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Chapter 1

Transportation Operations

Topics

1.0.0 Administration

2.0.0 Transportation Organization Titles and Duties

3.0.0 Embarkation

4.0.0 Advanced Base Planning

To hear audio, click on the box. 

Overview

Transportation operations consist of the control of and accountability for all Civil Engineer Support Equipment (CESE). Transportation operations include hauling of personnel, equipment, materials, and construction supplies; storage of and accountability for collateral equipment and attachments; support of construction projects; and support of the maintenance program and processing of equipment through mechanic shops. This chapter presents basic information required to effectively perform duties supporting the operations of a transportation pool.

Objectives

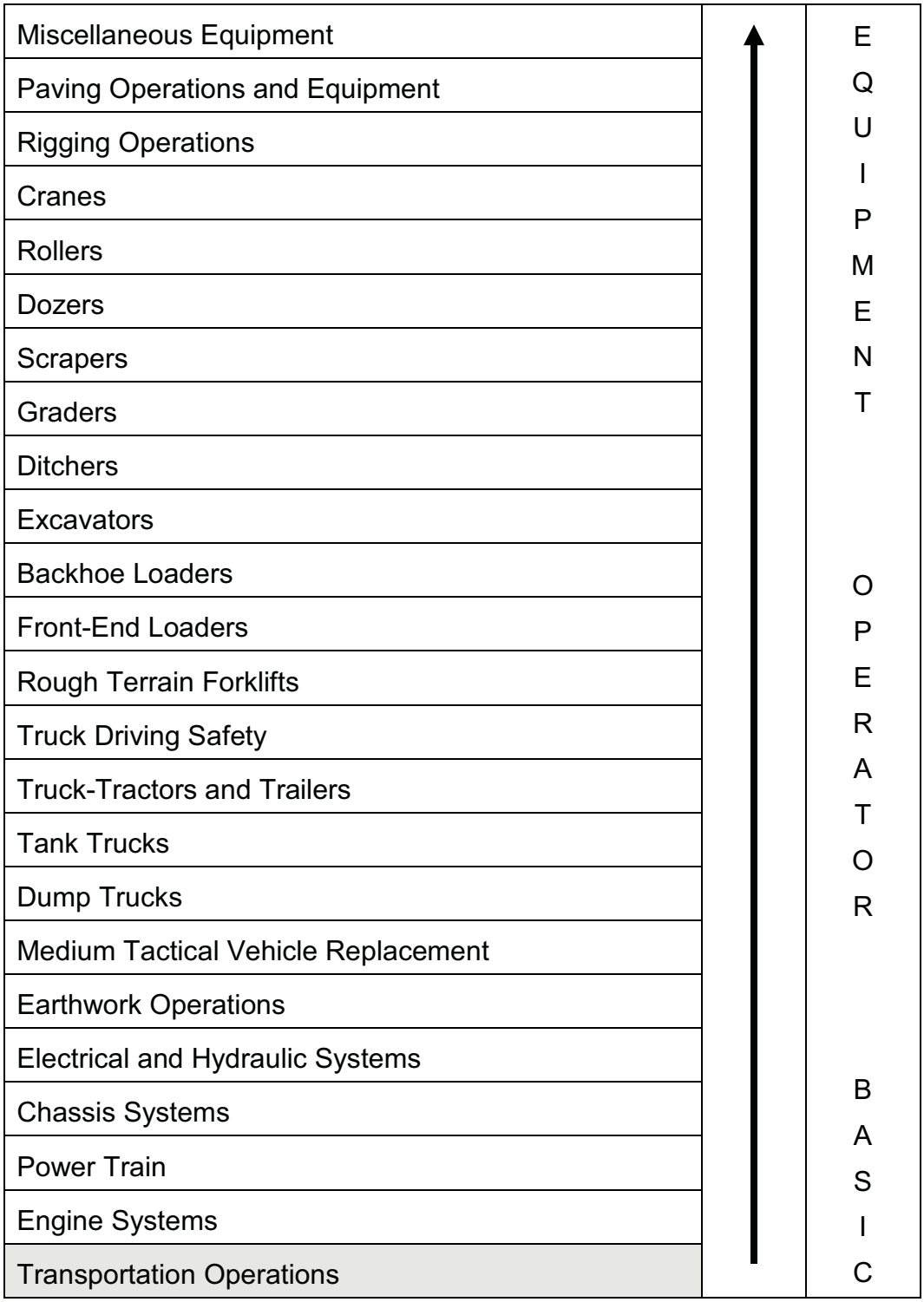
When you have completed this chapter, you will be able to do the following:

1. Identify the forms and licenses used for Transportation Operations.
2. Identify the duties of those involved in Transportation Operations.
3. Understand the procedures for embarkation.
4. Understand purpose and use of Advanced Base Functional Components (ABFC).

Prerequisites

None

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



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 ADMINISTRATION

The Navy invests millions of dollars in equipment, equipment repair parts, lubricants, and training that enables Seabees to perform assigned tasking. Possessing a basic knowledge of the procedures, reports, and forms used in the management of the transportation pool or department is part of the responsibility of an Equipment Operator.

1.1.0 License

A properly administered license program ensures that only thoroughly trained, physically and mentally qualified personnel are licensed as Equipment Operators.

According to *Management of Transportation Equipment,* NAVFAC P-300, all military personnel, civilian employees, and contractor personnel who operate vehicles and equipment on naval installations must be qualified and properly licensed. Navy policy accepts a valid operator's license issued by a state or jurisdiction as proof the applicant has achieved the proficiency level required to operate government vehicles up to 10,000 pounds gross vehicle weight (GVW).

According to *Equipment Management Manual,* NAVFAC P-404, all personnel in the Navy Construction Force (NCF) and Special Operating Units (SOU) who operate government-owned or rented equipment must be qualified and have a valid U.S. Government Operator's License. This license must cover the size and type of vehicle to be operated. A Government Operator's License is not an authorization for an operator to use a piece of equipment. The operator must also have a valid trip ticket to operate a piece of equipment.

1.2.0 Application Forms

To obtain an operator's license, submit an application form to the license examiner. Use the application for Vehicle Operator's Identification Card, NAVFAC 11240/10 (*Figures 1-1A and 1-1B*) to apply for an automotive or material-handling equipment (MHE) license and the Application for Construction Equipment Operator License, NAVFAC 11260/1(*Figures 1-2A and 1-2B*) to apply for a license for other types of equipment.

Both forms contain information pertinent to applying and issuing the licenses. Show the type of license you are requesting in part 1 of the application forms. All forms are completed by the applicant and then signed by the Company Commander or Company Chief. The NAVFAC P-300 states "Military personnel may operate government-owned or leased vehicles under 10,000 pounds GVW without a government license." However, all personnel in the NCF and SOU who operate government owned or rented equipment tunder he maintenance management policy of the NAVFAC P-404 shall be qualified and have in possession a valid U.S. government operator's license, covering the size and type of vehicle to be operated. The license examiner is responsible to storing the NAVFAC 11240/10, NAVFAC 11260/1, and the Optional Form 345 in a file.

APPLICATION FOR VEHICLE OPERATOR'S IDENTIFICATION CARD
NAVFAC 11240/10 (REV. 10-75) **S/N 0105-LF-012-4055**

NEW ☐ RENEWAL ☐

(See Privacy Act statement and instructions on reverse)

PART I - APPLICATION

1. NAME *(Last, First, Middle Initial)*	2. RANK/RATE/GRADE AND TITLE	3. ACTIVITY

4. AGE	5. DATE OF BIRTH	6. PLACE OF BIRTH	7. SOCIAL SECURITY NUMBER

8. SEX	9. WEIGHT	10. HEIGHT	11. COLOR OF HAIR	12. COLOR OF EYES

13. SHOP NAME/NUMBER AND APPLICANT'S BADGE NUMBER	14. SUPERVISOR *(Name)*	15. PHONE NUMBER

16a. TYPE OF IDENTIFICATION CARD *(Check)* — 16b. TYPES OF VEHICLES TO BE OPERATED *(Check)*

16a.		16b.		16b.		16b.	
	REGULAR		PASSENGER CAR		BUS (GAS AND DIESEL)		TRUCK 4 x 4
	RESTRICTED		PICKUP TRUCK		TRUCK TRACTOR & SEMITRAILER		TRUCK 6 x 6
	EXPLOSIVE		TRUCKS TO 2 TONS		FIRE TRUCK		TRUCK FIRE/CRASH
	EMERGENCY VEHICLE		TRUCKS TO 5 TONS		AMBULANCE		TRUCK TANK
	AVGAS REFUELER		TRUCKS TO 10 TONS		MOTORCYCLE & SCOOTERS		OTHER *(Explain below)*

17. EXPLANATION

18. VALID STATE VEHICLE OPERATOR'S LICENSE(S)

19. SIGNATURE OF REQUESTING OFFICIAL — *Date*

PART II - OPERATOR'S PAST PERFORMANCE RECORD

DATE	VEHICLE TYPE/SIZE	LICENSES ISSUED		NO. YRS. DRIVING EXP.	LIST ACCIDENTS, VIOLATIONS, ARRESTS *(If any)* AND ACTION TAKEN
		STATE	OTHER		
1	2	3	4	5	6

7. I CERTIFY THE ABOVE TO BE CORRECT. — SIGNATURE OF APPLICANT — DATE

PART III - EXAMINATION RESULTS

1. SCORES IN DRIVING TESTS	✓ SAT	✓ UNSAT	2. SCORES ACHIEVED IN TESTS	✓ SAT	✓ UNSAT	3. GOVERNMENT VEHICLES AUTHORIZED TO OPERATE *(List)*
a. ROAD TEST			a. WRITTEN			
b. EQUIPMENT INSPECTION			b. PHYSICAL			
			c. PSYCHOPHYSICAL			

REMARKS

PART IV - ACTION BY ADMINISTERING OFFICIAL

1. IDENTIFICATION CARD ISSUED	2. IDENTIFICATION CARD NUMBER	DATE ISSUED *(Mo., Day, Yr.)*	EXPIRATION DATE *(Mo., Day, Yr.)*
☐ YE ☐ NO			

3. IDENTIFICATION CARD MARKED "VOID UNLESS ACCOMPANIED BY VALID STATE LICENSE ☐ YE ☐ NO

4. OPERATOR INSTRUCTED TO TURN IN IDENTIFICATION CARD UPON LOSS OR SUSPENSION OF STATE DRIVER'S LICENSE ☐ YE ☐ NO

*IF "NO" EXPLAIN UNDER REMARKS

5. SIGNATURE OF ADMINISTERING OFFICIAL — *Date*

Figure 1-1A – Application for Vehicle Operator's Identification Card, NAVFAC 11240/10 (Page 1 of 2).

INSTRUCTIONS FOR COMPLETING APPLICATION FOR VEHICLE OPERATOR'S IDENTIFICATION CARD

NAVFAC 11240/10 (REV. 10-75)

PRIVACY ACT STATEMENT

Authority to request this information is derived from Title 40 United States Code 471. Purpose of this form is to obtain information to determine whether an individual is qualified to operate a government vehicle and/or equipment. Information is used by agency transportation officials and may be used by government and civil law enforcement authorities for court action. Providing information for this form is mandatory. If the information is not provided, the individual would be denied the privilege of operating a government vehicle and/or equipment.

GENERAL

Prepare in duplicate. File original in applicant's personnel jacket and retain copy in issuing office. Use typewriter or ball-point pen.

