispatcher for further processing.

Operator's Daily PM Report Construction & Allied Equipment NAVFAC 11260/4 Use reverse side for Remarks Explanatory Notes on reverse side.	USN No. Operator's Daily Services

Fuel	1	Fill to proper level. Remove debris from core.
	2	Inspect belts for proper tension, alignments, and condition.
OPR Hrs	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 conditions. 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 mechanics 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.

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 12 gal
13	Instruments		
14	Shutdown Precautions		
15	Other		
Date 12/11/88		Operator's Signature R. R. Ryan	

Remarks:

Figure 1-4 - Operator's Daily PM Report (Construction and Allied Equipment).

1.3.6 NCF Maintenance Program under 3M Preventive Maintenance

NCF fleet maintenance accomplishment procedures are intended to provide a first-time quality product completed in accordance with the 3-M system and technical directives, such as manufacturer's technical manuals and technical/service bulletins. Maintenance accomplishment is a direct function of four basic elements:

1. Training and qualification of the craftsmen who will perform the maintenance.
2. Supervision, including the direct oversight of the maintenance being performed, of the individual craftsmen assigned to accomplish the maintenance.
3. Formal Work Procedures (FWP), outlined in our standard MRCs, which provide the necessary sequence of actions that the individual uses to complete maintenance tasks.
4. Work Process, a series of actions planned and executed to accomplish a unit task. The work process can range from planning and executing planned maintenance to major component replacement and/or restoration/repair. Understanding work processes and their quality control elements is the fundamental core of a successful Quality Control Program. These elements form the cornerstone of the NCF CESE Maintenance Program and are essential to ensure that all maintenance is completed per applicable technical and administrative requirements and manuals.

Quality Control (QC) and Quality Assurance (QA) are integral parts of Preventive Maintenance. QC and QA are discussed in depth in COMFIRSTNCDINST 11200.2, *Naval Construction Force Equipment Management Instruction*.

1.3.7 Scheduled and Corrective Maintenance

Preventive Maintenance should continue as scheduled. Joint spot checks of the 3-M maintenance process should be performed by WCS, Maintenance Division Chiefs, Departmental 3-MAs, and Department Heads while the maintenance is performed on 20 percent of active and 100 percent of inactive CESE and the scheduled PMS. Corrective maintenance should be documented as required using MICROSNAP/OMMS. Repairs should be completed only for safety repairs that are critical to the equipment's operation. This work should be accomplished with minimum deferred work depending on repair parts availability and time allotted. Major body and paintwork will be identified in the CSMP using the 4790/2K and deferred during the Battalion Equipment Evaluation Program (BEEP).

1.3.8 SKED

SKED and MicroSNAP user information should be exchanged and updated to reflect incoming personnel, ensuring all key personnel have a firm understanding of 3-M system programs. All outgoing personnel will be deactivated or removed from systems as required.

SKED is a PMS Scheduler which generates required Preventative Maintenance Schedules for afloat work centers. It reads equipment names for each work center directly from a CD, saving Sailors from tedious manual entries. The program generates schedules using logic based on calculations derived from periodicity rules; users can interactively change these computer-generated schedules.

1.3.9 MicroSNAP

MicroSNAP is a logistics management information system that automates equipment configuration, equipment maintenance, requirement, requisition, receipt, inventory, and financial functions for afloat and shore activities.

1.4.0 Types of Maintenance

1.4.1 First Echelon Maintenance

The borrowing unit performs all maintenance as prescribed by the 3M System. Costs for Petroleum, Oil, and Lubricants (POL) and consumables required to perform these actions are borne by the borrowing unit.

1.4.2 Scheduled Preventive Maintenance

The borrowing unit provides the labor required to perform the PM as prescribed by the 3M System. The loaning unit provides the parts required to complete the maintenance action.

1.4.3 Inactive Equipment Maintenance (IEM)

Due to varying tasking from one deployment to the next, deployed units often have CESE/MHE on hand which are not used for extended periods during deployment. This extra equipment consumes maintenance man-hours and funds, and often suffers deterioration from exposure to the elements. Equipment should be placed in IEM when there is no foreseeable operational need for the equipment for a period of time covering thirty (30) days or more. Refer to NAVSEAINST 4790.8 and COMFIRSTNCDINST 4790.1.

1.4.3.1 Status I

Equipment that will remain on board and will be inactive for thirty days or longer and is not scheduled for corrective maintenance or overhaul.

1.4.3.2 Status II

Equipment that is inactive for thirty days or longer and is directly subject to corrective maintenance, overhaul, or removal for safe storage/replacement.

1.5.0 Repair Orders

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

1.5.1 Reporting Methods

3M requires all afloat activities report deferred and completed maintenance actions, configuration changes, configuration file corrections, and Consolidated Seabee

Allowance List (COSAL) Feedback Reports. As directed by Type Commander (TYCOM) or higher authority, 3M work centers at shore activities are to report corrective maintenance and configuration changes on all installed shipboard-identical equipment and equipment installed in service crafts and boats.

1.5.1.1 Manual Reporting Methods

The configuration and maintenance forms used for manual reporting are the Ship's Configuration Change Form Operational Navy (OPNAV) 4790/CK, the Ship's Maintenance Action Form OPNAV 4790/2K, Work Candidate and the Supplemental Form, OPNAV 4790/2L.

Appendix B of NAVSEAINST 4790.8B shows examples of how to document corrective and preventive maintenance actions. For nuclear alterations, consult TYCOM directives for CSMP procedures.

1.5.1.2 Automated Reporting Methods

MDS automated data reporting is basically the same as in the non-automated 3-M program. The terms "2K," "CK," and "Work Candidate" are perpetuated in supporting software even though the paper forms are not filled out (with the exception of the Supplemental Form, OPNAV 4790/2L).

Transactions are entered into the computer and up-line reported by using applicable software. Software instructions are developed and distributed by the 3-M Central Design Activities (CDAs) and supplemented by TYCOM instructions as required. Options are available in the systems to print simulated OPNAV 4790/2K, OPNAV 4790/CK and Work Candidate forms when desired. Check the applicable system's user manual or Online Help for additional information.

With an automated information system, the computer will provide online access to the data for identifying equipment and ordering parts. When documenting requirements, many of the data elements required for corrective maintenance and configuration change reporting, such as the Allowance Parts List (APL), Equipment Identification Code (EIC), Equipment Name, and Location, will be pre-filled and displayed when the applicable equipment is identified.

1.5.1.3 Data Elements

Appendix A of NAVSEAINST 4790.8B provides the data elements and allowed values (if applicable) for each type of reporting.

1.6.0 Equipment History Jackets

An Equipment History Jacket is maintained for each USN-numbered item of CESE and each USNG-numbered ISO container. The History Jacket should contain the respective vehicle's pertinent descriptive data and maintenance history. The descriptive data includes the appropriate *DOD Property Record*, DD Form 1342, and *Equipment Attachment Registration Records*, NAVFAC Form 6-11200/45, if applicable. The maintenance history includes the completed *PM Record Cards*, NAVFAC Form 11240/6, and completed OPNAV 4790/2K and OPNAV 4790/CK or computer-generated equivalent.

When a vehicle is transferred, remove the current PM Record Card from the PM group file and return it to the History Jacket. Then either hand carry or forward the jacket by certified mail to the receiving custodian. When a vehicle is transferred to a Property Disposal Office (PDO), the History Jacket should accompany it. All units that receive equipment by direct delivery from the manufacturer are required to establish the initial Equipment History Jacket.

Test your Knowledge (Select the Correct Response)

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

    A. Inspector
    B. Maintenance Supervisor
    C. Work Center Supervisor
    D. Work Center Supervisor (3M)

2. **(True or False)** Corrective maintenance is that maintenance which is performed in any designated maintenance shop.

    A. True
    B. False

3. What NAVFAC manual provides instructions for using an SRO?

    A. P-300
    B. P-307
    C. P-405
    D. P-445

4. **(True or False)** Equipment should be placed in IEM when there is no foreseeable operational need for the equipment for sixty (60) days or more.

    A. True
    B. False

2.0.0 MAINTENANCE SUPPORT

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

In a battalion, the Supply Department is under the control of the supply officer, who is assisted by a Chief Storekeeper. The supply section (S-4) is responsible for general supply, ship’s service, material control, and delivery. The material control section is responsible for ordering, receiving, and controlling tools, materials, and repair parts.

2.1.0 Repair Parts Support

The individual WCS relies on the Repair Part Petty Officer (RPPO) to provide Automotive Repair Parts (ARP).

2.1.1 Detachment Repair Parts Petty Officer (DET RPPO)

The DET RPPO maintains the Details, Detachments for Training (DFT), or Detachment repair parts status and accountability records, and is the liaison between the main body supply office and the Details, DFT, or Detachment. All requisitions for not in stock (NIS) and not carried (NC) materials must pass though the DET RPPO, who maintains the repair parts summary sheets.

2.1.2 Support Criteria

In the NCF a wide range of CESE is used. Because of the different design characteristics of each of these CESE items, different repair parts are required to meet the support requirements. The NCF initial outfitting repair parts is designed to support new or like-new CESE for the first 1,200 construction hours and is computed as two 10-hour shifts, seven days per week, for the first 60 days of deployment.

2.1.2.1 Allowance Parts List

The initial outfitting of repair parts is designed so that each CESE item has a list of parts, an Allowance Parts List (APL). From this data a publication called a COSAL is prepared and distributed to the NCF unit being supported, plus one copy to the requesting Command and one copy to the Naval Facilities Expeditionary Logistics Center. The Naval Facilities Expeditionary Logistics Center (NFELC) draws the required initial outfitting parts peculiar, called Modifier Code 98 kit, and parts common, called Modifier Code 96 kit and Modifier Code 97 kit, and packages and ships the parts to the unit. Note that in correspondence the Consolidated Parts List is referred to as the COSAL, the repair parts peculiar as the Mod 98, and the repair parts common as the Mod 96 and Mod 97.

2.1.2.2 Special Operating Units (SOU) New Receipts

SOUs receive initial parts support for new receipts upon submission of the DD Form 1342, Department of Defense (*DOD) Property Record*, to NFELC Code 1575. Stock replenishment thereafter is the user’s responsibility.

2.1.3 Levels of Support

Each repair part listed on an APL is assigned a three digit maintenance code that identifies one of four levels of support: "O," "G," "H," or "D."

- First digit is the lowest maintenance level authorized to remove the item.
- Second digit indicates the lowest maintenance level authorized to repair the item.
- Third digit indicates the lowest maintenance level authorized to dispose of the item.

2.1.3.1 Level of Support and Definitions

- Level O: Major detachments with a maintenance capability, as defined in P-300 Chapter 4, paragraph 4-2.2.b
- Level G: Major detachments with an intermediate level maintenance capability
- Level H: Main bodies with an intermediate maintenance capability, as defined in

P-300 Chapter 4, paragraph 4-2.2.b(2)

- Level D: Depot level maintenance, not currently used by the NCF

NOTE

Each higher level of support includes all lower levels. For example, "H" level includes "O" and "G" level items. When the second digit is "Z" the item is non-repairable and should be condemned and disposed of at the level indicated in the first position maintenance code column.

2.1.4 Categories of Repair Parts

Two basic types of repair parts are "parts peculiar," and "parts common."

2.1.4.1 Repair Parts Peculiar

Parts applicable to a specific make and model of equipment are Repair Parts Peculiar. All parts peculiar to a unit are listed on the APL.

2.1.4.2 Repair Parts Common

Common and consumable supplies that can be used on numerous types of equipment are Repair Parts Common. These items have been separated into a Repair Parts Common Assembly (NAVSUP Modifier 96 and 5-7 Modifier 97 kits) to reduce overstocking that could occur if these items were carried within separate Repair Parts Peculiar Allowance Parts Lists. The Mod 96 and Mod 97 kits are designed to supplement Repair Parts Peculiar for the first 60 days or 1,200 construction hours of a contingency operation. The Mod 97 kits are packaged as Modular Assemblies. A Mod 97 kit consists of 29 different kits, Mod 96 kit consists of 19 different kits, each of which has been assigned an individual APL number. This allows Repair Parts Common Assemblies to be printed in the same COSAL format and arrangement as Mod 98 kits. Also, illustrated NFELC catalogs are provided, called *NAVSUP Modifier Code 96 and 97 Catalogs.*

2.1.5 MicroSNAP Maintenance and Operations Support System (MOSS)

MicroSNAP MOSS is the replacement for the Seabee Automated Mobile Management Equipment Operations and Equipment Maintenance Systems. Implementation of MicroSNAP MOSS to the NCF sites took place during FY00. Micro SNAP MOSS is a state-of-the-art system designed to manage vehicle inventory, maintenance, and operations. The subsystem allows for the scheduling of preventive maintenance (PM) as well as recording corrective maintenance.