PART I - APPLICATION

1. Self-explanatory.
2. Enter military rank/rate or civilian grade and title.
3. Enter name and location of activity. Abbreviations may be used.
4. Self-explanatory.
5. Enter day, month and year of birth.
6. Enter city/town and state of birth.
7. Self-explanatory.
8. Enter male or female.
9. Self-explanatory.
10. Enter height in feet and inches; i.e., 6'2".
11. Enter color of hair; i.e., brown, black, gray.
12. Enter color of eyes; i.e., blue, brown, hazel.
13. Enter shop name and number, plus applicant's badge number.
14. Enter the name of the applicant's supervisor.
15. Enter the telephone number of the applicant's supervisor; i.e., 74056.
16. a. Check type of identification card applied for.
    b. Check types of vehicles to be operated for which operator's identification card is to be issued.
17. List other types of vehicles that applicant is required to operate not listed under 16 b.
18. Enter current valid state (name and number) vehicle operator's license(s).
19. Signature of requesting official; i.e., Commanding Officer or designated representative and date.

PART III - OPERATOR'S PAST PERFORMANCE RECORD

1. Self-explanatory.
2. Enter vehicle type/size that applicant is or has been authorized to operate.
3. Enter date of issue of previous or present state vehicle operator's license.
4. Enter date of issue of previous identification cards (if any).
5. Enter number of years of driving experience, both civilian and military, for each license entry.
6. Briefly list accidents, violations, arrests, if any, and action taken.
7. Signature of applicant and date.

PART III - EXAMINATION RESULTS

1&2. Check appropriate boxes.
3. List types of Government vehicles authorized to operate; i.e., pickup truck, truck tank.
4. Enter remarks, if any, the examiner considers necessary; i.e., restrictions, driving weaknesses, outstanding qualifications.

PART IV - ACTION BY ADMINISTERING OFFICIAL

1. Check appropriate box.
2. Enter serial number of identification card issued, date issued, and expiration date.
3. The phrase "Void unless accompanied by valid state license" may be overstamped on the card or typed on the back under "Other Records."
4. Check appropriate box.
5. Signature of administering official and date.

NAVFAC 11240/10 (REV. 10-75) (BACK)

Figure 1-1B – Application for Vehicle Operator's Identification Card, NAVFAC 11240/10 (Page 1 of 2).

Read the PRIVACY ACT STATEMENT on reverse before completing this applicantion

APPLICATION FOR CONSTRUCTION EQUIPMENT OPERATOR LICENSE

NAVFAC 11260/1 (Rev. 6/76)

S/N 0105-LF-012-6005

PART I - APPLICATION

1. NAVAL ACTIVITY	2. APPLICANT'S NAME	3. RANK, RATE OR CIVILIAN STATUS

4. DEPARTMENT, DIVISION AND/OR SHOP ASSIGNED TO	5. APPLICANT'S JOB TITLE

6. DESCRIPTION OF EQUIPMENT LICENSE REQUESTED

(a) TYPE OF EQUIPMENT	(b) TYPE OF CONTROL	(c) TYPE OF ATTACHMENT

7. STATEMENT OF QUALIFYING EXPERIENCE

8. DESCRIPTION OF EQUIPMENT APPLICANT IS CURRENTLY LICENSED TO OPERATE

9. SPONSOR'S STATEMENT OF APPLICANT'S READINESS AND/OR PREPARATORY TRAINING FOR TEST *(NOTE: The sponsor can be either a qualified instructor or licensed operator)*

Signature _____

Sponsor

PART II - REQUEST FOR ADMINISTERING TESTS AND EXAMINATIONS AND ISSUING LICENSE

FROM: Date

TO:

It is requested that the license for equipment descripted in item 6 above be issued to this applicant upon his successful completion of the required examinations and tests.

Signature _____

Title _____

Department, Division or Shop Supervisor

(OVER)

PART III - ACTION ON SUBJECT APPLICATION

FROM: Date
TO:

☐ Arrangements will be made to proceed with examinations and tests as requested.

☐ No action will be taken on this application for the following reason:

Signature _____

Title _____

PART IV - LICENSE ACTION

FROM: Date
TO:

☐ The subject license has been issued to the applicant as requested.

☐ The applicant has failed his physical examination.

☐ The applicant has failed to qualify for the subject license.

_____ number of days *(the established waiting period)* must elapse before a new application may be made for this license.

Signature _____

Title _____

PRIVACY ACT STATEMENT

This statement is provided in compliance with the provisions of the Privacy Act of 1974 (PL-93-579) (N00011 C02) which require that Federal agencies must inform individuals who are requested to furnish information about themselves as to the following facts concerning the information requested.

1. AUTHORITY: 5 U.S.C. 301 Departmental Regulations
2. PRINCIPAL PURPOSE(S): To apply for a license to operate government-owned vehicles.
3. ROUTINE USE(S): To be used by agency officials to determine the employee's eligibility to operate government-owned vehicles. May be used by safety and security officials to verify individual's qualifying experience.
4. MANDATORY OR VOLUNTARY DISCLOSURE: The disclosure of information requested is voluntary. However, failure to complete the form will result in nonissuance of license.

NAVFAC 11260/1 (BACK) **2**

Figure 1-2B – Application for Construction Equipment Operator

1.3.0. Physical Fitness Inquiry for Motor Vehicle Operators (Standard Form 47)

Standard Form 47 (*Figure 1-3*) is the Physical Fitness Inquiry for Motor Vehicle Operators. Operators cannot have physical defects or suffer emotional instability that might make them a hazard to themselves or others. A license examiner reviews and evaluates Standard Form 47 as well as other available information regarding the applicant's physical condition to determine if a physical examination is required. If a physical examination is required, the Medical Department performs it.

Standard Form 47

(Rev. 1-77)

PHYSICAL FITNESS INQUIRY FOR MOTOR VEHICLE OPERATORS

U.S. Civil Service Commission
FPM Chapter 930

47-105

1. Last Name-First Name- Middle Name	2. Date Of Birth	3. Title Of Position
4. Home Address (*Number, street or RFD, city or town, State& ZIP code)*		5. Employing Agency

6. Have you ever had or have you now (*place check at left of each item*):

YES	NO		YES	NO	
☐	☐	Poor vision in one or both eyes	☐	☐	Arthritis, rheumatism, swollen or painful joints
☐	☐	Eye disease	☐	☐	Loss of hand, arm, foot, or leg
☐	☐	Poor hearing in one or both ears	☐	☐	Deformity of hand, arm, foot, or leg
☐	☐	Diabetes	☐	☐	Nervous or mental trouble of any kind
☐	☐	Palpitation, chest pain, or shortness of breath	☐	☐	Blackouts or epilepsy
☐	☐	Dizziness or fainting spells	☐	☐	Sugar or albumin in urine
☐	☐	Frequent or severe headaches	☐	☐	Exsessive drinking habit (alcohol)
☐	☐	High or low blood pressure	☐	☐	Other serious defects or diseases
☐	☐	Drug or narcotic habit			

7. If your answer is "yes" to one or more of the above questions,explain fully in this space, indicating date of original condition and current status:

8. (A) Do you wear glasses (or contact lenses) while driving? ☐ YES ☐ NO

(B) Do you wear a hearing aid ? ☐ YES ☐ NO

PRIVACY ACT NOTICE

Authority: This information is provided pursuant to Public Law 93-579 (Privacy Act of 1974), December 31, 1974, for individuals completing Standard Form 47, Physical Fitness Inquiry for Motor Vehicle Operators U.S. Code, Title 5, section 301.

Purposes and Uses: SF 47 is used to ascertain the physical fitness of Federal employees, whose jobs are not regular motor vehicle operating jobs, to drive Government- owned motor vehicles. It is also used in the renewal of authorizations for all employees. Based on the information provided, employees may be referred for a medical examination before being given a renewal.

Effects of Non Disclosure: Nondisclosure of this information will result in the employee not being authorized to drive a Federal motor vehicle. The disclosure of this information is mandatory when an employee's job requires driving a Federal motor vehicle and is voluntary otherwise.

I certify that my answers are full and true, and I understand that a willfully false statement or dishonest answer to any question may be grounds for cancellation of my eligibility or my dismissal from the service and is punishable by law.

Signature	Date

REVIEW AND CERTIFICATION BY DESIGNATED OFFICIAL

I certify that I have reviewed this physical fitness inquiry form and other available information regarding the physical condition of the applicant, and that I have made the following determination:

☐ There is no information on this form or otherwise available to indicate that the applicant should be referred for physical examination.

☐ On the basis of items checked in this form or other information, this applicant must be referred for physical examination before he/she is authorized to operate a government- owned motor vehicle or his/her current authorization is renewed.

☐ Items checked on this form or otherwise available do not warrant referral for medical examination because of the following facts:

Signature of designated official	Date

Adapted For Computer Use 11/8/2000

Figure 1-3 – Physical Fitness Inquiry for Motor Vehicle Operator's Standard Form 47.

1.4.0 License Test

Written tests administered by a license examiner are a requirement of the licensing process. Tests are based on traffic laws and regulations, accident reporting procedures, operator's maintenance responsibilities, safe driving practices, and the characteristics and limitations of the types of equipment for which the test is given. Applicants who require information on a particular piece of equipment should use the operator's manual located in the technical library, which is normally housed in the mechanic shop.

1.4.1 Performance Qualification Test

Except for crane performance tests, all performance qualification tests on equipment are administered by a license examiner. The test enables the license examiner to evaluate the applicant's operating skills. The applicant must successfully pass an operational performance or road test and perform pre- and post-operator maintenance as outlined in the operator's manual.

The examiner should terminate any performance test that becomes hazardous. He or she may also terminate the test if an applicant demonstrates a lack of skill, undue nervousness, speeding, inattentiveness, or other unfavorable actions. The examiner notes any reason for failure on the application and places it in the applicant's license file.

1.4.1.1 Automotive Test

U.S. Government Motor Vehicle Operator's Identification Card, OF-346, applicants must pass a locally created driver skill test. The test is a locally devised checklist to determine the reaction of the applicant under various traffic conditions. The road test is administered in the largest capacity vehicle for which the license is to be issued.

1.4.1.2. Material Handling Equipment Test

Applicants for material-handling equipment (MHE) licenses are operationally tested and scored as prescribed in *Storage and Materials Handling,* DODINST 4145.19-R-1.

1.4.1.3 Construction Equipment Test

Construction Equipment Operator License applicants must be familiar with the standard Navy hand signals before taking a performance qualification test. The Navy uses a wide variety of construction and weight-handling equipment. For this reason, standard Navy-wide performance qualification tests are not practical; therefore, the local examiner must prepare such operational tests as required. Samples of operational tests are contained in the NAVFAC P-306.

1.5.0 Licenses Forms

After an applicant satisfactorily completes the required tests, the examiner issues a license listing each type of vehicle the license holder is authorized to operate and any imposed restrictions on the license.

1.5.1. U.S. Government Motor Vehicle Operator's Identification Card (OF-346)

The U.S. Government Motor Vehicle Operator's Identification Card, OF-346 (*Figure 1-4*) license is required for automotive motor vehicles and material-handling equipment.

Information that must be completed and validated on the OF-346 includes: card number, list of the operator's physical limitations or restrictions, description of the equipment the operator is qualified to operate, signature of the examiner, operator's signature, and any specific notations. The OF-346 is valid for 3 years and expires on the operator's birth date.

The OF-346 card number is also indicated on the Operator's Record, NAVFAC 11240/10, or NAVFAC 11260/3 (*Figure1-5*), Construction Equipment Operator License Record. The license examiner maintains a chronological record of all licenses issued.

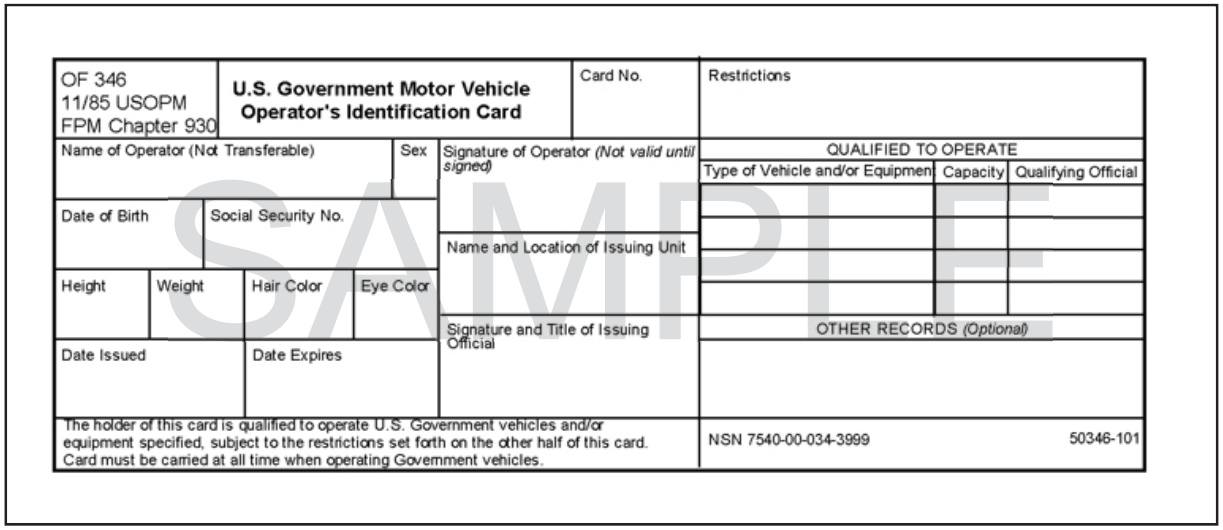
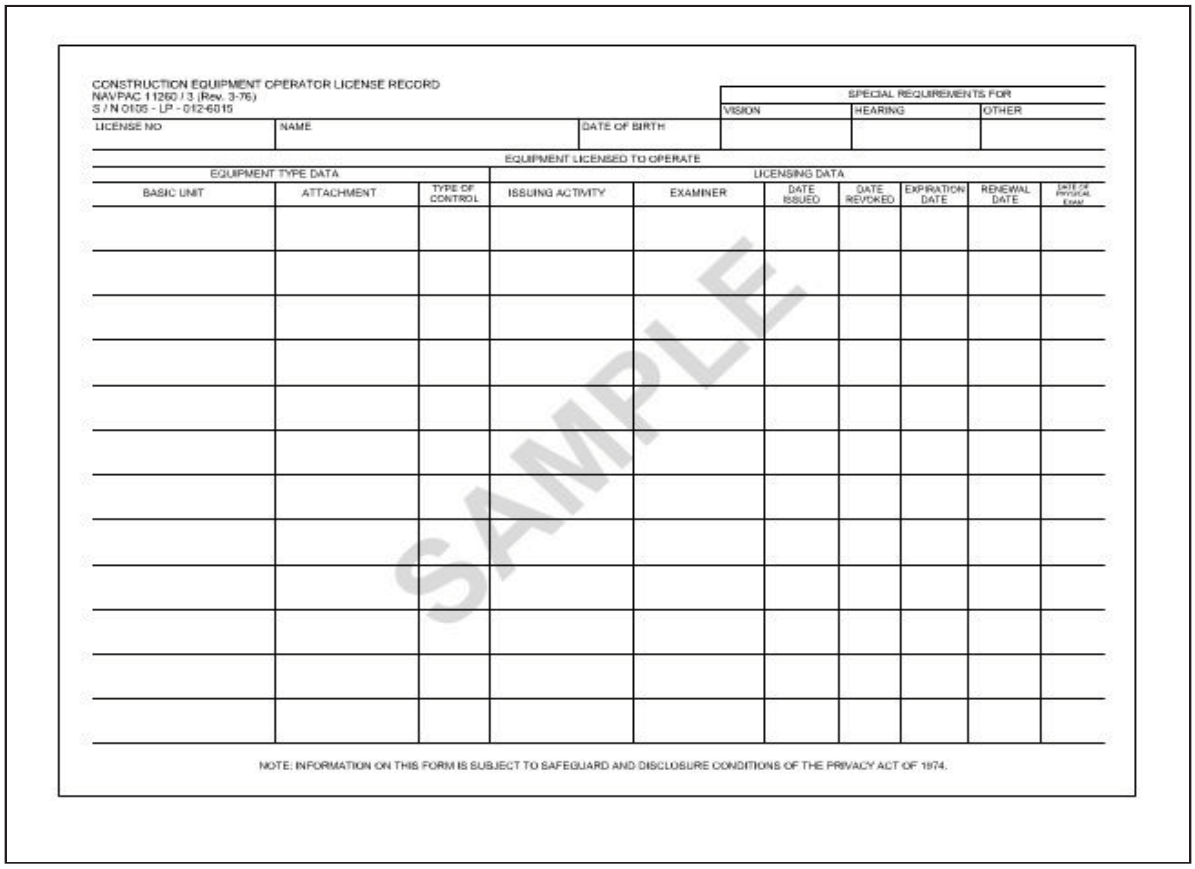


Figure 1-4 – U.S. Government Motor Vehicle Operator's Identification Card, OF-346.

The OF-346 card number is also indicated on the Operator's Record, NAVFAC 11240/10, or NAVFAC 11260/3(*Figure1-5*), Construction Equipment Operator License Record. The license examiner maintains a chronological record of all licenses issued.



CONSTRUCTION EQUIPMENT OPERATOR LICENSE RECORD
NAVFAC 11260 / 3 (Rev. 3-76)
S / N 0105 - LP - 012-6015

LICENSE NO	NAME	DATE OF BIRTH	SPECIAL REQUIREMENTS FOR: VISION	HEARING	OTHER

EQUIPMENT LICENSED TO OPERATE

EQUIPMENT TYPE DATA			LICENSING DATA						
BASIC UNIT	ATTACHMENT	TYPE OF CONTROL	ISSUING ACTIVITY	EXAMINER	DATE ISSUED	DATE REVOKED	EXPIRATION DATE	RENEWAL DATE	DATE OF PHYSICAL EXAM

SAMPLE

NOTE: INFORMATION ON THIS FORM IS SUBJECT TO SAFEGUARD AND DISCLOSURE CONDITIONS OF THE PRIVACY ACT OF 1974.

Figure 1-5 – Construction Equipment Operator License Record, NAVFAC 11260/3.

1.5.2. Construction Equipment Operator License, NAVFAC 11260/2

Construction Equipment Operator License, NAVFAC 11260/2 (*Figure 1-6*) is required for operating construction equipment. Information that must be completed and validated on the NAVFAC 11260/2 includes: card number, operator's name, description of the equipment, make and model of the equipment, types of controls, examiner's signature, and operator's signature. The NAVFAC 1260/2 is valid for 2 years and expires on the operator's birth date.

CONSTRUCTION EQUIPMENT OPERATOR LICENSE
NAVFAC 11260 2 (9 - 74)
Supersedes NAVDOCKS 2754
S / N 0105 - LF - 004 - 1510

CARD NO

NAME OF OPERATOR

DATE ISSUED

DATE EXPIRES

DATE OF BIRTH	COLOR OF HAIR	COLOR OF EYES	HEIGHT	WEIGHT

THE HOLDER OF THIS CARD IS QUALIFIED TO OPERATE U.S. GOVERNMENT HEAVY EQUIPMENT AS SPECIFIED ON REVERSE OF THIS CARD

SIGNATURE OF ISSUING OFFICIAL	TITLE *CERTIFIED EXAMINER*
SIGNATURE OF OPERATOR	TITLE OF POSITION

NOT TRANSFERABLE *Card must be carried at all times when operating Government equipment.*

SAMPLE

(Front)

QUALIFIED TO OPERATE

EQUIPMENT TYPE	SIZE AND CAPACITY	ATTACHMENT	TYPE CON-TROLS	EXAM

☆ U.S. GOVERNMENT PRINTING OFFICE: 1984-705-012/7317 2-1

SAMPLE

(Back)

Figure 1-6 – Construction Equipment Operator License NAVFAC 11260/2.

1.6.0 Dispatch Forms

Dispatch forms are recording and reporting tools that facilitate the efficient management of the equipment pool. The forms document miles, hours, equipment troubles, maintenance performed, operator names, etc. The operator is responsible for filling out and submitting assigned dispatch forms.

NAVFAC 9-11240/13 and NAVFAC 11260/4 are essential parts of the equipment maintenance program. The operator has the best opportunity to discover equipment problems or defects before they become serious. Reporting defects on the proper forms provides maintenance shop personnel with the information to make required repairs.

1.6.1 Maintenance Requirement Card (MRC)

The Operator's Daily PM Report, NAVFAC 11260/4 (*Figure1-7*), is issued to the operator when he or she uses construction equipment. The operator performs prestart maintenance checks of the listed items and indicates findings in the appropriate space. Record malfunctions or other items requiring attention observed during the working day, and enter hours operated during the day. Hour readings are taken from the equipment hour meter. After securing the equipment, take the NAVFAC 11260/4 to the dispatcher. The dispatcher reviews the report to ensure recorded entries are valid and notes any deficiencies.