MicroSNAP MOSS can be configured to operate as a single subsystem, or it can be set up as two separate subsystems, one for Maintenance and the other for Dispatch Operations. Additionally, it operates on a standalone PC or on a Local Area Network (LAN). MicroSNAP MOSS also provides a direct interface with the MicroSNAP Supply and Financial Management (SFM) subsystem, if operating on the same hardware. Specific instructions for entering/updating data and generating various maintenance and dispatch reports, and for using all other functions are provided in the F1 Help (screen and field help) menu option of the system.

There are specific options within MicroSNAP MOSS:

- Configuration Data: Allows review of the Equipment Configuration, Maintenance Actions, Collateral Equipment, Attachment Information, and Order Parts. Allows authorized users to add, modify, or delete vehicle configuration records and associated attachments, collateral equipment, and maintenance actions.
- Off-site Data Exchange: Provides for the transfer of specific equipment configuration data and collateral equipment data between Maintenance and Dispatch Operations when MicroSNAP MOSS is configured as two separate subsystems. It also provides for downloading closed maintenance actions.
- Reports: Provides options for generating online or printed forms and reports dealing with vehicle configuration, maintenance, and dispatch.
- Tech-Edit: Provides access to a variety of functions for processing Supply Requisitions/Purchase Orders when the MicroSNAP SFM subsystem is not installed.
- Subsystem Manager: Allows for establishing/maintaining of Sites' Unique data, including PM settings for Active and Live Storage equipment. Allows for establishing and maintaining valid users and the access rights to various functions.
- Dispatch Operations: Provides for the daily dispatch and return operations of vehicles.
- Manage Direct Turnover (DTO) Parts: Allows for ordering and issuing of DTO parts. Provides sequential records and proof of order of all parts requests.
- Maintenance Supervisor Review: Allows the Maintenance Supervisor to review and approve/disapprove the Configuration and Live Storage changes initiated by the Work Center Supervisor and Departmental 3M Assistant.
- Interfaces with MicroSNAP SFM: Order requests are sent directly to MicroSNAP SFM for approval and processing. Stock checks can be performed for MicroSNAP MOSS. Provides direct access to MicroSNAP SFM for ordering of non-maintenance related supplies.

2.1.6 COSAL Arrangement

COSAL arrangement and COSAL Allowance Changes are documented in NAVFAC P-300, *Management of Civil Engineering Support Equipment*.

2.1.7 Technical Manuals

An effective equipment management program needs technical data and guides for each item of equipment. Within the NCF, operator manuals, lubrication charts, parts manuals, and shop repair manuals are included in each unit's parts peculiar COSAL under NNFELC Hueneme local stock number "0NL-7610-LL-Lxx-xxxx." The quantity of technical manuals (TM) is determined by the same methods used for repair parts. This provides one copy for each piece of equipment of the same make and model assigned to the unit; two copies for two pieces of the same make and model; three copies for three to eight pieces of the same make and model; and four copies for nine to twenty pieces of the same make and model equipment.

2.1.7.1 Naval Facilities Expeditionary Logistics Center Responsibilities

The NFELC directs and administers the technical manual support program for NCF Units and requires equipment manufacturers to furnish the appropriate TMs with every purchase. These TMs can be the following types:

- Military (U.S. Army, USMC, USAF)
- Commercial (standard manufacturers)
- Modified Commercial (standard manufacturers TMs modified to meet specific requirements)
- Based on COSAL computations, NFELC Port Hueneme provides TMs to NCF units with the repair parts pack up.

2.1.7.2 Manual Maintenance

All NCF units must maintain all TMs listed in their COSAL. Inventory control of TMs must be maintained through periodic inventories and checkout procedures because replacement manuals for older equipment are usually hard to obtain. Manuals in excess of COSAL quantities must be returned to NFELC Hueneme marked for "M3 Stock." If the COSAL lists incorrect TMs or does not list all the required TMs, submit a NAVSUP Form 1220-2 to NFELC in accordance with P-300 paragraph 5.4.3. Replace technical manuals that are lost, damaged, worn out, or otherwise unserviceable by submission of funded requisitions to NNFELC Port Hueneme. The requisitions should include the TM stock numbers from the COSAL. If not available, provide all TM identification and equipment identification that includes USN number, make, model, year of manufacture, serial numbers, and original procurement contract number.

2.2.0 Using Part Numbers

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

2.2.1 Manufacturer’s Part Numbers

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

2.2.2 National Stock Numbers (NSN)

Effective September 1974, the United States agreed to replace its federal numbering system with a new 13-digit system that conforms to the NATO stock numbering format. This system is known as the NSN system. The 13-digit NSN is broken down into four major groups. The first four digits of the NSN are the Federal Supply Classification (FSC) that groups similar items into classes. The last 9 digits of the NSN are the National Item Identification Number (NIIN). The first 2 digits of the NIIN identify the NATO country that cataloged the item, and the last 7 digits identify the item.

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

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

2.3.0 Repair Parts Petty Officer Log (RPPO)

The RPPO log provides a cross-index between the requisition number, the department order number, and the USN number.

This cross-reference allows the RPPO clerk to determine the appropriate USN number for the part that was ordered. This is invaluable for follow-up actions in the event of lost or misfiled requisitions, shipping documents, and partial or duplicate parts shipments. The columns required to maintain an effective RPPO log are listed and explained below.

- Date – Date NAVSUP Form 1250 was submitted to supply. It is indicated by the Julian date: For example, December 12, 1996, is written 6347.
- Department Order Number – Internal control number assigned to each NAVSUP Form 1250 submitted to supply, numbered in sequence starting with 0001.
- USN Number – Identifies the vehicle for which the part was ordered.
- NSN/Part Number – NSN or part number of the ordered item.
- Item – Nomenclature or noun name of the item ordered.
- Unit Price – Price of a single item.
- Quantity – Total number of items ordered.
- Priority – Urgency-of-need Designator (A, B, or C).
- NC/NIS – Provides ready information on whether an item is Not Carried or Not In Stock.
- Requisition Number – Entered when the yellow copy is returned from supply. All supply office documents are filed by this number.
- Follow-Up Status – Status furnished by supply. Intervals for follow-ups should not exceed 7 days for NORS/ANORS, 14 days for priority "B," and 30 days for priority "C" requisitions.
- Received Date – Date indicating when the document ordering the items was processed.
- Issued Date – Date item was issued to the shop for installation.

Summary

In this chapter you have learned to perform various administrative duties within the CM rate, including opening and closing equipment repair orders, maintaining history jackets, updating preventive maintenance record cards, and ordering DTO or repair parts.

Review Questions (Select the Correct Response)

1. Guidelines for the maintenance of equipment assigned to the NCF are contained in what NAVFAC publication?

   A. P-280
   B. P-300
   C. P-315
   D. P-458

2. The equipment maintenance branch is normally under the overall supervision of a person having what rank?

   A. CMC
   B. CMCS
   C. EQCM
   D. GS-12

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

   A. Heavy Shop Supervisor
   B. Light Shop Supervisor
   C. Maintenance Supervisor
   D. Support Shop Supervisor

4. What person is responsible for Scheduled Maintenance Requirements and Preventive and Corrective Maintenance?

   A. Cost Control Supervisor
   B. Inspector
   C. Light Shop Supervisor
   D. Preventive maintenance clerk

5. What person should report any unscheduled repairs to a piece of CESE to the shop supervisor?

   A. Crew leader
   B. Inspector
   C. Maintenance Supervisor
   D. Preventive maintenance clerk

6. Under normal conditions, an inspector inspects an item of equipment brought into the maintenance shop a total of how many times?

   A. One
   B. Two
   C. Three
   D. Four

7. What person is responsible for maintaining the repair parts summary sheets?

   A. Detachment RPPO
   B. DTO clerk
   C. Preventive maintenance clerk
   D. Technical librarian

8. Which equipment services are included in organizational maintenance?

   A. Component rebuilding and major repairs
   B. Lubrication and minor adjustments
   C. Major overhaul and restoration
   D. All of the above

9. What is the primary objective of preventive maintenance?

   A. Ensure early detection of deficiencies
   B. Ensure that the equipment is clean and serviceable
   C. Maximize equipment availability and minimize repair cost
   D. Perform minor adjustments and services

10. What type of maintenance is performed on equipment requiring major overhaul or comprehensive restoration?

    A. Operational
    B. Organizational
    C. Intermediate
    D. Depot

11. NCF equipment is inspected for safety at what standard intervals?

    A. Once every 3 months or 3,000 miles
    B. Once every 4 months or 4,000 miles
    C. Once every 6 months or 6,000 miles
    D. Once every 12 months or 12,000 miles

12. What form should operators of construction and allied equipment (except weight handling equipment) use as a guide when performing daily PM services?

    A. NAVFAC 11200.1
    B. NAVFAC 11240/13
    C. NAVFAC 11260/4
    D. NAVFAC 11260.12B

13. In an NMCB, what person is responsible for general supply, ship’s service, material control, and delivery?

    A. S-2
    B. S-3
    C. S-4
    D. S-7

14. When an NMCB deploys, the initial supply of repair parts should support operations for how many days?

A. 60
B. 90
C. 120
D. 180

15. What is the lowest level of repair parts support?

A. O
B. H
C. G
D. D

16. Repair parts for use on one make and model of equipment are known by what term?

A. Common
B. Consumable
C. Peculiar
D. Specific

17. Which part of the COSAL provides a cross-reference between part numbers and stock numbers?

A. I
B. II
C. III
D. IV

18. What criterion is used to determine how many technical manuals are provided to a unit for each type of vehicle assigned?

A. Vehicle population
B. Location of the maintenance facilities
C. Size of the maintenance facilities
D. None, each unit receives two copies

19. Manuals in excess of COSAL quantities must be returned to M3 stock at what location?

A. SPCC Mechanicsburg, Pennsylvania
B. NFELC Gulfport, Mississippi
C. NFELC Port Hueneme, California
D. NFELC Davisville, Rhode Island

20. What digits of the NSN indicate the FSC that groups similar items into classes?

A. First four digits
B. Digits 5, 6, 7, and 8
C. Digits 9, 10, 11, and 12
D. Last four digits

21. What digits in an NSN identify the country where the part was cataloged?

A. lst, 2nd, 3rd, and 4th
B. 5th and 6th
C. 7th, 8th, and 9th
D. 10th, 11th, 12th, and 13th

Trade Terms Introduced in this Chapter

Calibration	The set of operations that establish, under specified conditions, the relationship between the values of quantities indicated by a measuring instrument and the corresponding values realized by standards.
Oil	A liquid lubricant, usually made from crude oil and used for lubrication between moving parts.
Fuel	The substance that is burned to produce heat and create motion of the piston on the power stroke of the engine.

Additional Resources and References

This chapter is intended to present thorough resources for task training. The following reference works are suggested for further study. This is optional material for continued education rather than for task training.

Management of Civil Engineering Support Equipment, NAVFAC P-300, Naval Facilities Engineering Command, Washington, D.C., 2003.

Management of Weight Handling Equipment, NAVFAC P-307, Naval Facilities Engineering Command, Washington, D.C., 2003.

Naval Construction Force Equipment Management, COMFIRSTNCD Instruction 11200.2, Commander, First Naval Construction Division, Norfolk, VA, 2006.

Ships' Maintenance and Material Management (3M) Manual, NAVSEA Instruction 4790.8B, Commander, Naval Sea Systems Command, Washington, D.C., 2003.

CSFE Nonresident Training Course – User Update

CSFE makes every effort to keep their manuals up-to-date and free of technical errors. We appreciate your help in this process. If you have an idea for improving this manual, or if you find an error, a typographical mistake, or an inaccuracy in CSFE manuals, please write or email us, using this form or a photocopy. Be sure to include the exact chapter number, topic, detailed description, and correction, if applicable. Your input will be brought to the attention of the Technical Review Committee. Thank you for your assistance.

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Rate____ Course Name____

Revision Date__________ Chapter Number____ Page Number(s)____________

Description

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(Optional) Correction

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(Optional) Your Name and Address

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Chapter 2

Principles of an Internal Combustion Engine

Topics

1.0.0 Internal Combustion Engine

2.0.0 Engines Classification

3.0.0 Engine Measurements and Performance

To hear audio, click on the box.

Overview

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

This chapter discusses the theory and operation of an internal combustion engine and the various terms associated with them.

Objectives

When you have completed this chapter, you will be able to do the following:

1. Understand the principles of operation, the different classifications, and the measurements and performance standards of an internal combustion engine.
2. Identify the series of events, as they occur, in a gasoline engine.
3. Identify the series of events, as they occur in a diesel engine.
4. Understand the differences between a four-stroke cycle engine and a two-stroke cycle engine.
5. Recognize the differences in the types, cylinder arrangements, and valve arrangements of internal combustion engines.
6. Identify the terms, engine measurements, and performance standards of an internal combustion engine.

Prerequisites

None

This course map shows all of the chapters in Construction Mechanic Basic. The suggested training order begins at the bottom and proceeds up. Skill levels increase as you advance on the course map.

Automotive Chassis and Body	↑	C
Brakes		M
Construction Equipment Power Trains		
Drive Lines, Differentials, Drive Axles, and Power Train Accessories		
Automotive Clutches, Transmissions, and Transaxles		
Hydraulic and Pneumatic Systems		
Automotive Electrical Circuits and Wiring		B A
Basic Automotive Electricity		S
Cooling and Lubrication Systems		I
Diesel Fuel Systems		C
Gasoline Fuel Systems		
Construction of an Internal Combustion Engine		
Principles of an Internal Combustion Engine		
Technical Administration		

Features of this Manual

This manual has several features which make it easy to use online.

- Figure and table numbers in the text are italicized. The figure or table is either next to or below the text that refers to it.
- The first time a glossary term appears in the text, it is bold and italicized. When your cursor crosses over that word or phrase, a popup box displays with the appropriate definition.
- Audio and video clips are included in the text, with italicized instructions telling you where to click to activate it.
- Review questions that apply to a section are listed under the Test Your Knowledge banner at the end of the section. Select the answer you choose. If the answer is correct, you will be taken to the next section heading. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.
- Review questions are included at the end of this chapter. Select the answer you choose. If the answer is correct, you will be taken to the next question. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

1.0.0 INTERNAL COMBUSTION ENGINE

1.1.0 Development of Power

The power of an internal combustion engine comes from burning a mixture of fuel and air in a small, enclosed space. When this mixture burns, it expands significantly; building pressure that pushes the piston down, in turn rotating the crankshaft. Eventually this motion is transferred through the transmission and out to the drive wheels to move the vehicle.

Since similar action occurs in each cylinder of an engine, let's use one cylinder to describe the steps in the development of power. The four basic parts of a one-cylinder engine is: the cylinder, piston, connection rod, and the crankshaft, as shown in *Figure 2-1*.

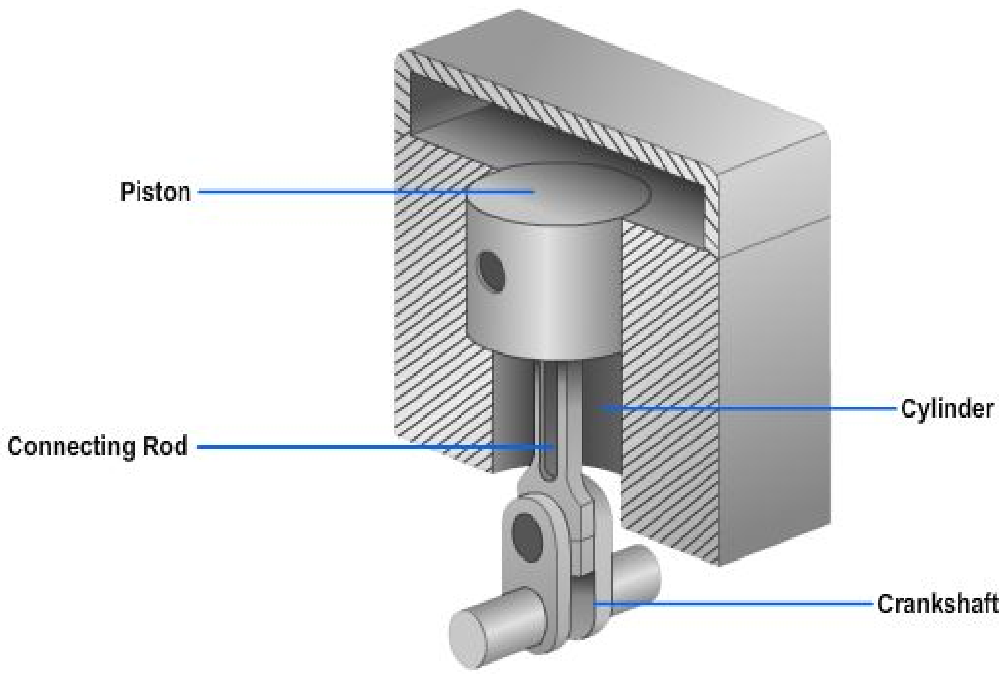


Figure 2-1 – Cylinder, piston, connecting rod, and crankshaft for a one-cylinder engine.

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

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

This motion is changed into rotary motion by the use of a connecting rod that attaches the piston to the crankshaft throw.

The throw is an offset section of the crankshaft that scribes a circle as the shaft rotates. Since the top of the connecting rod is attached to the piston, it must travel up and down. The bottom of the connecting rod is attached to the throw of the crankshaft; as it travels up and down, it also is moved in a circle. So remember, the crankshaft and connecting rod combination is a mechanism for the purpose of changing straight line, or reciprocating motion to circular, or rotary motion.

1.2.0 Four-Stroke-Cycle Engine

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

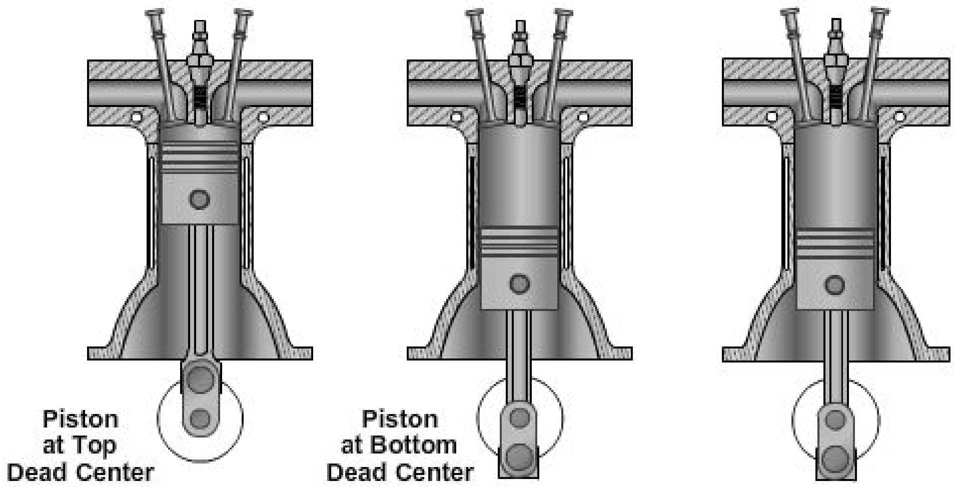


Figure 2-2 – Piston stroke technology.

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

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

1.2.1 Intake Stroke

The intake stroke draws the air-fuel mixture into the cylinder. During this stroke, the piston is moving downward and the intake valve is open. This downward movement of the piston produces a partial vacuum in the cylinder, and the air-fuel mixture rushes into the cylinder past the open intake valve.

1.2.2 Compression Stroke

The compression stroke begins when the piston is at bottom dead center. As the piston moves upwards, it compresses the fuel and air mixture. Since both the intake and exhaust valves are closed, the fuel and air mixture cannot escape. It is compressed to a fraction of its original volume.

1.2.3 Power Stroke

The power stroke begins when the piston is at top dead center (TDC). The engine ignition system consists of spark plugs that emit an electrical arc at the tip to ignite the fuel and air mixture. When ignited, the burning gases expand, forcing the piston down. The valves remain closed so that all the force is exerted on the piston.

1.2.4 Exhaust Stroke

After the air-fuel mixture has burned, it must be cleared from the cylinder. This is done by opening the exhaust valve just as the power stroke is finished, and the piston starts back up on the exhaust stroke. The piston forces the burned gases out of the cylinder past the open exhaust valve. *Figure 2-3* shows the operations of a four-stroke-cycle gasoline engine.

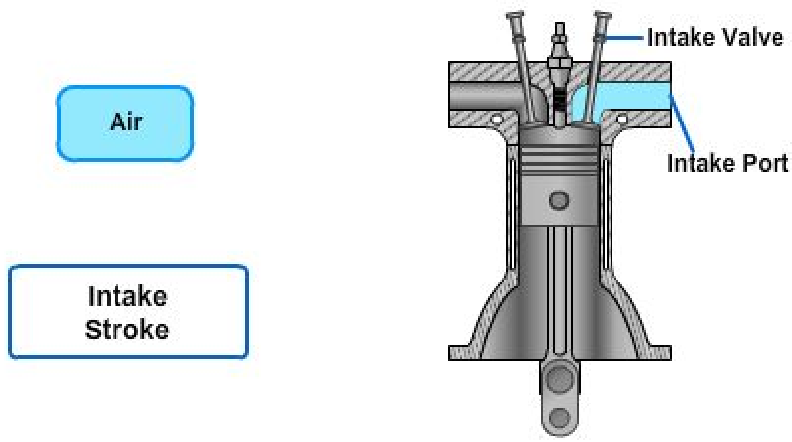


Figure 2-3 – Four-stroke cycle gasoline engine in operation.

1.3.0 Two-Stroke-Cycle Engine

Figure 2-4 depicts the two-stroke-cycle engine. The same four events (intake, compression, power, and exhaust) take place in only two strokes of the piston and one complete revolution of the crankshaft. The two piston strokes are the compression stroke (upward stroke of the piston) and power stroke (the downward stroke of the piston).

As shown, a power stroke is produced every crankshaft revolution within the two-stroke-cycle engine, whereas the four-stroke-cycle engine requires two revolutions for one power stroke.

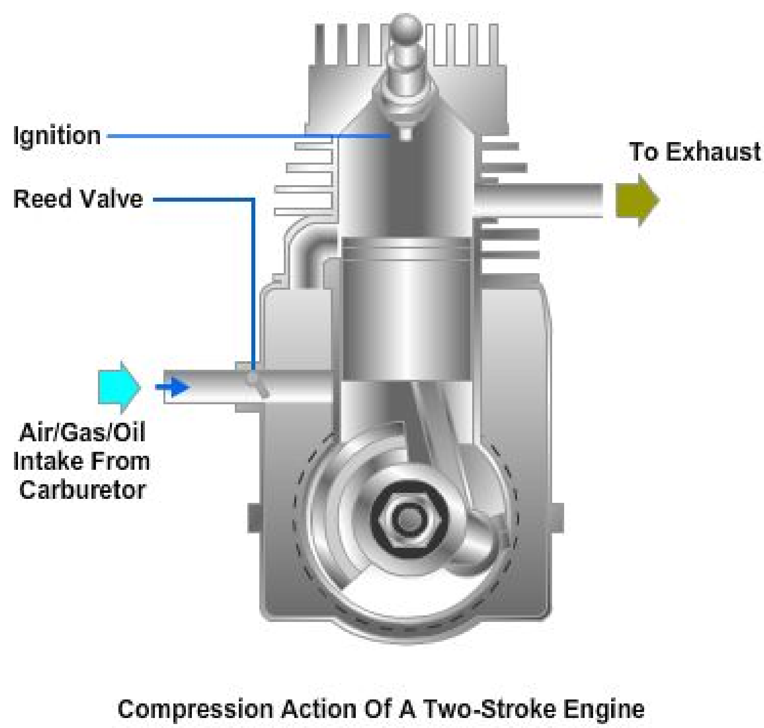


Figure 2-4 — Two-stroke-cycle engine.

2.0.0 ENGINES CLASSIFICATION

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

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

2.1.0 Diesel Engine

Diesel engines can be classified by the number of cylinders they contain. Most often, single cylinder engines are used for portable power supplies. For commercial use, four, six and eight cylinder engines are common. For industrial use such as locomotives and marine use, twelve, sixteen, twenty and twenty-four cylinder arrangements are seen.

2.1.1 Engine Cycle Design

The four-stroke cycle diesel engine is similar to the four-stroke gasoline engine. It has the same operating cycle consisting of an intake, compression, power, and exhaust stroke. Its intake and exhaust valves also operate in the same manner. The four-stroke cycle of a diesel engine is as follows:

- Diesel Engine Intake Stroke – The intake stroke begins when the piston is at top dead center. As the piston moves down, the intake valve opens. The downward movement of the piston draws air into the cylinder. As the piston reaches bottom dead center, the intake valve closes.
- Diesel Engine Compression Stroke – The compression stroke begins when the piston is at bottom dead center. As the piston moves upwards, the air is compressed to as much as 500 pounds per square inch (psi) at a temperature approximately 1000°F.
- Diesel Engine Power Stroke – The power stroke begins when the piston is at top dead center. The engine's fuel injection system delivers fuel into the combustion chamber. The fuel is ignited by the heat of the compression. The expanding force of the burning gases pushes the piston downwards, providing power to the crankshaft. The diesel fuel will continue to burn through the entire power stroke (a more complete burning of fuel). The gasoline engine has a power stroke with rapid combustion in the beginning, but little to no combustion at the end.
- Diesel Engine Exhaust Stroke – The exhaust stroke begins with the piston at bottom dead center. As the piston move upwards, the exhaust valve opens. The burnt gases are pushed out through the exhaust port. As the piston reaches top dead center, the exhaust valve closes and the intake valve opens. The engine is now ready to begin the next cycle.