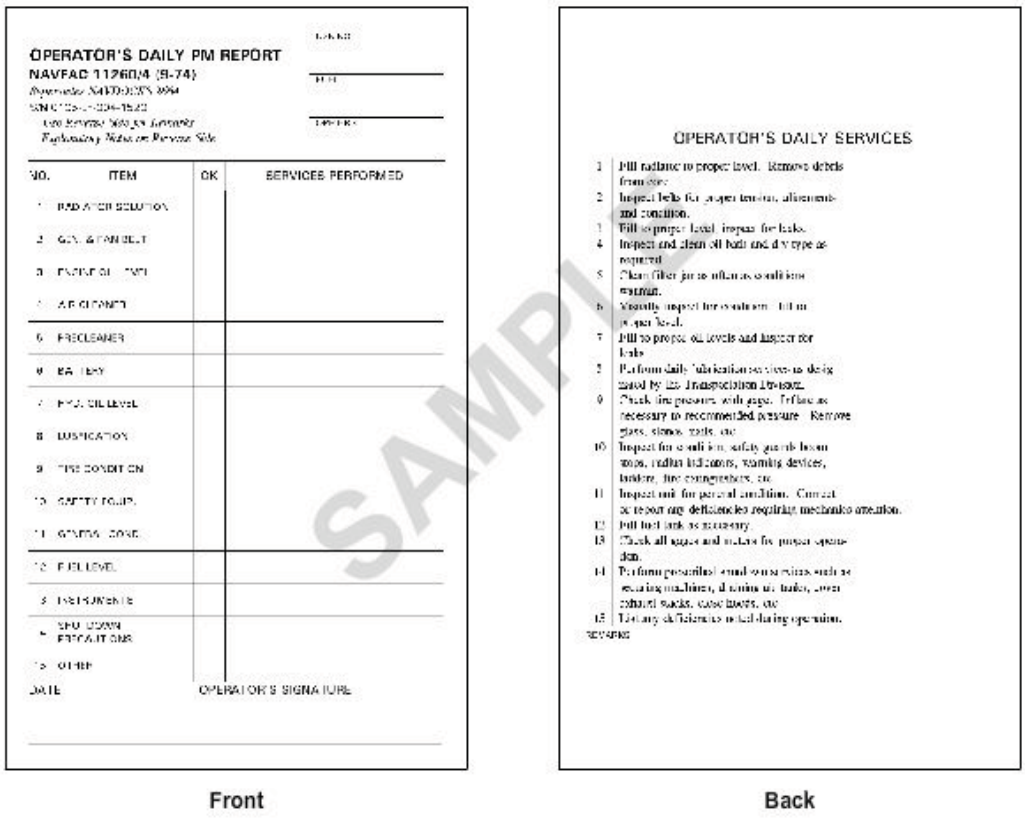
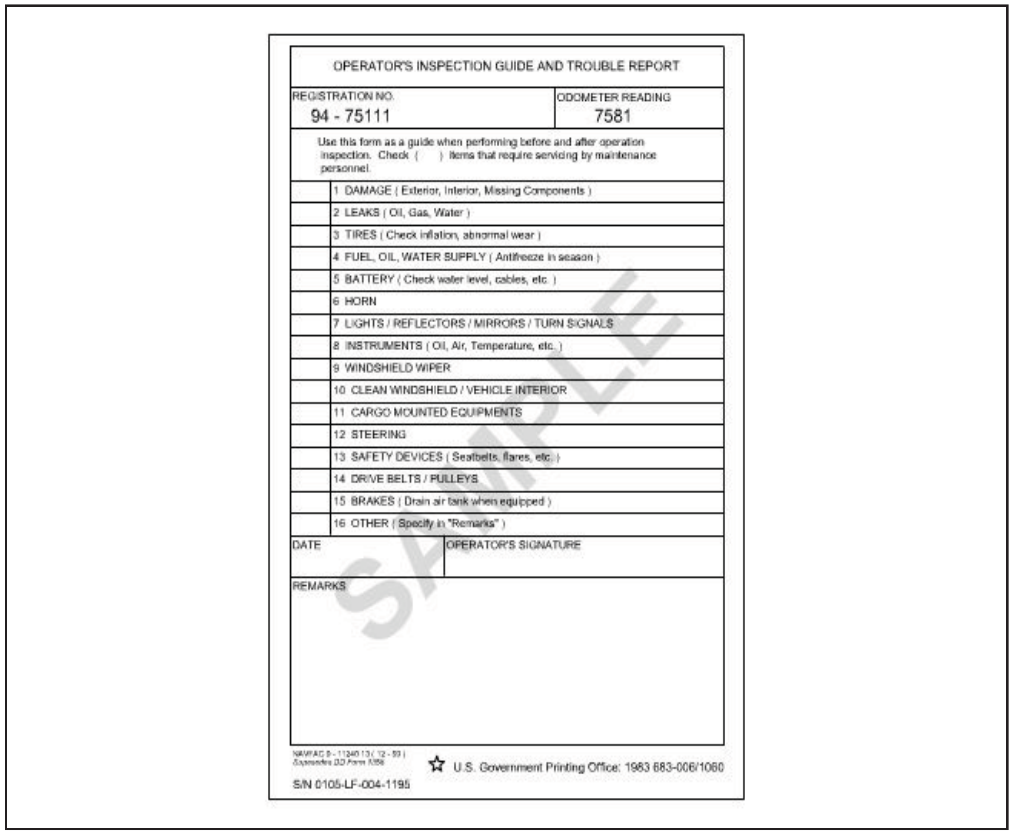


Figure 1-7 – Operators Daily PM Report NAVFAC 11260/4.

1.6.2. Operator's Inspection Guide and Trouble Report "Hard-Card" (NAVFAC 9-11240/13)

The Operator's Inspection Guide and Trouble Report, NAVFAC 9-11240/13 (*Figure1-8*), commonly known as the Hard Card**,** is a guide for operator's maintenance. It is one of the forms used to document problems encountered during pre- and post-operations. The form provides a uniform list of services operators must perform before, during, and after operation.

A check mark indicates items requiring servicing by maintenance personnel. The Remarks space is used for items not listed or for additional information concerning deficiencies indicated by a check mark. Submit the completed form to the dispatcher, who will determine if the vehicle can be used or if it requires additional maintenance. Units have a procedure to process the Hard Card when a vehicle needs repairs.



OPERATOR'S INSPECTION GUIDE AND TROUBLE REPORT

REGISTRATION NO.	ODOMETER READING
94 - 75111	7581

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

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

DATE	OPERATOR'S SIGNATURE

REMARKS

SAMPLE

NAVFAC 9-11240/13 (12 - 89)
Supersedes DD Form 1356

☆ U.S. Government Printing Office: 1983 683-006/1060

S/N 0105-LF-004-1195

Figure 1-8 – Operators Inspection Guide and Trouble Report NAVFAC 9-11240/13.

1.6.3. Motor Vehicle Utilization Record "Trip Ticket" (DD 1970)

The Motor Vehicle Utilization Record, Form DD 1970 (*Figures1-9A and 1-9B*), is an operator's official authorization to operate a vehicle driven by the person requesting the vehicle or by other personnel in the motor pool. The dispatcher and the operator must fill out and sign Form DD 1970. Commonly known as the Trip Ticket, the form is a record verifying a vehicle was on an official trip. The trip ticket information includes: operator's destination, time of departure and arrival, odometer reading and other pertinent trip(s) information.

NOTE

If the odometer is broken, the operator must estimate the amount of miles traveled.

MOTOR EQUIPMENT UTILIZATION RECORD

1. DATE *(YYYYMMDD)*	2. TYPE OF EQUIPMENT	3. REGISTRATION NO./SERIAL NO.	4. ADMINISTRATION NO.

5. ORGANIZATION NAME	6a. FUEL	b. OIL

ACTION	9. TIME		10. MILES	11. HOURS	
7a. 1ST OPERATOR *(Last Name, First, M.I.)*	a. IN				12a. REPORT TO *(Last Name, First, M.I.)*
	b. OUT				
8a. OPERATOR'S SIGNATURE	c. TOTAL		0	0	13a. DISPATCHER'S SIGNATURE
7b. 2ND OPERATOR *(Last Name, First, M.I.)*	a. IN				12b. REPORT TO *(Last Name, First, M.I.)*
	b. OUT				
8b. OPERATOR'S SIGNATURE	c. TOTAL		0	0	13b. DISPATCHER'S SIGNATURE
7c. 3RD OPERATOR *(Last Name, First, M.I.)*	a. IN				12c. REPORT TO *(Last Name, First, M.I.)*
	b. OUT				
8c. OPERATOR'S SIGNATURE	c. TOTAL		0	0	13c. DISPATCHER'S SIGNATURE
7d. 4TH OPERATOR *(Last Name, First, M.I.)*	a. IN				12d. REPORT TO *(Last Name, First, M.I.)*
	b. OUT				
8d. OPERATOR'S SIGNATURE	c. TOTAL		0	0	13d. DISPATCHER'S SIGNATURE

14. DESTINATION	15. TIME		16. RELEASED BY *(Signature)*	17. REMARKS
	a. ARRIVE	b. DEPART		
(1) FROM				
(2) TO				
(3) TO				
(4) TO				
(5) TO				
(6) TO				
(7) TO				
(8) TO				
(9) TO				
(10) TO				
(11) TO				
(12) TO				
(13) TO				
(14) TO				
(15) TO				
(16) TO				

DD FORM 1970, NOV 1999

Figure 1-9A – Motor Vehicle Utilization Record, Form DD 1970 (Page 1 of 2).

14. DESTINATION	15. TIME		16. RELEASED BY *(Signature)*	17. REMARKS
	a. ARRIVE	b. DEPART		
(17) TO				
(18) TO				
(19) TO				
(20) TO				
(21) TO				
(22) TO				
(23) TO				
(24) TO				
(25) TO				
(26) TO				
(27) TO				
(28) TO				
(29) TO				

INSTRUCTIONS

*1. Date. Enter the calendar date the equipment is to be used.

2. Type of Equipment. Enter the type of equipment as designated in the equipment log.

3. Registration Number or Serial Number. Enter the equipment/ registration number or serial number.

4. Administration Number. Enter the unit number or administrative number.

5. Organization Name. Enter the organization to which the equipment is assigned.

6. Fuel/Oil. Enter the amount of fuel (gallons) and/or oil (quarts) obtained for the equipment.

*7. Operator. Enter the name of the equipment operator.

8. Operator's Signature. The equipment operator (item 6) will enter signature immediately upon receipt of equipment.

*9. Time. Indicate time to the nearest 5 minutes using the 24-hour clock.
a. In. Enter time equipment was returned from dispatch or use.
b. Out. Enter the time the equipment was released for operation by the dispatcher.
c. Total. Enter total time the equipment was in the possession of the operator. Time is obtained by subtracting the time listed in "Out" line from that listed on the "In" line.

*10. Miles. Will be recorded to the nearest whole mile.
a. In. The operator will enter the mileage reading when the equipment is returned. If odometer is inoperative, enter estimated mileage.
b. Out. The dispatcher will enter the mileage reading at the time of dispatch.
c. Total. Enter the difference between the "Out" and "In" mileage.

*11. Hours. Will be recorded to the nearest whole hour. On those items which require servicing on an hourly basis and are not equipped with an hour meter, enter the estimated hours of operation.
a. In. The operator will enter the hour meter reading upon completion of the equipment usage.
b. Out. The dispatcher will neter the hour meter reading prior to equipment release.
c. Total. Enter the total hours dispatched for operation.

*12. Report To. Enter the name of the individual to whom the operator is to report.

13. Dispatcher's Signature. Self-explanatory.

14. Destination. Indicate each location at which a trip begins and ends. Normally this starts from the equipment pool ("From" Line) and ends at the same place after one or more intervening destinations.

*15. Time. All time will be recorded using the 24-hour clock, rounded off to the nearest 5 minutes.
a. Arrive. Enter the arrival time at each destination.
b. Depart. Enter the departure time from the motor pool and each succeeding location.

16. Released By. The person in charge of equipment on dispatch will release by signing on the line indicating the destination where the equipment was released to the operator. Upon termination of equipment used, but not moved, the person in charge will release the equipment by signing in the top block of this column.

17. Remarks. The remarks column will be used by the operator to record unusual operation or abnormal occurrences during operation, or other information as directed.

*Items marked with an asterisk (*) have been registered in the DOD Data Element Program.

Figure 1-9B – Motor Vehicle Utilization Record, Form DD 1970 (Page 2 of 2).

1.6.4. Operator's Report of Motor Vehicle Mishap Form (Standard Form 91)

Every mishap involving a Navy motor vehicle or item of construction equipment must be reported on an Operator's Report of Motor Vehicle Accident, Standard Form 91 *(Figures 1-10A, 1-10B, 1-10C and 1-10D*). Copies of the SF 91, mishap instructions, and pencil should be carried in every Navy vehicle at all times. In case of a mishap involving another vehicle, the operator must complete the form even if the driver of the other vehicle states that he or she will file no claim for damages. The form must also be completed when a mishap does not involve another vehicle. The operator must deliver the mishap form or ensure its immediate delivery to the supervisor. The supervisor is responsible for forwarding the form to the battalion mishap investigator.

As an operator, if you are involved in a mishap, your first responsibility is to render aid to the injured. After rendering aid, complete the mishap report. As an aid in completing Standard Form 91, comply with the following instructions:

1. Properly spell names and street addresses of persons involved in the mishap and any personnel that may have witnessed the mishap.
2. Carefully note weather conditions, road conditions, position of the vehicle involved, and other details.
3. Provide a clear picture of what actually happened. Diagram the mishap, showing exactly where the vehicles were before and after the mishap.
4. Document visual damage, such as "crushed right rear wheel or crumpled fender," and provide an estimate of the amount of damage. If someone claims he or she has damaged property but the damage is not observable, make a note on the accident report stating that he or she "claims bent fender," etc. Follow the same procedures with injuries. Document observable injuries including; cuts, burns, broken bones, etc. Make a note when a person "claims" an injury when there is no way of knowing the truth. If exact information is unavailable for a particular item, write "unknown" to indicate it was not overlooked.
5. If sufficient space is not available for an item, write "see attached sheet," and attach an extra sheet containing the additional information.
6. After the form is finished, carefully review the report and ensure it is complete and accurate. When satisfied with the completed report, sign and submit it to the mishap investigator.

MOTOR VEHICLE ACCIDENT REPORT

Please read the Privacy Act Statement on Page 3.

INSTRUCTIONS: Sections I thru IX are filled out by the vehicle operator. Section X, Items 72 thru 82c are filled out by the operator's supervisor. Sections XI thru XII are filled out by an accident investigator for bodily injury, fatality, and/or damage exceeding $500.

SECTION I - FEDERAL VEHICLE DATA

1. DRIVER'S NAME *(Last, first, middle)*	2. DRIVER'S LICENSE NO./STATE/LIMITATIONS	3. DATE OF ACCIDENT

4a. DEPARTMENT/FEDERAL AGENCY PERMANENT OFFICE ADDRESS	4b. WORK TELEPHONE NUMBER

5. TAG OR IDENTIFICATION NUMBER	6. EST. REPAIR COST	7. YEAR OF VEHICLE	8. MAKE	9. MODEL	10. SEAT BELTS USED
	$				☐ YES ☐ NO

11. DESCRIBE VEHICLE DAMAGE	

SECTION II - OTHER VEHICLE DATA *(Use Section VII if additional space is needed.)*

12. DRIVER'S NAME *(Last, first, middle)*	13. DRIVER'S LICENSE NUMBER/STATE/LIMITATIONS

14a. DRIVER'S WORK ADDRESS	14b. WORK TELEPHONE NUMBER

15a. DRIVER'S HOME ADDRESS	15b. HOME TELEPHONE NUMBER

16. DESCRIBE VEHICLE DAMAGE	17. ESTIMATED REPAIR COST
	$

18. YEAR OF VEHICLE	19. MAKE OF VEHICLE	20. MODEL OF VEHICLE	21. TAG NUMBER AND STATE

22a. DRIVER'S INSURANCE COMPANY NAME AND ADDRESS	22b. POLICY NUMBER
	22c. TELEPHONE NUMBER

23. VEHICLE IS	24a. OWNER'S NAME(S) *(Last, first, middle)*	24b. TELEPHONE NUMBER
☐ CO-OWNED ☐ RENTAL ☐ LEASED ☐ PRIVATELY OWNED		

25. OWNER'S ADDRESS(ES)

SECTION III - KILLED OR INJURED *(Use Section VII if additional space is needed.)*

A

26. NAME *(Last, first, middle)*	27. SEX	28. DATE OF BIRTH

29. ADDRESS

30. MARK "X" IN TWO APPROPRIATE BOXES	31. IN WHICH VEHICLE	32. LOCATION IN VEHICLE	33. FIRST AID GIVEN BY
☐ KILLED ☐ DRIVER ☐ PASSENGER ☐ INJURED ☐ HELPER ☐ PEDESTRIAN	☐ FED ☐ OTHER (2)		

34. TRANSPORTED BY	35. TRANSPORTED TO

B

36. NAME *(Last, first, middle)*	37. SEX	38. DATE OF BIRTH

39. ADDRESS

40. MARK "X" IN TWO APPROPRIATE BOXES	41. IN WHICH VEHICLE	42. LOCATION IN VEHICLE	43. FIRST AID GIVEN BY
☐ KILLED ☐ DRIVER ☐ PASSENGER ☐ INJURED ☐ HELPER ☐ PEDESTRIAN	☐ FED ☐ OTHER (2)		

44. TRANSPORTED BY	45. TRANSPORTED TO

46. Pedestrian

a. NAME OF STREET OR HIGHWAY	b. DIRECTION OF PEDESTRIAN *(SW corner to NE corner, etc.)*	
	FROM	TO

c. DESCRIBE WHAT PEDESTRIAN WAS DOING AT TIME OF ACCIDENT (Crossing intersection with signal, against signal diagonally, in roadway playing, walking, hitchhiking, etc.)

1-20

Figure 1-10A- D - Operator's Report of Motor Vehicle Accident, Standard Form 91

SECTION IV - ACCIDENT TIME AND LOCATION *(Use Section VIII if additional space is needed.)*

47. DATE OF ACCIDENT	48. PLACE OF ACCIDENT *(Street address, city, state, ZIP Code; Nearest landmark; Distance nearest intersection; Kind of locality (industrial, business, residential, open country, etc.); Road description).*
49. TIME OF ACCIDENT AM PM	

50. INDICATE ON THIS DIAGRAM HOW THE ACCIDENT HAPPENED

Use one of these outlines to sketch the scene. Write in street or highway names or numbers.

a. *Number Federal vehicle as 1, other vehicle as 2, additional vehicle as 3 and show direction of travel with arrow.*

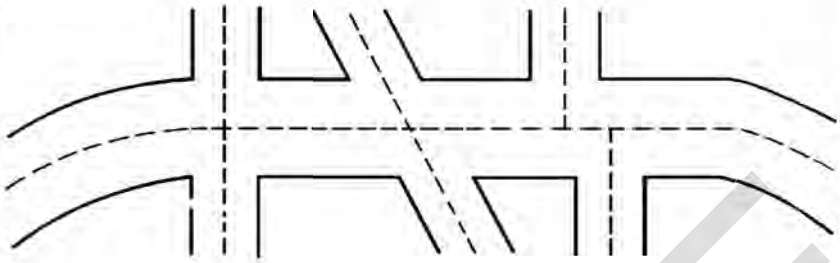
Example: 1 2

b. Use solid line to show path before accident 2
and broken line after the accident 2

c. Show pedestrian by

d. Show railroad by

e. Place arrow in this circle to indicate *NORTH*



51. POINT OF IMPACT *(Check one for each vehicle)*

FED	2	AREA
		a. FRONT
		b. R. FRONT
		c. L. FRONT
		d. REAR
		e. R. REAR
		f. L. REAR
		g. R. SIDE
		h. L. SIDE

52. DESCRIBE WHAT HAPPENED *(Refer to vehicles as "Fed", "2", "3", etc. Please include information on posted speed limit, approximate speed of the vehicles, road conditions, weather conditions, driver visibility, condition of accident vehicles, traffic controls (warning light, stop signal, etc.) condition of light (daylight, dusk, night, dawn, artificial light, etc.) and driver actions (making U-turn, passing, stopped in traffic, etc.).*

SECTION V - WITNESS/PASSENGER *(Witness must fill out SF 94, Statement of Witness) (Continue in Section VIII.)*

A	53. NAME *(Last, first, middle)*	54. WORK TELEPHONE NUMBER	55. HOME TELEPHONE NUMBER
	56. BUSINESS ADDRESS	57. HOME ADDRESS	
B	58. NAME *(Last, first, middle)*	59. WORK TELEPHONE NUMBER	60. HOME TELEPHONE NUMBER
	61. BUSINESS ADDRESS	62. HOME ADDRESS	

SECTION VI - PROPERTY DAMAGE *(Use Section VIII if additional space is needed.)*

63a. NAME OF OWNER		63b. OFFICE TELEPHONE NUMBER	63c. HOME TELEPHONE NUMBER
63d. BUSINESS ADDRESS		63e. HOME ADDRESS	
64a. NAME OF INSURANCE COMPANY		64b. TELEPHONE NUMBER	64c. POLICY NUMBER
65. ITEM DAMAGED	66. LOCATION OF DAMAGED ITEM		67. ESTIMATED COST $

SECTION VII - POLICE INFORMATION

68a. NAME OF POLICE OFFICER		68b. BADGE NUMBER	68c. TELEPHONE NUMBER
69. PRECINCT OR HEADQUARTERS		70a. PERSON CHARGED WITH ACCIDENT	70b. VIOLATION(S)

SECTION VIII - EXTRA DETAILS

SPACE FOR DETAILED ANSWERS. INDICATE SECTION AND ITEM NUMBER FOR EACH ANSWER. IF MORE SPACE IS NEEDED, CONTINUE ITEMS ON PLAIN BOND PAPER.

SECTION IX - FEDERAL DRIVER CERTIFICATION

In compliance with the Privacy Act of 1974, solicitation of the information requested on this form is authorized by Title 40 U.S.C. Section 491. Disclosure of the information by a Federal employee is mandatory as the first step in the Government's investigation of a motor vehicle accident. The principal purposes for using this information is to provide necessary data for legal counsel in legal actions resulting from the accident and to provide accident information/statistics in analyzing accident causes and developing methods of reducing accidents. Routine use of information may be by Federal, State or local governments, or agencies, when relevant to civil, criminal, or regulatory investigations or prosecutions. An employee of a Federal agency who fails to report accurately a motor vehicle accident involving a Federal vehicle or who refuses to cooperate in the investigation of an accident may be subject to administrative sanctions.

I certify that the information on this form *(Sections I thru VIII)* is correct to the best of my knowledge and belief.

71a. NAME AND TITLE OF DRIVER	71b. DRIVER'S SIGNATURE AND DATE

SECTION X - DETAILS OF TRIP DURING WHICH ACCIDENT OCCURRED

72. ORIGIN	73. DESTINATION

74. EXACT PURPOSE OF TRIP

	DATE	TIME *(Circle one)*		DATE	TIME *(Circle one)*
75. TRIP BEGAN		a.m. p.m.	76. ACCIDENT OCCURRED		a.m. p.m.

77. AUTHORITY FOR THE TRIP WAS GIVEN TO THE OPERATOR	78. WAS THERE ANY DEVIATION FROM DIRECT ROUTE
☐ ORALLY ☐ IN WRITING *(Explain)*	☐ NO ☐ YES *(Explain)*
79. WAS THE TRIP MADE WITHIN ESTABLISHED WORKING HOURS	80. DID THE OPERATOR, WHILE ENROUTE, ENGAGE IN ANY ACTIVITY OTHER THAN THAT FOR WHICH THE TRIP WAS AUTHORIZED.
☐ YES ☐ NO *(Explain)*	☐ NO ☐ YES *(Explain)*

81. COMPLETED BY DRIVER'S SUPERVISOR	a. DID THIS ACCIDENT OCCUR WITHIN THE EMPLOYEE'S SCOPE OF DUTY	b. COMMENTS
	☐ YES ☐ NO	

82a. NAME AND TITLE OF SUPERVISOR	82b. SUPERVISOR'S SIGNATURE AND DATE	82c. TELEPHONE NUMBER

SECTION XI - ACCIDENT INVESTIGATION DATA

83. DID THE INVESTIGATION DISCLOSE CONFLICTING INFORMATION. ☐ YES ☐ NO *(If "Yes", explain below.)*

84. PERSONS INTERVIEWED

NAME	DATE	NAME	DATE
a.		c.	
b.		d.	