2.1.2 Cylinder Arrangement

Figure 2-5 shows the most common types of engine designs. The inline cylinder arrangement is the most common design for a diesel engine. They are less expensive to overhaul, and accessory items are easier to reach for maintenance. The cylinders are lined up in a single row. Typically there are one to six cylinders and they are arranged in a straight line on top of the crankshaft. In addition to conventional vertical mounting, an inline engine can be mounted on its side. This is common in buses when the engine is under the rear seating compartment. When the cylinder banks have an equal number on each side of the crankshaft, at 180 degrees to each other, it is known as a horizontally-opposed engine.

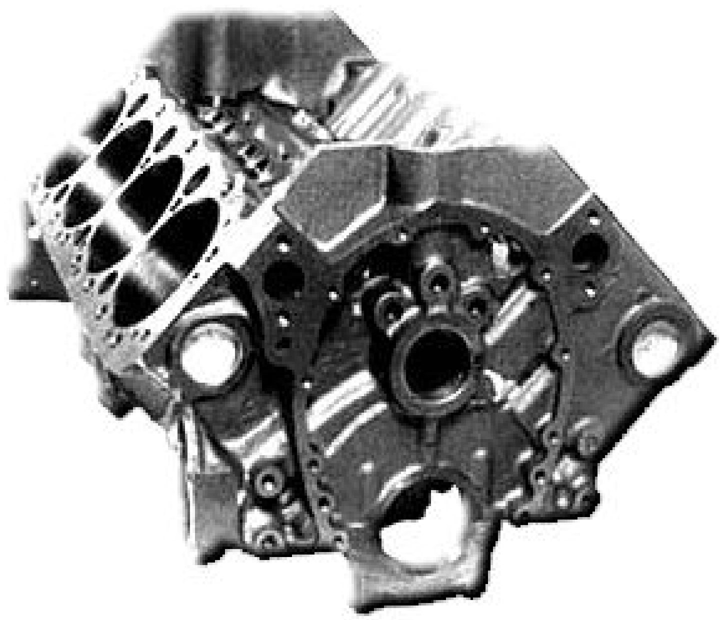


Figure 2-5 — Engine block designs.

V-type engines are another popular engine configuration. Cylinders are set up on two banks at different angles from the crankshaft, as shown in *Figure 2-5*. A V-type engine looks like the letter V from the front view of the engine. Typical angles are 45, 50, 55, 60 and 90 degrees. The angle is dependent on the number of cylinders and design of the crankshaft. The typical V-type engines are available in six through twenty-four cylinders; however, other configurations are available.

The W-type engine design is like two V-type engines made together and operating a single crankshaft. These engines are used primarily in marine applications, as shown in *Figure 2-5*.

2.1.3 Combustion Chamber Design

In order to have the best power with low emissions, you need to achieve complete fuel combustion. The shape of the combustion chamber combined with the action of the piston was engineered to meet that standard. *Figure 2-6* shows the direct injection, precombustion and swirl chamber designs.

Direct injection is the most common and is found in nearly all engines. The fuel is injected directly into an open combustion chamber formed by the piston and cylinder head. The main advantage of this type of injection is that it is simple and has high fuel efficiency.

In the direct combustion chamber, the fuel must atomize, heat, vaporize and mix with the combustion air in a very short period of time. The shape of the piston helps with this during the intake stroke. Direct injection systems operate at very high pressures of up to 30,000 psi.

Indirect injection chambers were used mostly in passenger cars and light truck applications. They were used previously because of lower exhaust emissions and quietness. In today's technology with electronic timing, direct injection systems are superior. Therefore, you will not see many indirect injections system on new engines. They are, however, still on many older engines.

Precombustion chamber design involves a separate combustion chamber located in either the cylinder head or wall. As *Figure 2-6* shows, this chamber takes up from 20% - 40% of the combustion chambers TDC volume and is connected to the chamber by one or more passages. As the compression stroke occurs, the air is forced up into the precombustion chamber. When fuel is injected into the precombustion chamber, it partially burns, building up pressure. This pressure forces the mixture back into the combustion chamber, and complete combustion occurs.

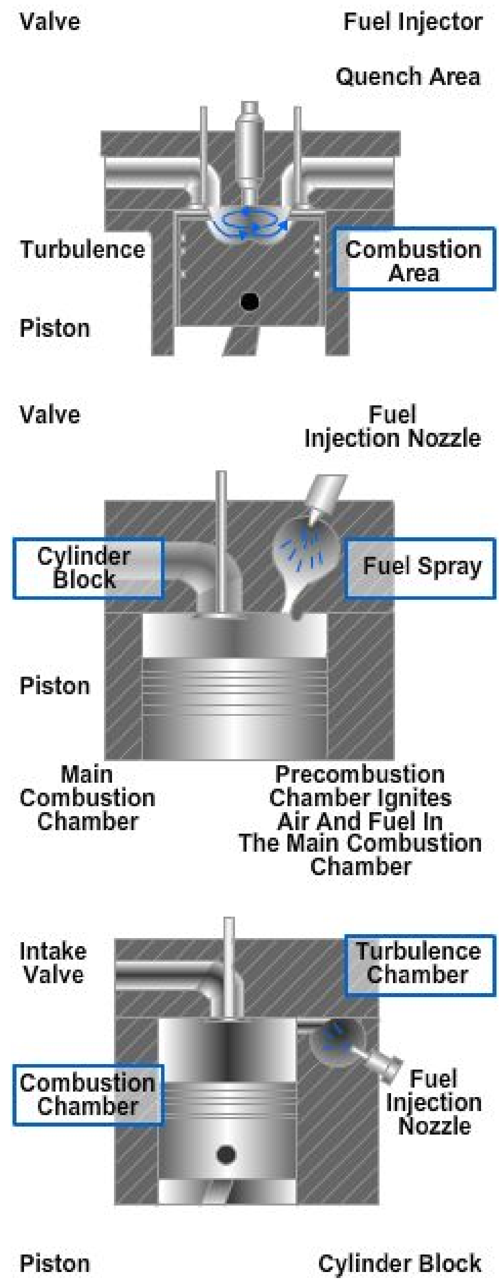


Figure 2-6 — Direct and indirect injection.

Swirl chamber systems use the auxiliary combustion chamber that is ball-shaped and opens at an angle to the main combustion chamber. The swirl chamber contains 50% - 70% of the TDC cylinder volume and is connected at a right angle to the main combustion chamber. A strong vortex (mass of swirling air) is created during the compression stroke. The injector nozzle is positioned so the injected fuel penetrates the vortex, strikes the hot wall, and combustion begins. As combustion begins, the flow travels into the main combustion chamber for complete combustion.

Energy cells are used with pintle type injectors. As shown in *Figure 2-7*, the system consists of two separate chambers connected with a passageway. As injection occurs, a portion of the fuel passes through the combustion chamber to the energy cell. The atomized portion of the fuel starts to burn. Due to the size and shape of the cell, the flame is forced back into the main combustion chamber, forcing the complete ignition. Because of the smooth flow and steady combustion rate, the engine runs smooth and the fuel efficiency is excellent.

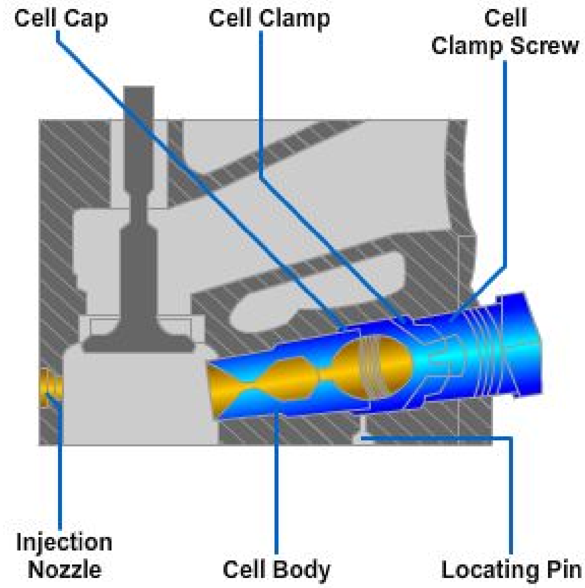


Figure 2-7 – Energy cells.

2.1.4 Fuel Injection System Design

The heart of the diesel engine is the injection system. It needs to be designed to provide the exact same amount to each cylinder so the engine runs smooth, and it needs to be timed correctly so peak power can be achieved. If it is delivered too early, the temperature will be down, resulting in incomplete combustion. If it is too late, there will be too much room in the combustion chamber and there will be a loss of power. The system also needs to be able to provide a sufficient pressure to the injector; in some cases as much as 5,000 psi is needed to force the fuel into the combustion chamber. A governor is needed to regulate the amount of fuel fed to the cylinders. It provides enough pressure to keep the engine idling without stalling, and cuts off when the maximum rated speed is achieved. The governor is in place to help from destroying the engine because of the fuel pressure available.

There are six different types of fuel injection systems: individual pump systems; multiple-plunger, inline pump systems; unit injector systems; pressure-time injection systems; distributor pump systems, and common rail injection systems.

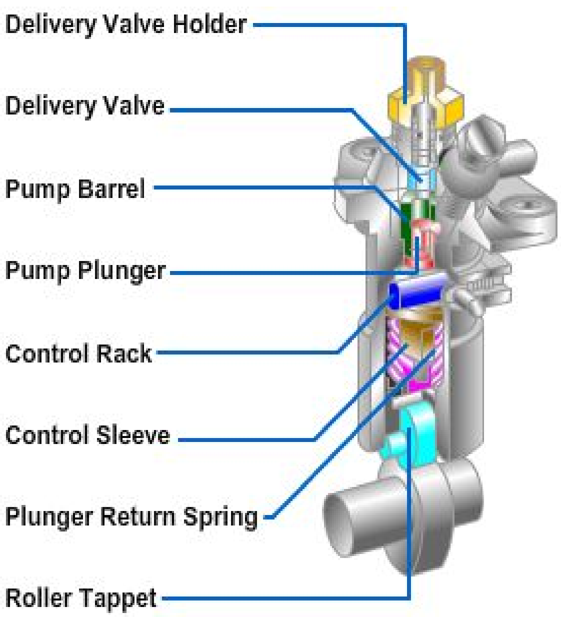


Figure 2-8 – Individual pump system.

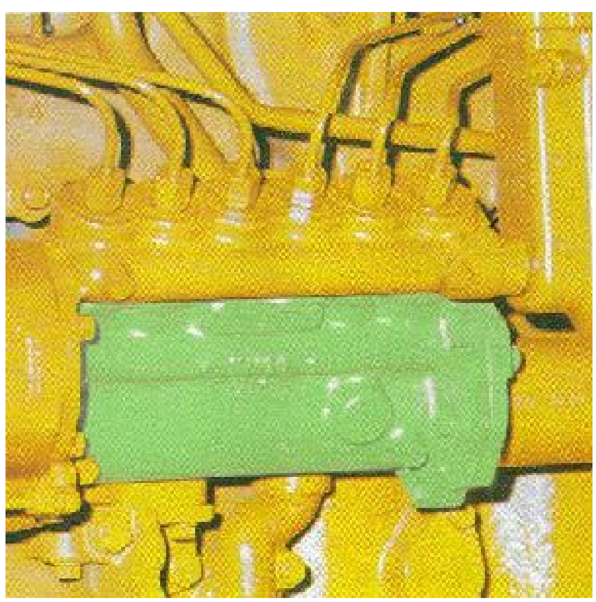


Figure 2-9 – Multiple-plunger, inline pump system.

- The individual pump system is a small pump contained in its own housing, and supplies fuel to one cylinder. The individual plunger and pump barrel, shown in *Figure 2-8*, are driven off of the engine's cam shaft. This system is found on large-bore, slow speed industrial or marine diesel engines and on small air-cooled diesels; they are not used on high speed diesels.
- Multiple-plunger, inline pump systems, shown in *Figure 2-9*, use individual pumps that are contained in a single injection pump housing. The number of plungers is equal the number of cylinders on the engine and they are operated on a pump camshaft. This system is used on many mobile applications and is very popular with several engine manufacturers.

  The fuel is drawn in from the fuel tank by a pump, sent through filters, and then delivered to the injection pump at a pressure of 10 to 35 psi. All pumps in the housing are subject to this fuel. The fuel at each pump is timed, metered, pressurized, and delivered through a high-pressure fuel line to each injector nozzle in firing order sequence.
- Unit injector systems utilize a system that allows timing, atomization, metering, and fuel pressure generation that takes place inside the injector body and services a particular cylinder. This system is compact and delivers a fuel pressure that is higher than any other system today.

  Fuel is drawn from the tank by a transfer pump, is filtered and then delivered. The pressure is 50 – 70 psi before it enters the fuel inlet manifold located within the engine's cylinder head. All of the injectors are fed through a fuel inlet or jumper line. The fuel is pressurized, metered, and timed for proper injection to the combustion chamber by the injector. This system uses a camshaft-operated rocker arm assembly or a pushrod-actuated assembly to operate the injector plunger.
- Pressure-time injection system (PT system) got its name from two of the primary factors that affect the amount of fuel injected per combustion cycle. Pressure or "P" refers to the pressure of the fuel at the inlet of the injector. Time or "T" is the time available for the fuel to flow into the injector cup. The time is controlled by how fast the engine is rotating.

  The PT system uses a camshaft-actuated plunger, which changes the rotary motion of the camshaft to a reciprocating motion of the injector. The movement opens and closes the injector metering orifice in the injector barrel. Fuel will only flow when the orifice is open; the metering time is inversely proportional to engine speed. The faster the engine is operating, the less time there is for fuel to enter. The orifice opening size is set according to careful calibration of the entire set of injection nozzles.
- Distributor pump systems are used on small to medium-size diesel engines. These systems lack the capability to deliver high volume fuel flow to heavy-duty, large displacement, high speed diesel engines like those used in trucks. These systems are sometimes called rotary pump systems. Their operating systems are similar to how an ignition distributor operates on a gasoline engine. The rotor is located inside the pump and distributes fuel at a high pressure to individual injectors at the proper firing order.

- Common rail injection systems are the newest high-pressure direct injection system available for passenger car and light truck applications. This system uses an advanced design fuel pump that supplies fuel to a common rail and then delivers it to the injectors by a short high-pressure fuel line. This system utilizes an electronic control unit that precisely controls the rail pressure, timing, and duration of the fuel. The injector nozzles are operated by rapid-fire solenoid valves or piezo-electric triggered actuators. This is the only system designed to be operated by an electronically-controlled fuel injection system. This is necessary to meet modern performance, fuel efficiency, and emission standards. Of all of the systems available today, the common rail injection system has emerged as the predominant choice for diesel engines today.

2.2.0 Gasoline Engine

2.2.1 Operational Cycles

In the four-stroke cycle gasoline engine, there are four strokes of the piston in each cycle: two up and two down. The four strokes of a cycle are intake, compression, power, and exhaust. A cycle occurs during two revolutions of the crankshaft.

- Intake Stroke – The intake stroke begins when the piston is at top dead center. As the piston moves downwards, the intake valve opens. The downward movement of the piston creates a vacuum in the cylinder, causing the fuel and air mixture to be drawn through the intake port and into the combustion chamber. As the piston reaches bottom dead center, the intake valve closes.
- Compression Stroke – The compression stroke begins when the piston is at bottom dead center. As the piston moves up upwards, it compresses the fuel and air mixture. Since both the intake and exhaust valves are closed, the fuel and air mixture cannot escape. It is compressed to a fraction of its original volume.
- Power Stroke – The power stroke begins when the piston is at top dead center. The engine ignition system consists of spark plugs that emit an electrical arc at the tip to ignite the fuel and air mixture. When ignited, the burning gases expand, forcing the piston down. The valves remain closed so that all the force is exerted on the piston.
- Exhaust Stroke – The exhaust stroke begins when the piston nears the end of the power stroke and the exhaust valve opens. As the piston moves upwards, it pushes the burnt gases out of the combustion chamber through the exhaust port. After the piston reaches top dead center, the exhaust valve closes. The next cycle begins when the intake valve opens. *Figure 2-10* shows the operations of a four-stroke cycle gasoline engine.

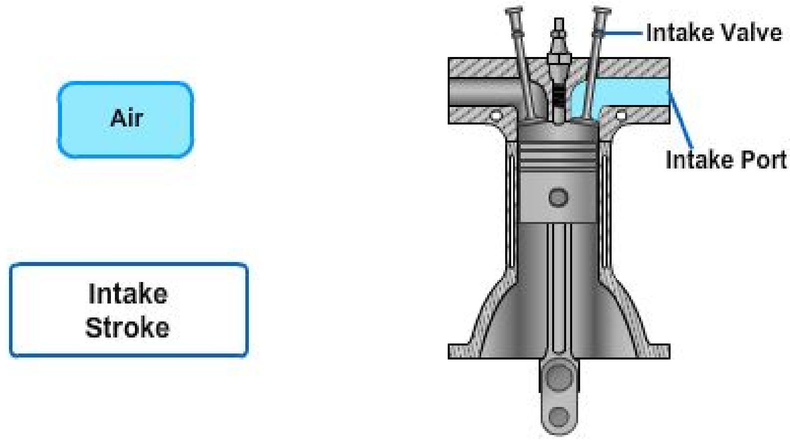


Figure 2-10 – Four-stroke cycle gasoline engine in operation.

2.2.2 Number of Cylinders

Engines come with a variety of cylinder configurations. Typically in automotive settings, engines have either four, six or eight cylinders. A few may have three, five, ten, twelve or sixteen. Usually the greater the number of cylinders an engine has, the greater the horsepower is generated with an increase of smoothness of engine. Generally a four or five cylinder engine is an inline design while a six cylinder can have an inline or V –type. Eight, ten or twelve are usually a V-type design.

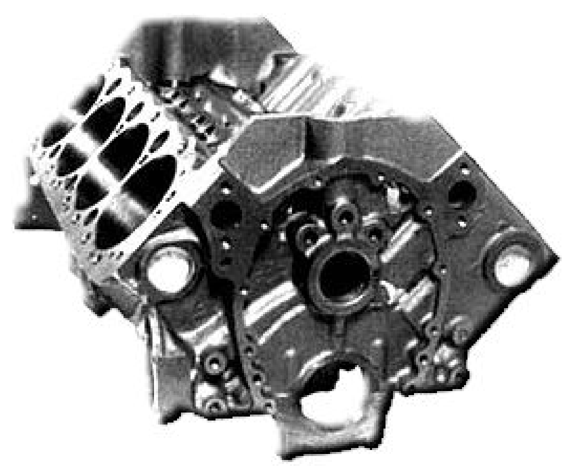
2.2.3 Cylinder Arrangement

The position of the cylinders in relation to the crankshaft determines the cylinder arrangement. *Figure 2-11* depicts the five basic arrangements:

In an inline engine the cylinders are lined up in a single row. Typically there are one to six cylinders arranged in a straight line on top of the crankshaft.

A V-type engine looks like the letter V from the front view of the engine. There are two banks of cylinders at an angle to each other on top of the crankshaft. The benefit of this design is a shorter and lighter engine block.

A slant engine is similar to an inline except the bank of cylinders is off to an angle over the crankshaft. This is done to save space in the engine compartment.



"V" Type Engine Block

Figure 2-11 – Cylinder arrangements.

The W-shaped engine looks like the letter W from the front view of the engine. Two banks of cylinders form the V shape, except the cylinders are slightly offset, forming a very narrow V. This allows the manufacturer to make an engine with a bigger displacement without making a bigger engine block.

The opposed cylinder engine lies flat on its side with the crankshaft between the cylinder banks; because of the way the engine looks, it is sometimes referred to as a pancake engine.

2.2.4 Valve Train Type

The valve train consists of the valves, camshaft, lifters, push rods, rocker arms and valve spring assemblies as shown in *Figure 2-12*.

The purpose is to open and close the valves at the correct time to allow gases into or out of the combustion chamber, as shown in *Figure 2-12*. As the camshaft rotates, the lobes push the push rods that open and close the valves.

The camshaft is connected to the crankshaft by belt, chain or gears. As the crankshaft rotates, it also rotates the camshaft. There are three common locations of the camshaft that determine the type of valve train the engine has. These are shown in *Figure 2-13*: the valve in block or L head, the cam in block (also called the I head or overhead valve), and the overhead cam.

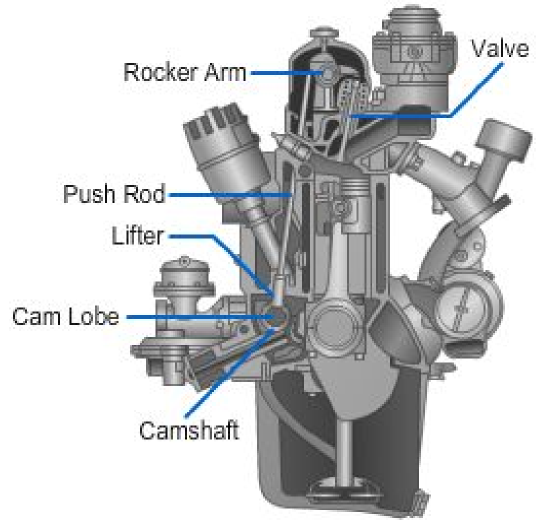


Figure 2-12 – Valve train parts.

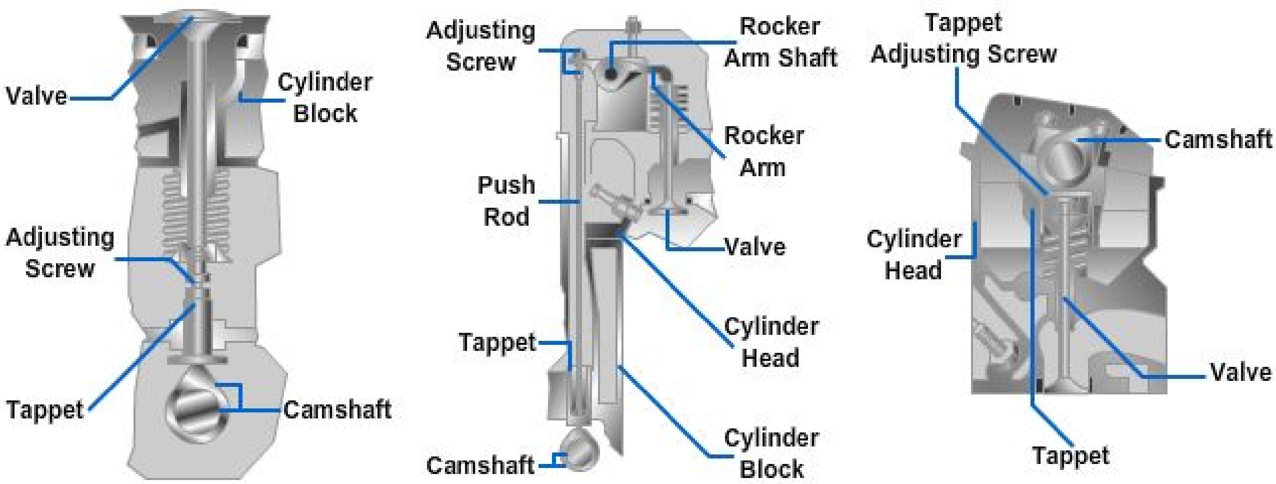


Figure 2-13 – Valve train type.

2.2.5 Cooling System

The cooling system has many functions. It must remove heat from the engine, maintain a constant operating temperature, increase the temperature of a cold engine and provide a source of heat for the passengers inside the automobile. Without a cooling system, the engine could face catastrophic failure in only a matter of minutes.

There are two types of cooling systems: liquid, the most common, and air. Although both systems have the same goal, to prevent engine damage and wear caused by heat from moving engine parts (friction) the liquid system is the most common.

The air cooling system uses large cooling fins located around the cylinder on the outside. These fins are engineered to use the outside air to draw the heat away from the cylinder. The system typically uses a shroud (enclosure) to route the air over the cylinder fins. Thermostatically-controlled flaps open and close the shroud to regulate air flow and therefore control engine temperature.

There are two types of liquid cooling systems; open and closed.

The closed cooling system has an expansion tank or reservoir, and a radiator cap with pressure and vacuum valves. There is an overflow tube that connects the radiator and the reservoir tank. The pressure and vacuum valve in the radiator cap pushes or pulls coolant into the reservoir tank instead of leaking out onto the ground. As the temperature rises, the fluid is pressurized causing the fluid to transfer to the reservoir tank. When the engine is shut off, the temperature decreases, causing a vacuum and moving the coolant to the radiator.