85. ADDITIONAL COMMENTS *(Indicate section and item number for each comment.)*

SECTION XII - ATTACHMENTS

LIST ALL ATTACHMENTS TO THIS REPORT

SECTION XIII - COMMENTS/APPROVAL

86. REVIEWING OFFICIAL'S COMMENTS

87. ACCIDENT INVESTIGATOR	88. ACCIDENT REVIEWING OFFICIAL
a. SIGNATURE AND DATE	a. SIGNATURE AND DATE
b. NAME *(First, middle, last)*	b. NAME *(First, middle, last)*
c. TITLE	c. TITLE
d. OFFICE	d. OFFICE
e. OFFICE TELEPHONE NUMBER	e. OFFICE TELEPHONE NUMBER

1.6.5. Accident Identification Card (DD Form 518)

The Accident-Identification Card, DD Form 518 (*Figure 1-11*), provides any person involved in a mishap with a Navy vehicle with the name and organizational assignment of the Navy operator. Always fill out the DD Form 518 at the scene of the mishap, and give a copy to the driver of the other vehicle. If the mishap involves a parked car, and the owner or operator is not available, place the DD Form 518 in or on the parked vehicle. Notify the police immediately and remain at the scene of the mishap until the police arrive or the owner or operator is located.

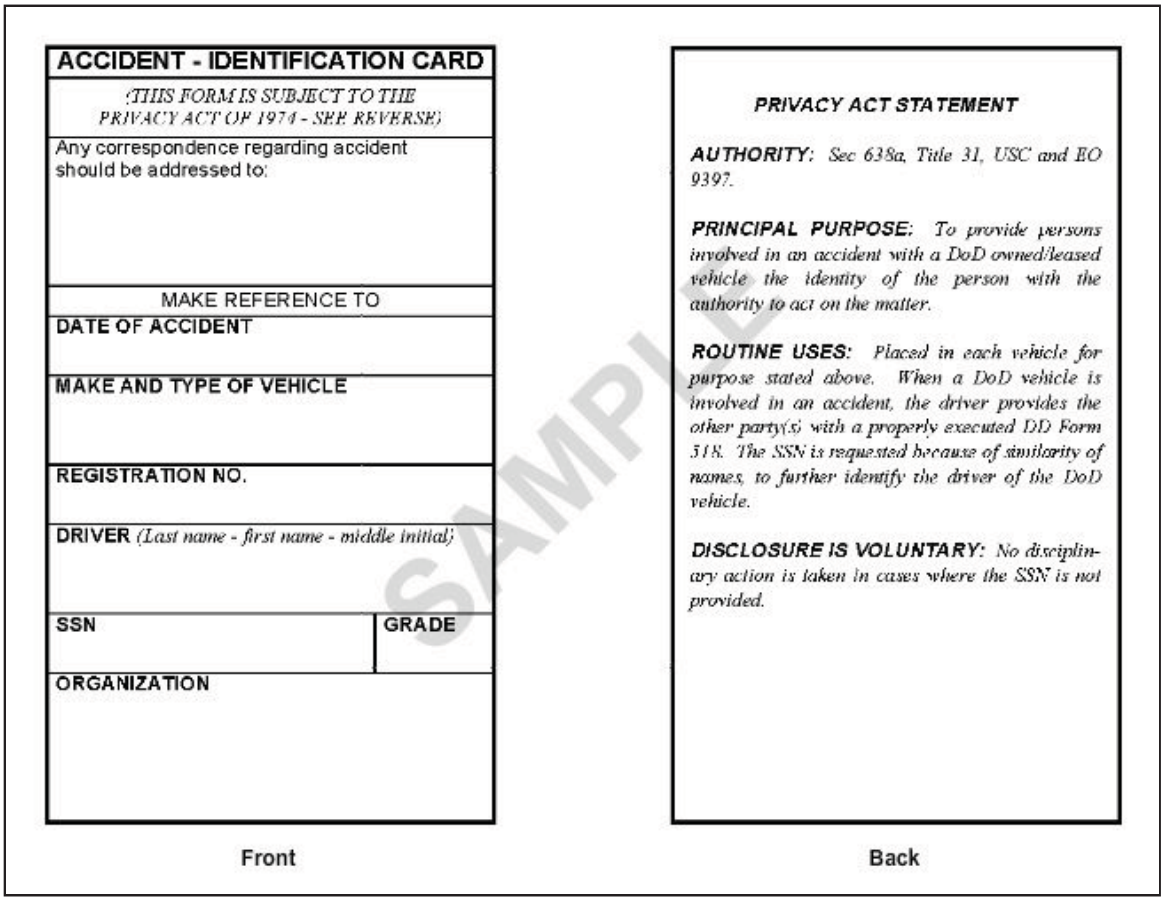


Figure 1-11 – Accident Identification Card, DD Form 518.

Test your Knowledge (Select the Correct Response)

1. What is the proper authorization to use a piece of equipment?

   A. Government Operator's License
   B. Valid trip ticket
   C. Trainers license
   D. Hard card

2. Which of the following personnel administer the written license test?

   A. The operations chief
   B. The license examiner
   C. The test mechanic
   D. The dispatcher

3. Which of the following conditions can terminate a performance qualification test?

   A. Lack of skill
   B. Undue nervousness
   C. Inattentiveness
   D. All of the above

4. When does the Operator's Identification Card expire?

   A. At the projected rotation date (PRD) of the operator
   B. Three years from the date of issue
   C. At 2 year intervals from the date of issue
   D. On the birth date of the operator and is valid for 3 years

5. Which of the following personnel have a better opportunity than anyone else to discover defects on equipment before they become serious problems?

   A. A mechanic
   B. The yard boss
   C. An operator
   D. The washrack attendant

6. Which of the following items should be carried in every Navy vehicle at all times?

   A. Copies of the SF 91
   B. Mishap instructions
   C. A pencil
   D. All of the above

7. What is your first responsibility if you are involved in a mishap?

   A. Determine what person was at fault
   B. Compute the amount of damage
   C. Render aid to the injured
   D. Notify your supervisor of the mishap

2.0.0 TRANSPORTATION ORGANIZATION TITLES and DUTIES

The transportation organization is composed of many positions, each assigned specific duties. The duties performed by each position are critical to efficient transportation operations. The positions described in more detail below include; Transportation Supervisor, Dispatcher, Yard Boss, License Examiner, Collateral Equipment Custodian, Attachment Custodian, and Equipment Operator.

2.1.0 Transportation Supervisor

The transportation officer in public works and the Alpha company commander designated as the equipment officer in an NMCB are directly responsible to the commanding officer of the activity for the management and maintenance of all assigned CESE. In an NMCB, the Alpha company operations chief, transportation supervisor, and

senior petty officers are responsible to the equipment officer for the administration, operations, and operator maintenance of all assigned CESE.

The transportation supervisor is responsible for supervising and controlling operations, operator maintenance, and the cycle of automotive, construction, and weight-handling equipment. The transportation supervisor also ensures the transportation pool supports the transport of personnel, equipment, and materials and maintains and operates all fuel, petroleum oil, and lubricant storage and dispensing facilities. The transportation supervisor's primary goals are:

- Ensuring safe and serviceable equipment is available for use
- Maximization of equipment service life

2.2.0 Dispatcher

The primary duty of the dispatcher is to manage the assigned equipment resources efficiently within the general policies and directives of the Navy and policies set forth by the equipment officer. Policies and directives for dispatch operations are outlined in the NAVFAC P-300, *Management of Transportation;* NAVFAC P-404, *Equipment Management Manual;* and COMFIRSTNCDINST 11200.2 A Series, Naval Mobile Construction Battalion (NMCB) Equipment Management Instruction.

The dispatcher is the key equipment management position in a unit and is the hub of communication for daily equipment operations. A competent dispatcher must possess the knowledge, skill, and ability to accomplish the following:

- Convey information and instruction in a concise and tactful manner.
- Exercise good judgment and make decisions quickly.
- Work efficiently under pressure.
- Conduct administrative, clerical, and recordkeeping duties
- Possess knowledge of equipment sizes, types, uses, and limitations.

In addition to possessing the aforementioned knowledge, skills, and abilities, the dispatcher is responsible for performing the following job requirements:

1. Route information: The dispatcher understands and conveys information to operators concerning weather conditions, road conditions, routes to travel, and emergency procedures. The dispatcher is knowledgeable of weight limits on roads and bridges, low clearances, traffic hazards, and local transportation systems, schedules, and routes.
2. Equipment status: The dispatcher must know the current status and location of every assigned item of equipment.
3. Keys: The dispatcher controls the keys to all vehicle locking devices and ignition keys. Spare keys are maintained in the equipment history jacket.
4. Records: The dispatcher checks operator licenses, and issues the Operator's Daily PM Report, NAVFAC 11260/4, for documenting pre- and post-operational checks on construction, weight-handling, and material-handling equipment. The Operator's Inspection Guide and Trouble Report, NAVFAC 9-11240/13, and the Motor Equipment Utilization Record, DD Form 1970, are used for documenting pre and post-operational checks and recording the utilization of automotive equipment. Additionally, the dispatcher ensures equipment required to operate

over the road contains mishap reporting procedures and forms. The proper forms are a Standard Form 91 and a description of local mishap reporting procedures.

2.2.1 Equipment Status Board

The Equipment Status Board is a means of listing, by USN number, all equipment assigned to a unit. The status board should be color-coded to identify the current status, general assignment, and location of each piece of CESE (*Figure 1-12*). The dispatcher is responsible for knowing the current status and location of every assigned piece of equipment.

*	Code	USN	Description	Location	PM Group	Remarks
(1)	030700	94-88650	Trk 14 Util	A CO CDR	37	
(1)	036000	95-19190	Trk 1-1/4 Util Cargo	Pool	1	
(2)		95-21098		Ops Supervisor	21	Shop 2.20 Deadlined 2.24
(1)	053900	95-16749	Trk 2-1/2T Cargo		2	
(3)	058700	96-27071	Trk 5t Dump	UT Project	3	Excess Ltr 4570 Ser XXX
(3)		96-27072		Pool	23	Excess Ltr 4570 Ser XXX
(4)		96-33439				Due 3,3 Ltr 4610 SerXXX
(4)		96-33451				Due 3,3 Ltr 4610 SerXXX
(1)	058800	96-32607	Trk 5t Cargo	UT Project	7	
(1)	060700	96-32926	Trk 5t TT	Pool	5	
(1)	073000	96-36101	Trk Wrecker	Heavy Shop	11	

* Optional column for color disc usage

Legend
(1) Black - In-service, Operational
(2) Red - Deadline
(3) Green - Pending Replacement
(4) Orange - Ordered in
(5) Blue - Optional Detachment, Etc.

Figure 1-12 – Equipment Status Board.

2.2.2. Dispatcher's Log

The dispatcher records all vehicles and equipment that are dispatched on the Dispatcher's Log, NAVFAC 9-11240/2 (*Figure 1-13*). The log sheet is a ready reference for the location of all the vehicles and equipment dispatched.

The dispatcher normally maintains a Heavy Equipment Dispatcher's Log, a class C assigned Dispatcher's Log, and a class B assigned Dispatcher's Log. The heavy equipment log is used for dispatching construction and weight-handling equipment, the class C log for dispatching automotive and material-handling equipment, and the class B assigned log to record dispatched class B assigned vehicles.

Vehicles assignments are divided into three dispatch categories: Class A, Class B, and Class C.

Class A dispatch category is the full-time assignment of a vehicle to an individual; it is only authorized by the Chief of Naval Operations (CNO).