The open system does not use a coolant reservoir. There is simply an overflow hose attached to the radiator; when the coolant heats up and expands, the coolant overflows the radiator and out onto the ground. This system is no longer used; it has been replaced with the closed system because it is safer for the environment and easier to maintain.

The liquid cooling system, as shown in *Figure 2-14*, is comprised of several components which make it a system. The most common are the water pump, radiator, radiator hoses, fan, and thermostat.

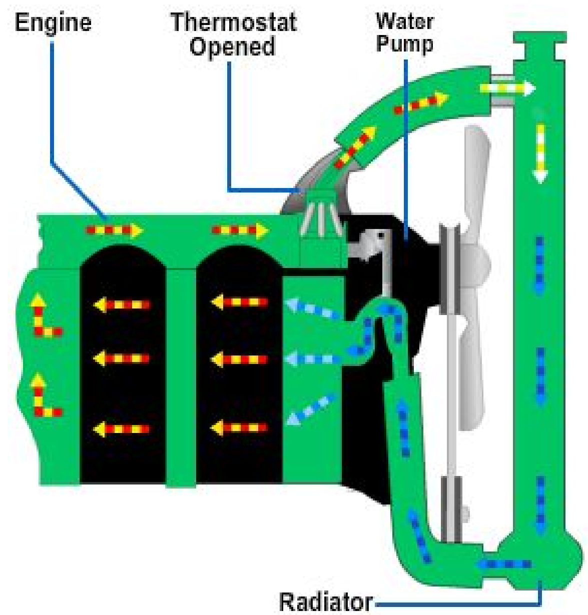


Figure 2-14– Closed cooling system.

- The water pump does just what the name says-it moves water/coolant through the engine to the radiator. It is often driven by a belt, but in some cases it can be gear-driven.
- The radiator transfers the heat from the coolant inside it to the outside air, and is normally mounted in front of the engine. The radiator core is made up of tubes and cooling fins. As the air moves over these fins, the heat is transferred to the outside air, thereby lowering the temperature of the coolant.
- Radiator hoses are a means to transfer the coolant from the engine to and from radiator. The upper hose usually connects the radiator to the engine via the thermostat housing. The lower hose usually connects the radiator to the water pump inlet housing.
- The cooling system fan pulls air across the fins in the radiator to transfer the heat from the coolant. Its main function is to prevent overheating when the vehicle is not moving or not moving very fast and the air transfer across the radiator is decreased. There are two basic types of fans, engine-powered and electric-powered. The engine-powered fan is run off a drive belt from the crankshaft pulley. There are also three types of engine-powered fans. A flex fan has thin flexible blades. As the engine is at idle, requiring more air, the blades are curved and draw a lot of air; however, as the engine speeds up, the blades flex until they are almost straight, drawing little air but at the same time reducing used engine power.

  The fluid coupling fan is designed to slip at higher engine speed. As the engine is at idle, the fluid engages the blade to turn it; when the engine speeds up, the fluid is not able to keep up and allows the blade to slip. This allows for a reduction of engine power consumed.

The thermostatic fan clutch has a temperature sensitive metal spring that controls the fan speed. The spring controls oil flow in the fan clutch. When the spring is cold, it allows the clutch to slip. As the spring heats up, the clutch locks and forces air circulation.

The thermostat senses the temperature of the engine and opens or closes to control water flow as required. The thermostat has a wax-filled pellet contained in a cylinder. A spring holds the piston and valve in a normally closed position. As the temperature increases, the wax heats up and expands, allowing the valve to open. As the temperature decreases, the wax cools, retracts, and closes the valve.

2.2.6 Fuel Type

An engine burns fuel as a source of energy. Various types of fuel will burn in an engine: gasoline, diesel fuel, gasohol, alcohol, liquefied petroleum gas, and other alternative fuels.

Gasoline is the most common type of automotive fuel. It is abundant and highly flammable. Extra chemicals like detergents and antioxidants are mixed into it to improve its operating characteristics. Antiknock additives are introduced to slow down the burning of gasoline. This helps prevent engine ping, or the knocking sound produced by abnormal, rapid combustion.

Gasoline has different octane ratings. This is a measurement of the fuel's ability to resist knock or ping. A high octane rating indicates that fuel will not knock or ping easily. High-octane gasoline should be used in high-compression engines. Low-octane gasoline is more suitable for low-compression engines.

Diesel fuel is the second most popular type of automotive fuel. A single gallon of diesel fuel contains more heat energy than a gallon of gasoline. It is a thicker fraction or part of crude oil. Diesel fuel can produce more cylinder pressure and vehicle movement than an equal part of gasoline.

Since diesel fuel is thicker and has different burning characteristics than gasoline, a high-pressure injection system must be utilized. Diesel fuel will not vaporize as easily as gasoline. Diesel engines require the fuel to be delivered directly into the combustion chamber.

Diesel fuel has different grades as well: No. 1, No. 2, and No. 4 diesel. No. 2 is normally recommended for use in automotive engines. It has a medium viscosity (thickness or weight) grade that provides proper operating traits for the widest range of conditions. It is also the only grade of diesel fuel at many service stations.

No. 1 diesel is a thinner fuel. It is sometimes recommended as a winter fuel for the engines that normally use No. 2. No. 1 diesel will not provide the adequate lubrication for engine consumption.

One of the substances found in diesel fuel is paraffin or wax. At very cold temperatures, this wax can separate from the other parts of diesel fuel. When this happens the fuel will appear cloudy or milky. When it reaches this point it can clog fuel filters and prevent diesel engine operation.

Water contamination is a common problem with diesel fuel. Besides clogging filters, it also can cause corrosion within the system, and just the water alone can cause damage to the fuel pumps and nozzles.

Diesel fuel has a cetane rating instead of an octane rating like gasoline. A cetane rating indicates the cold starting ability of diesel fuel. The higher the rating, the easier the engine will start and run in cold weather. Most automakers recommend a rating of 45, which is the average value for No. 2 diesel fuel.

Alternative fuels include any fuel other than gasoline and diesel fuel. Liquefied petroleum gas, alcohol, and hydrogen are examples of alternative fuels.

Liquefied petroleum gas (LPG) is sometimes used as a fuel for automobiles and trucks. It is one of the lightest fractions of crude oil. The chemical makeup of LPG is similar to that of gasoline. At room temperature, LPG is a vapor, not a liquid. A special fuel system is needed to meter the gaseous LPG into the engine. LPG is commonly used in industrial equipment like forklifts; it is also used in some vehicles like automobiles and light trucks. LPG burns cleaner and produces fewer exhaust emissions than gasoline.

Alcohol has the potential to be an excellent alternative fuel for automobile engines. The two types of alcohol used are ethyl alcohol and methyl alcohol.

Ethyl alcohol, also called grain alcohol or ethanol, is made from farm crops. Grain, wheat, sugarcane, potatoes, fruits, oats, soy beans, and other crops rich in carbohydrates can be made into ethyl alcohol.

Methyl alcohol, also called wood alcohol or methanol, can be made out of wood chips, petroleum, garbage, and animal manure.

Alcohol is a clean-burning fuel for automobile engines. It is not common because it is expensive to produce and a vehicle’s fuel system requires modification to burn it. An alcohol fuel system requires twice the amount burned as gasoline, therefore cutting the economy in half.

Gasohol is a mixture of gasoline and alcohol. It generally is 87 octane gasoline and grain alcohol; the mixture can be from 2-20% alcohol. It is commonly used as an alternative fuel in automobiles because there is no need for engine modifications. The alcohol tends to reduce the knocking tendencies of gasoline; it acts like an anti-knock additive. A 10% alcohol volume can increase 87 octane gasoline to 91 octane. Gasohol can be burned in high-compression engines without detonating and knocking.

Synthetic fuels are fuels made from coal, shale oil rock, and tar sand. These fuels are synthesized or changed from solid hydrocarbons to a liquid or gaseous state. Synthetic fuels are being experimented with as a means of supplementing crude oil because of the price and availability of these fuels.

Hydrogen is a highly flammable gas that is a promising alternative fuel for the future, and it is one of the most abundant elements on the planet. It can be produced through the electrolysis of water. It burns almost perfectly, leaving only water and harmless carbon dioxide as a by-product.

3.0.0 ENGINE MEASUREMENTS and PERFORMANCE

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

3.1.0 Definitions

3.1.1 Work

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

3.1.2 Energy

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

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

3.1.3 Power

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

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

$$Hp = \frac{ft\ lb\ \ per\ \min}{33000} = \frac{LxW}{33000xT}$$

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

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

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

A number of devices are used to measure the hp of an engine. The most common device is the dynamometer, which will be discussed later in the chapter.

3.1.4 Torque

Torque, also called moment or moment of force, is the tendency of a force to rotate an object about an axis, fulcrum, or pivot. Just as a force is a push or a pull, a torque can be thought of as a twist.

In more basic terms, torque measures how hard something is rotated. For example, imagine a wrench or spanner trying to twist a nut or bolt. The amount of "twist" (torque) depends on how long the wrench is, how hard you push down on it, and how well you are pushing it in the correct direction.

When the torque is being measured, the force that is applied must be multiplied by the distance from the axis of the object. Torque is measured in pound-feet (not to be confused with work which is measured in foot-pounds). When torque is applied to an object, the force and distance from the axis depends on each other. For example, when 100 foot-pounds of torque is applied to a nut, it is equivalent to a 100-pound force being applied from a wrench that is 1-foot long. When a 2-foot-long wrench is used, only a 50-pound force is required.

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

3.1.5 Friction

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

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

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

3.1.6 Engine Torque

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

3.1.7 Chassis Dynamometer

The chassis dynamometer, shown in *Figure 2-15*, is used for automotive service since it can provide a quick report on engine conditions by measuring output at various speeds and loads. This type of machine is useful in shop testing and adjusting an automatic transmission. On a chassis dynamometer, the driving wheels of a vehicle are placed on rollers. By loading the rollers in varying amounts and by running the engine at different speeds, you can simulate many driving conditions. These tests and checks are made without interference by other noises, such as those that occur when you check the vehicle while driving on the road.

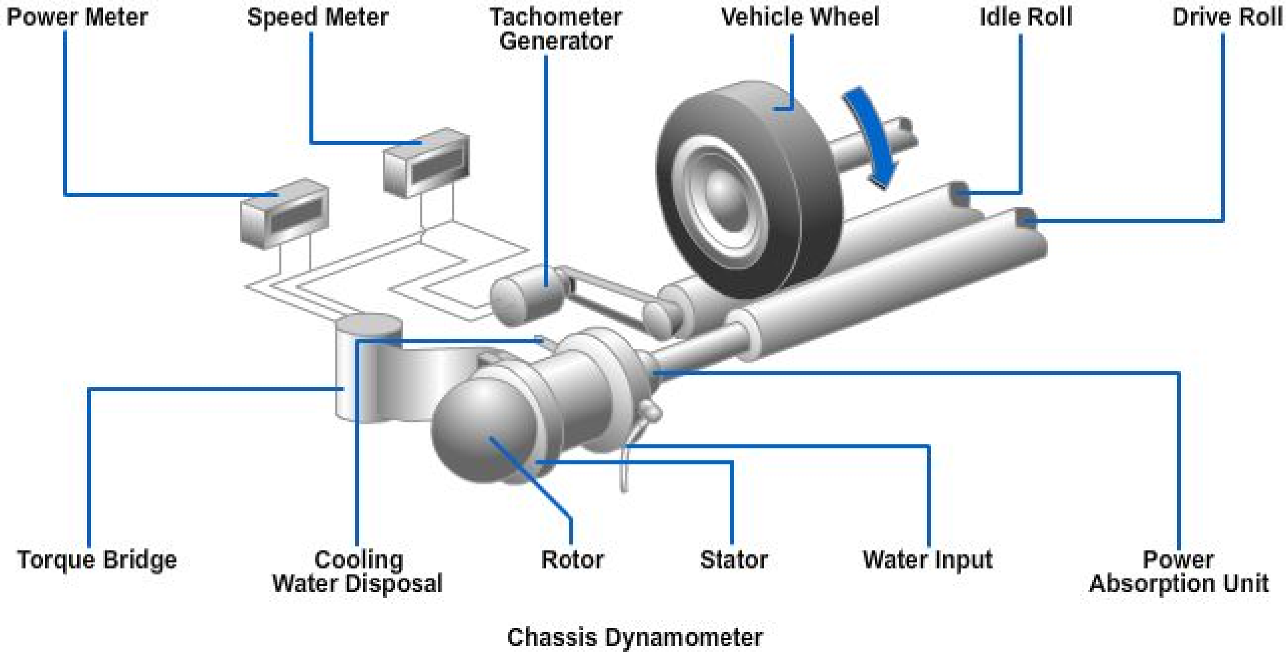


Figure 2-15 — Chassis dynamometer.

3.1.8 Engine Dynamometer

An engine dynamometer, shown in *Figure 2-16*, may be used to bench test an engine that has been removed from a vehicle. If the engine does not develop the recommended horsepower and torque of the manufacturer, you know further adjustments and/or repairs on the engine are required.

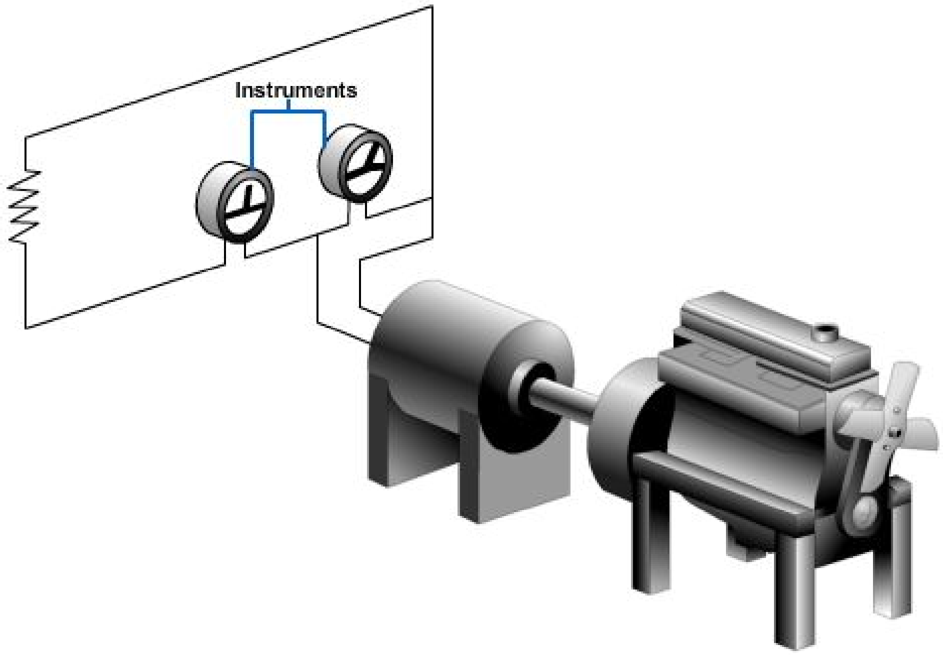


Figure 2-16 — Engine Dynamometer.

3.1.9 Mechanical Efficiency

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

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

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

3.1.10 Thermal Efficiency

Thermal efficiency is calculated by comparing the horsepower output to the amount of fuel burned. It will be indicated by how well the engine can use the fuel's heat energy. Thermal efficiency measures the amount of heat energy that is converted into the crankshaft rotation. Generally speaking, engine thermal efficiency is 20-30%. The rest is absorbed by the metal parts of the engine.

3.2.0 Linear Measurements

The size of an engine cylinder is indicated in terms of bore and stroke, as shown in *Figure 2-17*. Bore is the inside diameter of the cylinder. Stroke is the distance between top dead center (TDC) and bottom dead center (BDC). The bore is always mentioned first. For example, a 3 1/2 by 4 cylinder means that the cylinder bore, or diameter, is 3 1/2 inches and the length of the stroke is 4 inches. These measurements are used to figure displacement.

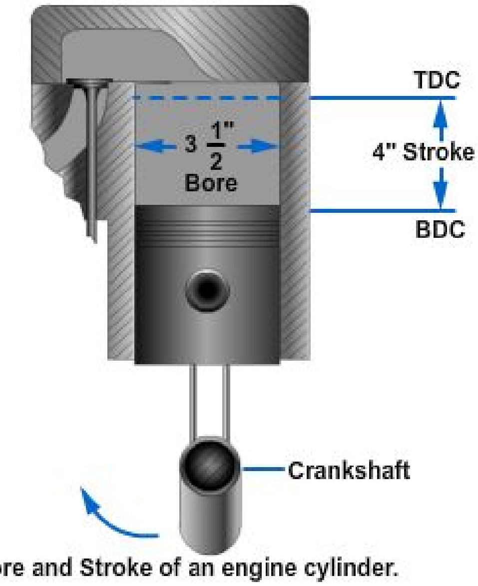


Figure 2-17 – Bore and stroke of an engine cylinder

3.2.1 Piston Displacement

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

V = πR^2 x S

If the formula is applied to *Figure 2-18*, the piston displacement is computed as follows:

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

π = 3.14

V = π $(1 .75)^2$ x 4

V = 3.14 x 3.06 x 4

V = 38.43 cu in.

3.2.2 Engine Displacement

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

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

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

307.44 cu in. x 16.39 = 5,038.9416 cc

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

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

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

3.3.0 Engine Performance

3.3.1 Compression Ratio

The compression ratio of an engine is a measurement of how much the air-fuel charge is compressed in the engine cylinder. It is calculated by dividing the volume of one cylinder with the piston at BDC by the volume with the piston TDC, as shown in *Figure 2-18*. You should note that the volume in the cylinder at TDC is called the clearance volume.

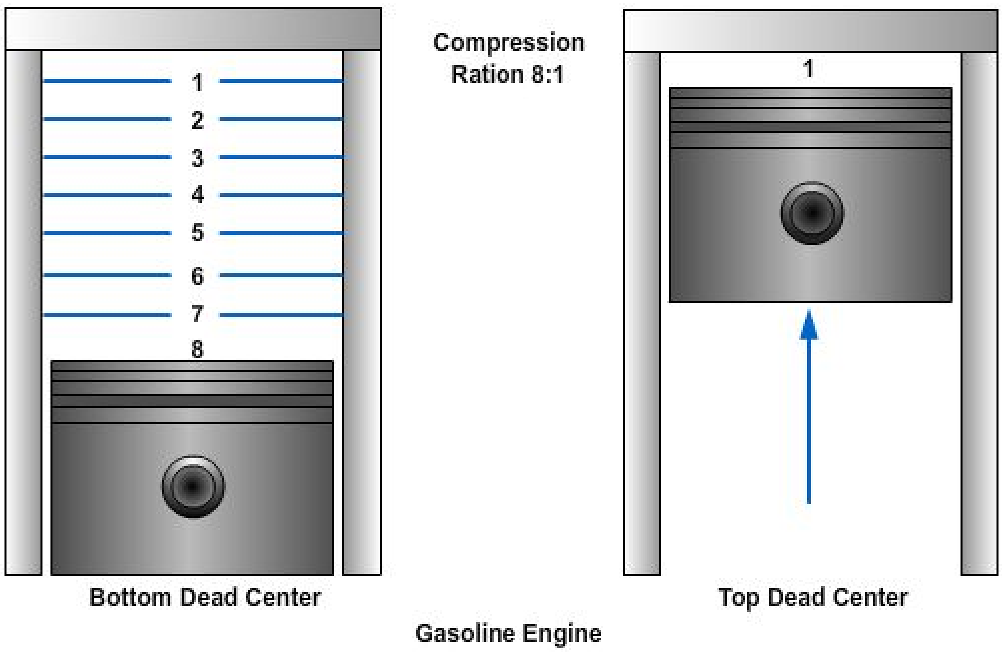


Figure 2-18 — Compression ratio.

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

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

Diesel engines have a very high compression ratio. Because the diesel engine is a compression-ignition engine, the typical ratio for diesel engines ranges from 17:1 to 25:1.

Factory supercharged and turbo-charged engines have a lower compression ratio than that of a naturally aspirated engine. Because the supercharger or turbocharger forces the fuel charge into the combustion chamber, it in turn raises the compression ratio. Therefore, the engine needs to start with a lower ratio.

3.3.2 Valve Arrangement

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

L-HEAD —The intake and the exhaust valves are both located on the same side of the piston and cylinder, as shown in *Figure 2-19*. The valve operating mechanism is located directly below the valves, and one camshaft actuates both the intake and the exhaust valves.

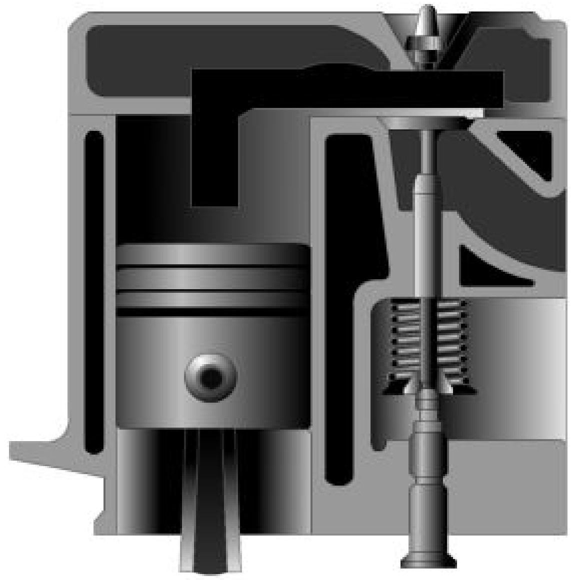


Figure 2-19– L-Head engine.

I-HEAD —The intake and the exhaust valves are both mounted in a cylinder head directly above the cylinder, as shown in *Figure 2-20*. This arrangement requires a tappet, a pushrod, and a rocker arm above the cylinder to reverse the direction of valve movement. Although this configuration is the most popular for current gasoline and diesel engines, it is rapidly being superseded by the overhead camshaft.

F-HEAD —The intake valves are normally located in the head, while the exhaust valves are located in the engine block, as shown in *Figure 2-21*. The intake valves in the head are actuated from the camshaft through tappets, pushrods, and rocker arms. The exhaust valves are actuated directly by tappets on the camshaft.

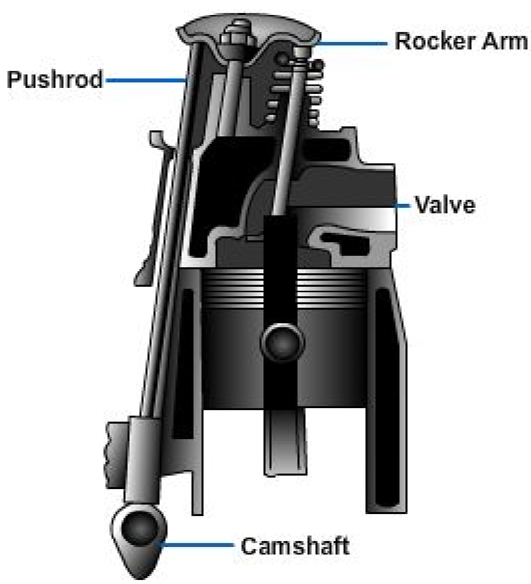


Figure 2-20 – I-Head engine.

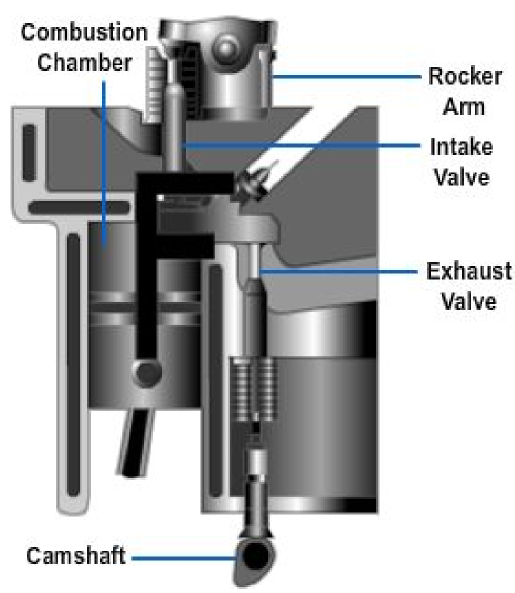


Figure 2-21 – F-Head engine.

T-HEAD —The intake and the exhaust valves are located on opposite sides of the cylinder in the engine block, each requires their own camshaft, as shown in *Figure 2-22*.

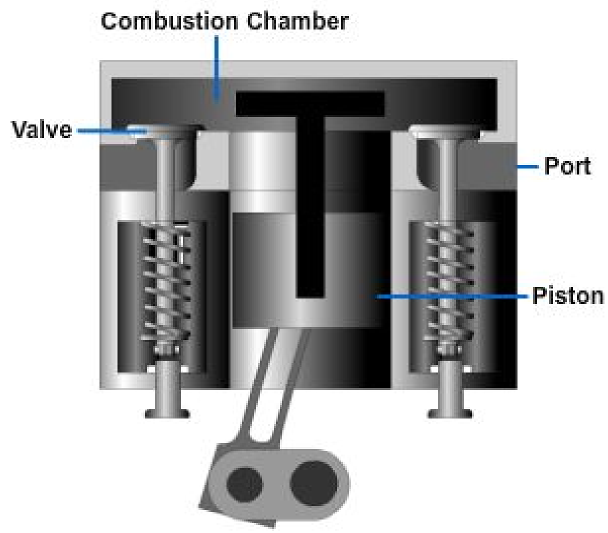


Figure 2-22 – T-Head engine.