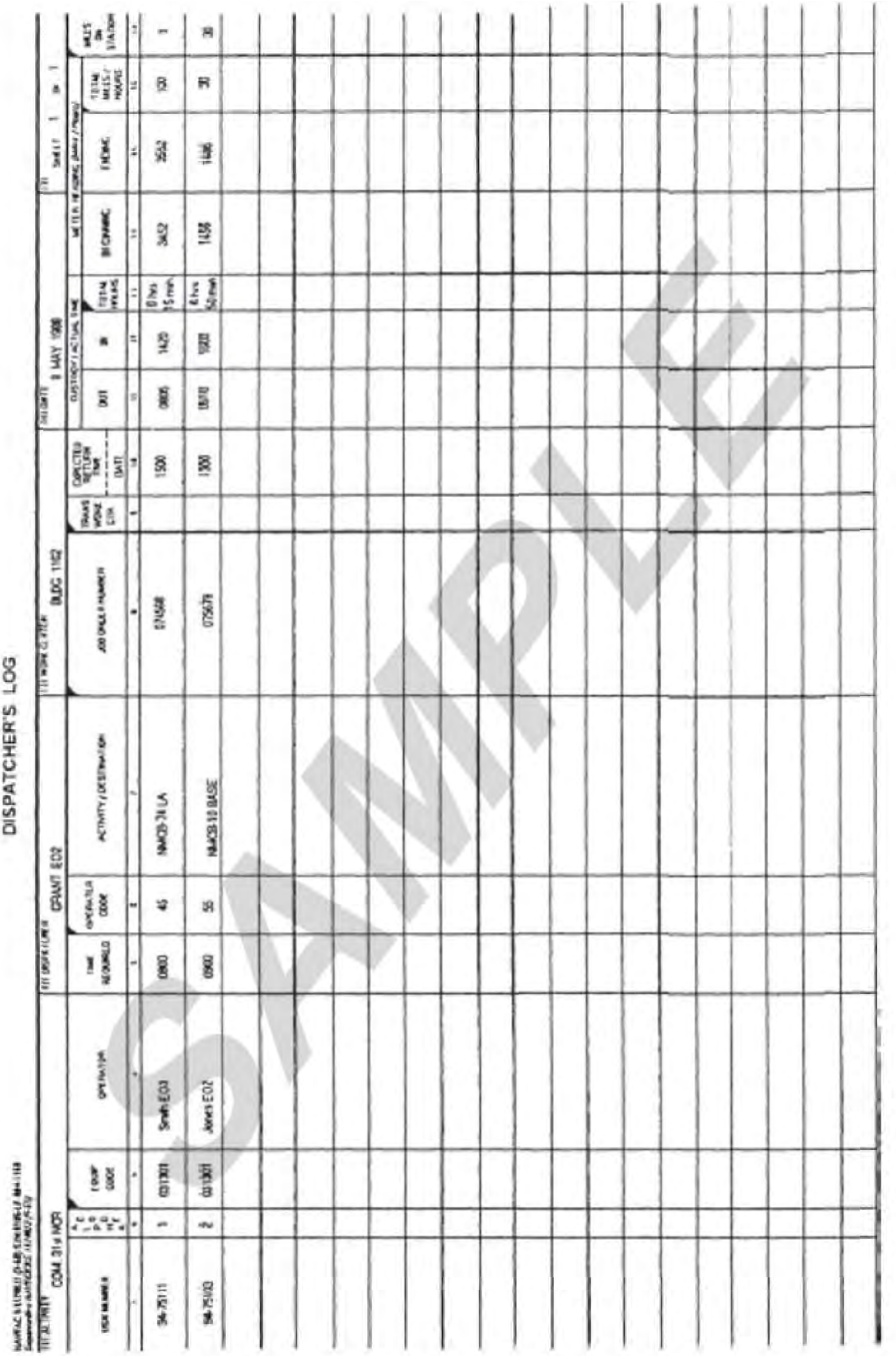
Class B dispatch category in the NCF is the once a week assignment of a vehicle that requires a DD Form 1970. Class B assignment in an NMCB is recommended by the equipment officer and approved by the commanding officer.

Class C dispatch category covers all equipment not under class A or class B. Class C assignments are made on an “as-needed” basis. However, project crews are normally assigned the same vehicle each day.

The dispatcher closes out the heavy equipment and class C logs daily, and the class B assigned log weekly. Closing out a log is done by adding all the ending mileage and hour meter readings and enclosing the reports and records inside the appropriate folded dispatcher’s log. On the outside of the log, the dispatcher records the date, total mileage, and total operating hours of all the equipment dispatched.

On the first work day of each week, the transportation supervisor collects the dispatcher’s logs for the Alpha company operations supervisor for review as required by the COMSECOND/ COMTHIRDNCBINST 11200.1 Series.

In the NCF, the dispatcher retains logs on file for 90 days. At a public works, the DD Form 1970 is retained for 90 days and the dispatcher’s logs for 36 months.



DISPATCHER'S LOG

USN NUMBER	ALPHA CODE	EQUIP CODE	OPERATOR	TIME REQUIRED	OPERATOR CODE	ACTIVITY / DESTINATION	JOB ORDER NUMBER	TRANS WONE CTR	EXPECTED RETURN TIME / DATE	OUT	IN	TOTAL HOURS	METER READING BEGINNING	ENDING	TOTAL MILES / HOURS	MILES ON STATION
94-75111	1	031301	Smith EO3	0800	45	NMCB-74 LA	074568		1500	0805	1420	0 hrs 15 min	3452	3552	100	1
94-75103	2	031301	Jones EO2	0900	55	NMCB-10 BASE	075679		1300	1510	1000	6 hrs 50 min	1456	1486	30	30

Figure 1-13 – Dispatchers Log, NAVFAC 9-11240/2.

2.3.0 Yard Supervisor (Yard Boss)

The yard boss and the dispatcher work as a team. The yard boss plays a key part in the Equipment Management Program by enforcing and providing technical guidance for operator pre- and post-operational checks and maintenance procedures that reduce equipment breakdown. Additionally, the yard boss manages the equipment yard and the vehicles parked in it and establishes and enforces traffic control through the yard, including stop signs, speed limits, and one-way-traffic flow. The yard boss is also in charge of yard maintenance and the establishment of parking lines and areas, such as a ready line and awaiting-entry-into-shop line. The yard boss sees and hears the equipment that dispatchers cannot see while sitting behind their desks.

The yard boss has a tool kit which provides tools for operator maintenance procedures. The Kit 80111 provides the minimum tools and equipment resources necessary to support operator maintenance. For control and accountability of the tools, the yard boss should have operators sign a log book for the tools checked out. In addition to the kit, the yard boss must provide grease guns, valve caps, and light bulbs.

The yard boss is also responsible for cycling equipment in the pool that is not regularly used. Equipment must be maintained in a standby status and cycled on a weekly basis. Cycling exercises equipment and protects it from deterioration. Equipment cycling must be documented in a cycle log maintained by the yard boss, documenting the date, USN number, duration of cycle, and deficiencies.

2.4.0 License Examiner

The license examiner should be the best qualified licensed equipment operator available. The license examiner is appointed by letter by the commanding officer. The examiner is responsible for being familiar with and maintaining a library of the following publications:

- Storage and Materials Handling, DODINST 4145.19-R-1
- Motor Vehicles Management Acquisition and Use, OPNAVINST 11240.16A Motor
- Vehicles Driver's Handbook, NAVSEA OP-2239, and Ammunition,
- Explosives, and Related Hazardous Materials
- Management of Transportation Equipment, NAVFAC P-300
- Testing and Licensing of Construction Equipment Operators, NAVFAC P-306
- Management of Weight-Handling Equipment Maintenance and Certification, NAVFAC P-307
- Navy Driver's Handbook, NAVFAC MO-403
- Naval Construction Force Equipment Management Manual, NAVFAC P-404
- Naval Construction Force Safety Manual, COMSECOND/COMTHIRDNCBINST Series
- Federal Motor Carrier Safety Regulations, Parts 390-397

Additionally, the license examiner maintains a license file under lock and key for each licensed operator in the command. The files provide information on the types of

equipment the operator is qualified to operate, applicants' background and experience, examination findings, special requirements, traffic violations, and accident history.

The license examiner must comply with the Privacy Act of 1974 in the maintenance of all files of licensed operators. The license examiner maintains a tickler file of each operator's license expiration date and ensures all personnel are properly trained on the equipment before issuing the Operator's Identification Card, OF-346, or Construction Equipment Operator License, NAVFAC 11260/2.

2.4.1 Mishap Investigator

The license examiner is typically assigned the responsibilities of the motor vehicle mishap investigator. The Mishap Investigation, Reporting and Record Keeping, DODINST 6055.7, states all accidents involving DoD motor vehicles, including rented CESE, are investigated to determine the cause and circumstances.

The motor vehicle mishap investigator makes thorough investigations of all accidents and documents evidence promptly for use in the event a claim is filed against the government. Accidents that appear trivial may eventually result in legal suits. Therefore, mishap investigators must follow the mishap investigation guidelines set forth in the Mishap Investigating and Reporting OPNAVINST 5102.1 latest edition.

A mishap investigator works closely with the command safety chief to develop safety and accident prevention programs for the command. These programs include the safe operation of CESE, provisions for the mandatory use of seat belts, and the prohibition against smoking in vehicles. They also perform joint investigations of serious mishaps that include injury or fatalities.

According to OPNAVINST 5102.1, government owned or leased motor vehicles involved in a fatality or injury, or that sustains a total damage of $2,000 or more, require a NAVGRAM sent to the Naval Safety Center. The command must send the NAVGRAM within 30 days of the mishap to the Commander, Naval Safety Center, Naval Air Station, Norfolk, Virginia. On-duty motor vehicle accidents resulting in hospitalization of five or more persons are reported by priority message or telephone.

2.4.2 Road Master

In most cases, the license examiner is assigned to serve as the battalion road master. The road master ensures the safe operation of the battalion's equipment and enforces regulations as directed by the Alpha Company Commander. Additionally, the road master should escort oversized loads and check prospective routes of travel for obstructions.

2.5.0 Collateral Equipment Custodian

As a member of the transportation pool, an EO may be assigned as the collateral equipage custodian. The two basic types of collateral equipage are component collateral equipage and tactical collateral equipage.

Component collateral equipage consists of items, such as hoses for pumps and bits for the earth auger. These items are normally procured on the same contract as the basic machine. The history jacket should contain a list of the amount and types of component collateral equipage.

Tactical collateral equipage consists of items common to the equipment, such as top canvas and tarpaulin, bows and side racks, spare tire and rim, jack and lug wrench, and chains with hooks and binders.

The collateral equipage custodian maintains a Collateral Custody Record Card, COMSECOND/ COMTHIRDNCB 60 Form (*Figure 1-14*), for each line item of equipage for each unit of equipment. On the CB 60 form, the equipage custodian enters all outstanding requisitions, receipts, issues, location, and losses and annotates the allowance of a particular line item of equipage for each CESE. The equipage custodian maintains the CB 60 forms in folders for each USN-numbered unit of CESE. The CB 60 forms are pulled on the PM date to perform an inventory of mounted or stored collateral equipage for each unit of CESE entering the shop.

(ECC)	(USN)	(NSN/Part#	(NOUN NAME)		Allowance	(UI)	(Augment)/(Organic)	
FIRST NCD CB60 FORM					LOCATION BIN #			
TRANSACTION RECORD					I acknowledge custody of this item in the quantity indicated.		Inventory Record	
Date	Requisition #	Rec'd from/Expended to	Stored	Mounted	Balance		Date	Qty
							By:	
							Date	Qty
							By:	
							Date	Qty
							By:	
							Date	Qty
							By:	
							Date	Qty
							By:	
							Date	Qty
							By:	
							Date	Qty
							By:	
							Date	Qty
							By:	
							Date	Qty

Figure 1-14 – Collateral Custody Record Card, COMSECOND/ COMTHIRDNCB 60 Form.

Operators of class B assigned CESE sign the CB 60 form, assuming full custody of mounted collateral gear. The yard boss signs CB 60 forms for class C mounted collateral gear on CESE. The mounted collateral gear is annotated on the daily trip ticket, and the operator who signs the trip ticket assumes custody, or the collateral equipage can be issued and returned to collateral each time the unit of CESE is dispatched.