3.3.3 Cam Arrangement

There are basically only two locations a camshaft can be installed, either in the block or in the cylinder head.

The cam in block engine uses push rods to move the rocker arms that will move the valves.

In an overhead cam engine, the camshaft is installed over the top of the valves. This type of design reduces the number of parts in the valve train, which reduces the weight of the valve train and allows the valves to be installed at an angle, in turn improving the breathing of the engine. There are two types of overhead cam engines: single overhead cam and dual overhead cam.

The Single Overhead Cam (SOHC) engine has one camshaft over each cylinder head. This cam operates both the intake and the exhaust valves, as shown in *Figure 2-23.*

The Dual Overhead Cam (DOHC) engine has two camshafts over each head. One cam runs the intake valves and the other runs the exhaust as shown in *Figure 2-24*.

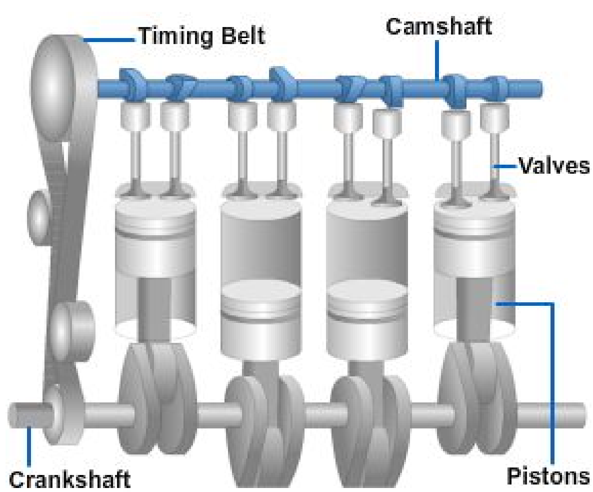


Figure 2-23 – Single Overhead Cam.

Figure 2-24 – Dual Overhead Cam.

3.3.4 Induction Type

An air induction system typically consists of an air filter, throttle valves, sensors, and connecting ducts. Airflow enters the inlet duct and flows through the air filter. The air filter traps harmful particles so they do not enter the engine. Plastic ducts route the clean air into the throttle body assembly. The throttle body assembly in multiport injection systems contain the throttle valve and idle air control device. After leaving the throttle body, the air flows into the engine's intake manifold. The manifold is divided into runners or passages that direct the air to each cylinder head intake port.

3.4.0 Timing

3.4.1 Valve Timing

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

3.4.1.1 Conventional

Conventional valve timing is a system developed for measuring valve operation in relation to crankshaft position (in degrees), particularly the points when the valves open, how long they remain open, and when they close. Valve timing is probably the single most important factor in tailoring an engine for special needs.

3.4.1.2 Variable

Variable valve timing means that the engine can alter exactly when the valves are open with relation to the engine's speed. There are various methods of achieving variable timing; some systems have an extra cam lobe that functions only at high speeds. Some others may include hydraulic devices or electro-mechanical devices on the cam sprocket to advance or retard timing.

3.4.2 Ignition Timing

Ignition timing or spark timing refers to how early or late the spark plugs fire in relation to the position of the engine pistons.
Ignition timing has to change with changes in engine speed, load, and temperature, as shown in *Figure 2-25*.

Timing advance occurs when the spark plug fires sooner on the engine's compression stroke. The timing is set to several degrees before TDC. More timing is required at higher engine speed to give combustion enough time to develop pressure on the power stroke.

Timing retard is when the spark plug fires later on the compression stroke. It is the opposite or timing advance. It is needed when the engine is operating at lower speed and under a load. Timing retard

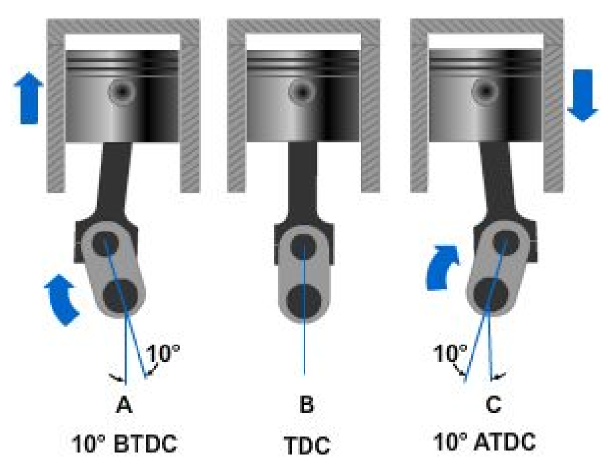


Figure 2-25 – Engine timing.

prevents the fuel from burning too much on the compression stroke that in turn causes spark knock or ping (an abnormal combustion).

3.4.2.1 Conventional

There are two types of conventional ignition system spark timing: distributor centrifugal advance and distributor vacuum advance.

The centrifugal advance makes the ignition coil and spark plugs fire sooner as the engine speeds up. It uses spring-loaded weights, centrifugal force, and lever action to rotate the distributor cam or trigger wheel on the distributor shaft. By rotating the cam against distributor shaft rotation, spark timing is advanced. Centrifugal advance help maintain correct ignition timing for maximum engine power.

At lower engine speed, small springs hold the advance weights inward to keep timing retarded. As engine speed increases, the weights are thrown outward acting on the cam. This makes the points open sooner causing the coil to fire with the engine pistons farther down in their cylinders.

The distributor vacuum advance system provides additional spark at part throttle positions when the engine load is low. The vacuum advance system is a mechanism that increases fuel economy because it helps maintain ideal spark advance.

The vacuum advance mechanism consists of a vacuum advance diaphragm, a link, a movable distributor plate, and a vacuum supply line. At idle, the vacuum port is covered. Since there is no vacuum, there is no advance in timing. At part throttle, the vacuum port is uncovered and the port is exposed to engine vacuum. This causes the distributor diaphragm to be pulled toward the vacuum. The distributor plate is then rotated against the distributor shaft rotation and spark timing is advanced.

3.4.3 Electronic/Computer

An electronic or computer-controlled spark advance system uses engine sensors, an ignition control module, and/or a computer (engine control module or power train control module) to adjust ignition timing. A distributor may or may not be used in this type of system. If a distributor is used, it will *not* contain centrifugal or vacuum advance mechanisms.

Engine sensors check various operating conditions and send electrical data representing these conditions to the computer. The computer can then analyze the data and change the timing for maximum engine efficiency.

Sensors that are used in this system include:

- Crankshaft position sensor- Reports engine rpm to the computer.
- Camshaft position sensor-Tells the computer which cylinder is on its power stroke.
- Manifold absolute pressure sensor- Measures engine intake manifold vacuum, an indicator of load.
- Intake air temperature sensor- Checks temperature of air entering the engine.

  Engine coolant temperature sensor- Measures the operating temperature of the engine.
- Knock sensor- Allows the computer to retard timing when the engine pings or knocks.

- Throttle position sensor- Notes the position of the throttle.

The computer receives input signals from these many sensors. It is programmed to adjust ignition timing to meet different engine operating conditions.

Summary

In order to be a successful mechanic, you must know the principles behind the operation of an internal combustion engine. Being able to identify and understand the series of events involved in how an engine performs will enable you to make diagnoses on the job, wherever you may be. During your career as a CM, you will apply these and other principles of operation in your daily job routines.

Review Questions (Select the Correct Response)

1. An engine is a device that converts what type of energy into kinetic energy?

   A. Reciprocating
   B. Physical
   C. Heat
   D. Kinetic

2. **(True or False)** In a four-stroke-cycle gasoline engine, a cycle occurs during four revolutions of the crankshaft.

   A. True
   B. False

3. A one-cylinder engine consists of how many basic parts?

   A. 6
   B. 4
   C. 3
   D. 1

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

   A. Back and forth
   B. Rotary
   C. Angular
   D. Linear

5. The movement of a piston from top to bottom or from bottom to top is known as _______.

   A. top dead center
   B. bottom dead center
   C. timing
   D. stroke

6. What is the definition of top dead center?

   A. The position of the piston just before its motion changes from up to down.
   B. The position of the piston at the instant its motion changes from up to down.
   C. The position of the piston just after its motion changes from up to down.
   D. The position of the piston at the instant its motion changes from down to up.

7. How many times will the crankshaft rotate on one complete cycle of a two-stroke engine?

   A. 4
   B. 3
   C. 2
   D. 1

8. What is the reaction that occurs when the fuel and air mixture is ignited in the engine cylinder?

   A. Combustion
   B. Explosion
   C. Detonation
   D. Convulsion

9. The connecting rod transmits the reciprocating motion of the cylinder to the _______.

   A. camshaft
   B. crankshaft
   C. connecting shaft
   D. rod shaft

10. The Most common method to classify an engine is by the _______.

   A. cooling method used
   B. fuel burned
   C. number of cylinders
   D. arrangement of cylinders

11. During the intake stroke in a four-stroke gasoline engine, what condition causes the fuel and air mixture to enter the combustion chamber?

   A. Compression
   B. Vacuum
   C. Combustion
   D. Expansion

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

   A. 270
   B. 180
   C. 90
   D. 45

13. In a four-stroke diesel engine, where do air and fuel mix?

A. Combustion chamber
B. Injection chamber
C. Catalytic converter
D. Intake manifold

14. A direct injection fuel system operates up to how many psi?

A. 30,000
B. 20,000
C. 3,000
D. 2,000

15. Which type of fuel injection is most common on diesel engines?

A. Indirect
B. Direct
C. Swirl
D. Direct combustion

16. Which is the only fuel injection system that was designed to be electronically controlled?

A. Pressure-time injection
B. Common rail injection
C. Unit injector
D. Distributor pump

17. A diesel engine has greater torque than a gasoline engine because of the power developed from the _______.

A. high-compression ratio
B. high-heat transfer
C. low-compression ratio
D. low-heat transfer

18. Gasoline uses what rating system to determine its combustion ability?

A. Cetane
B. Ratio
C. Octane
D. Fathom

19. Diesel fuel uses what rating system to determine its combustion ability?

A. Cetane
B. Ratio
C. Octane
D. Fathom

20. **(True or False)** A single gallon of Diesel fuel contains more heat than a single gallon of gasoline.

A. True
B. False

21. **(True or False)** Diesel fuel contains wax.

A. True
B. False

22. **(True or False)** The water pump draws coolant from the bottom of the radiator.

A. True
B. False

23. **(True or False)** The cooling system warms up the engine to its normal operating temperature.

A. True
B. False

24. On a cold engine, what restricts the circulation of coolant?

A. Shutter
B. Overflow tank
C. Water jacket
D. Thermostat

25. The _________ is mounted in series with the lower radiator hose and is used to supply extra room for coolant.

A. overflow tank
B. reservoir tank
C. expansion tank
D. extortion tank

26. The cooling action on air-cooled engines is based on what principle?

A. Incoming airflow is cooler than the engine metal.
B. Incoming airflow is cooler than the coolant.
C. Incoming airflow is easier to control than coolant.
D. Incoming airflow is easier to control than engine heat.

27. When does the radiator vacuum valve open?

A. When the pressure in the cooling system raises above the outside air pressure.
B. When the pressure in the cooling system drops below the outside air pressure.
C. When the pressure in the cooling system exceeds its maximum limit.
D. When the pressure in the cooling system drops below the normal pressure.

28. Which radiator system part provides more cooling area and aids in directing airflow when the vehicle is not moving?

A. Fan
B. Fins
C. Baffles
D. Shroud

29. How is piston displacement calculated?

A. Add bore and stroke
B. Divide stroke by bore
C. Multiply stroke by bore
D. Divide bore by stroke

30. Turbo-charged and supercharged engines need a lower ______.

A. compression aspect
B. intake ratio
C. compression ratio
D. intake aspect

31. What are the two possible locations of a camshaft in an engine?

A. Block and crankcase
B. Block and head
C. Head and intake
D. Block and intake

32. As the engine speeds up, the timing needs to _____.

A. be retarded
B. be advanced
C. remain steady
D. be rotated

Additional Resources and References

This chapter is intended to present thorough resources for task training. The following reference works are suggested for further study. This is optional material for continued education rather than for task training.

Modern Automotive Technology Sixth Edition, James E. Duffy, The Goodheart-Willcox Company, Inc., 2004. (ISBN-13: 978-1-59070-186-7)

Diesel Technology Seventh Edition, Andrew Norman and John “Drew” Corinchock, The Goodheart-Wilcox Company, Inc., 2007. (ISBN-13: 978-1-59070-770-8)

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