The equipage custodian uses a NAVSUP Form 1250-1 (*Figure 1-15*), or a 1250-2 (*Figure 1-16*), for lost, damaged, or deteriorated collateral equipment. The maintenance supervisor reviews and approves NAVSUP Form 1250s.

NOTE

The inventory procedures are accountable man-hours on the Equipment Repair Order.

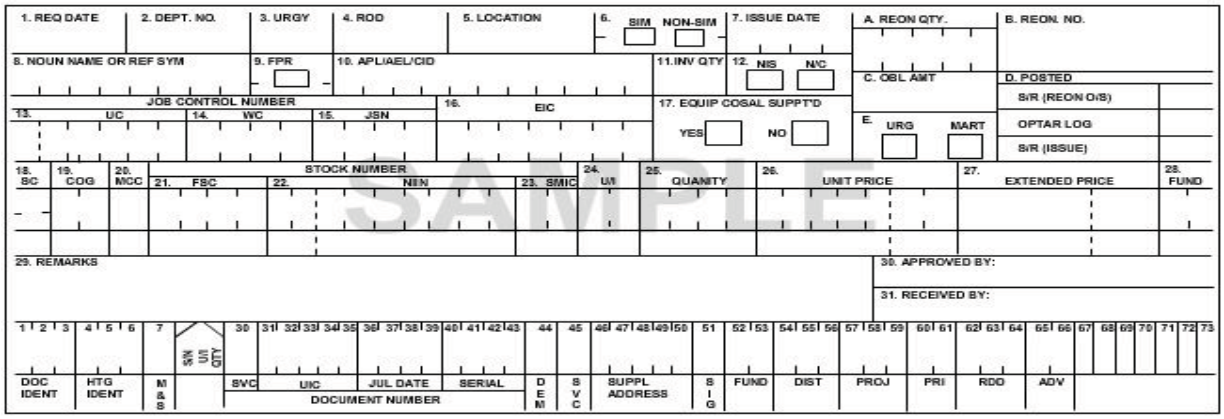
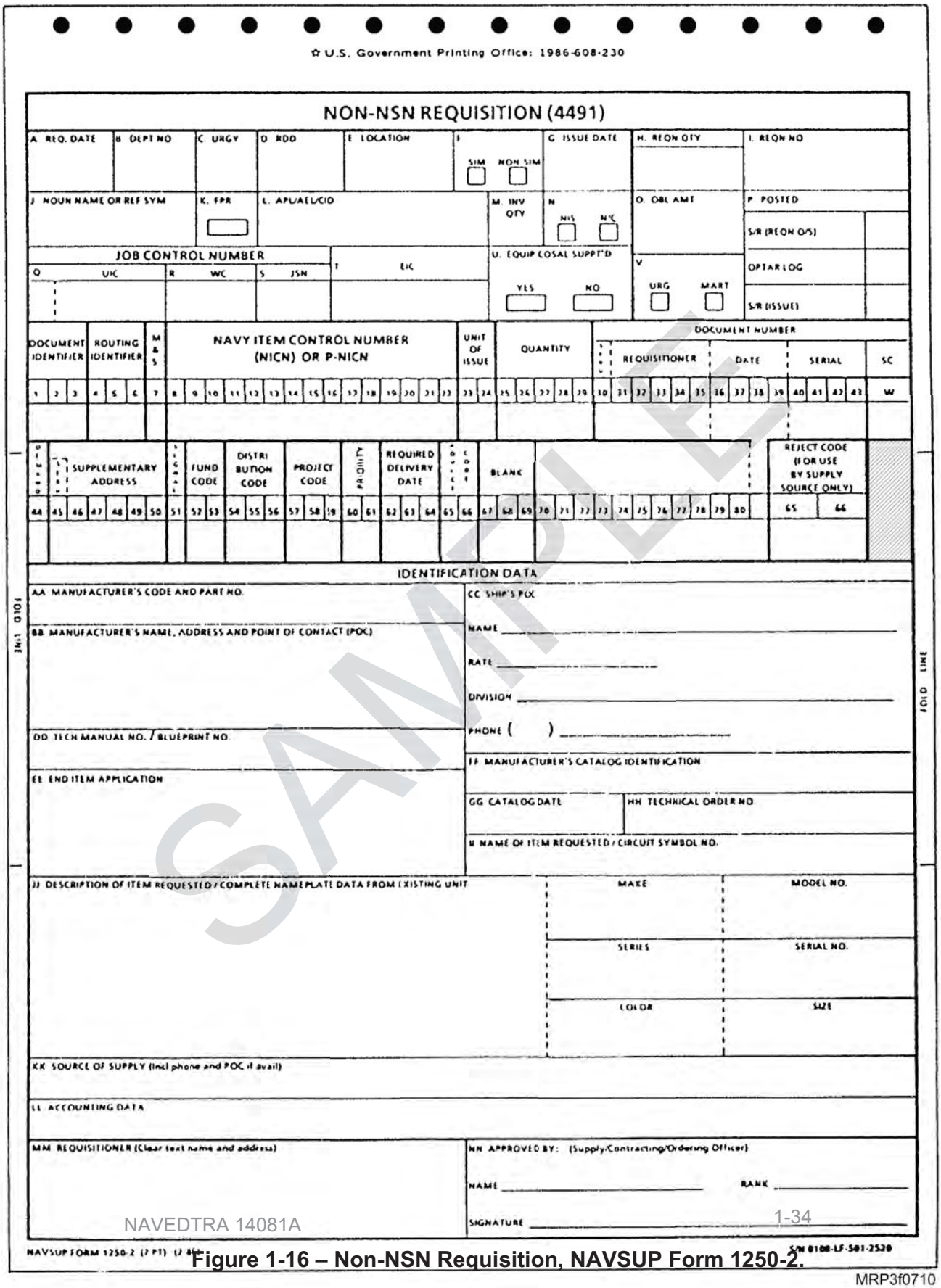


Figure 1-15 – Single-Line Item Consumption/Management Document (Manual), NAVSUP Form 1250-1.



☆ U.S. Government Printing Office: 1986-608-230

NON-NSN REQUISITION (4491)

A REQ. DATE | B DEPT NO | C URGY | D RDD | E LOCATION | F SIM NON SIM | G ISSUE DATE | H. REQN QTY | I. REQN NO

J NOUN NAME OR REF SYM | K. FPR | L. APUAEL/CID | M. INV QTY | N NIS NSC | O. OBL AMT | P POSTED | S/R (REQN O/S)

JOB CONTROL NUMBER | Q UIC | R WC | S JSN | T EIC | U. EQUIP COSAL SUPPT'D YES NO | V URG MART | OPTAR LOG | S/R (ISSUE)

DOCUMENT IDENTIFIER	ROUTING IDENTIFIER	M & S	NAVY ITEM CONTROL NUMBER (NICN) OR P-NICN	UNIT OF ISSUE	QUANTITY	DOCUMENT NUMBER: REQUISITIONER	DATE	SERIAL	SC
1 2 3	4 5 6	7	8 9 10 11 12 13 14 15 16 17 18 19 20 21 22	23 24	25 26 27 28 29	30 31 32 33 34 35	36 37 38 39	40 41 42 43	W

ORDER NO	SUPPLEMENTARY ADDRESS	SIGNAL CODE	FUND CODE	DISTRIBUTION CODE	PROJECT CODE	PRIORITY	REQUIRED DELIVERY DATE	ADVICE CODE	BLANK	REJECT CODE (FOR USE BY SUPPLY SOURCE ONLY)
44	45 46 47 48 49 50	51	52 53	54 55 56	57 58 59	60 61	62 63 64	65 66	67 68 69 70 71 72 73 74 75 76 77 78 79 80	65 66

IDENTIFICATION DATA

AA MANUFACTURER'S CODE AND PART NO.

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

CC SHIP'S POC
NAME
RATE
DIVISION
PHONE ( )

DD TECH MANUAL NO. / BLUEPRINT NO.

EE END ITEM APPLICATION

FF MANUFACTURER'S CATALOG IDENTIFICATION

GG CATALOG DATE | HH TECHNICAL ORDER NO.

II NAME OF ITEM REQUESTED / CIRCUIT SYMBOL NO.

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

MAKE | MODEL NO.
SERIES | SERIAL NO.
COLOR | SIZE

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

LL ACCOUNTING DATA

MM REQUISITIONER (Clear text name and address)

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

FOLD LINE

NAVSUP FORM 1250-2 (7 PT) (7 86)

S/N 0108-LF-501-2530

SAMPLE

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

MRP3f0710

2.6.0 Attachment Custodian

The attachment custodian maintains a card file and log showing an accurate inventory of receipts and issues of attachments, when the attachments were last lubricated, and any damage incurred from one operation to another. The attachment custodian is also responsible for the segregated storage of all attachments and their associated accessories.

Attachments are accessories to construction equipment that enable the basic equipment to perform its function or add versatility. Attachments are stored on hardstands to keep the items out of sand, mud, and water. Hydraulic lines and fittings are sealed for protection from dirt and moisture.

Attachment accessories, such as bucket teeth, sprockets, drum lagging, and wedges are placed in boxes or on pallets and marked for the appropriate equipment. Wire rope, sheaves, and bolt threads are lubricated. Nuts and bolts are stored in their respective holes on the attachments when possible. Exposed machined surfaces and open parts are preserved to prevent oxidation and damage. Storage is maintained so all attachments belonging to one USN number are stored together.

2.6.1 Attachment Status Board

The attachment custodian is responsible for the Attachments Status Board (Figure 1-17), maintained in the dispatcher's office. The Attachments Status Board reflects the attachment code, NAVFAC identification number, abbreviated description, the USN number of the equipment to which the attachment is assigned, the PM group (same as the equipment the attachment is assigned), the location of the attachment, and remarks. The collateral equipage custodian normally performs the duties of the attachment custodian.

ATTACHMENTS STATUS BOARD

Code	NAVFAC I.D. NO.	Description	USN No. Assigned	PMG	Location and Remarks
A01000	L175-BH-5	Backhoe	45-01799	17	Attachment Pad
A02500	255-BB-56	Boom Butt	42-01778	9	42-01778
A03000	32-BE-72	Boom Ext	82-03173	14	Attachment Pad

Figure 1-17 – Attachment Status Board.

2.7.0 Bus and Taxi Services

An EO must be both knowledgeable and versatile with many forms of equipment operations. The following section briefly describes the procedures for bus and taxi services.

2.7.1 Bus Service

An EO may be required to serve as a bus driver. A bus driver must be mature and reliable and must ensure a bus is safe. Besides performing the normal prestart procedures, the following are items the operator must ensure are in good working order:

- Service brakes
- Parking brake
- Steering mechanism
- Lights and reflectors
- Tires and horn
- Windshield wipers
- Rearview mirror or mirrors
- Wheels and rims

Additionally, check the interior of the bus to ensure rider safety. Aisles and stairwells must always be clear and the following must be in a safe working condition:

- Each handhold and railing
- Floor covering
- Signal devices (emergency door buzzer)
- Emergency exit handles
- Emergency exit sign visible
- Seats secured to the bus

NOTE

The bus must have a fire extinguisher and emergency reflectors as outlined in the *Federal Motor Carrier Safety Regulations Pocketbook*, 7-ORS-A. The bus must also have spare electrical fuses unless equipped with circuit breakers.

When performing the normal prestart inspection procedures for a bus, the operator should use the Bus Inspection Memory Aid (*Figure 1-18*).

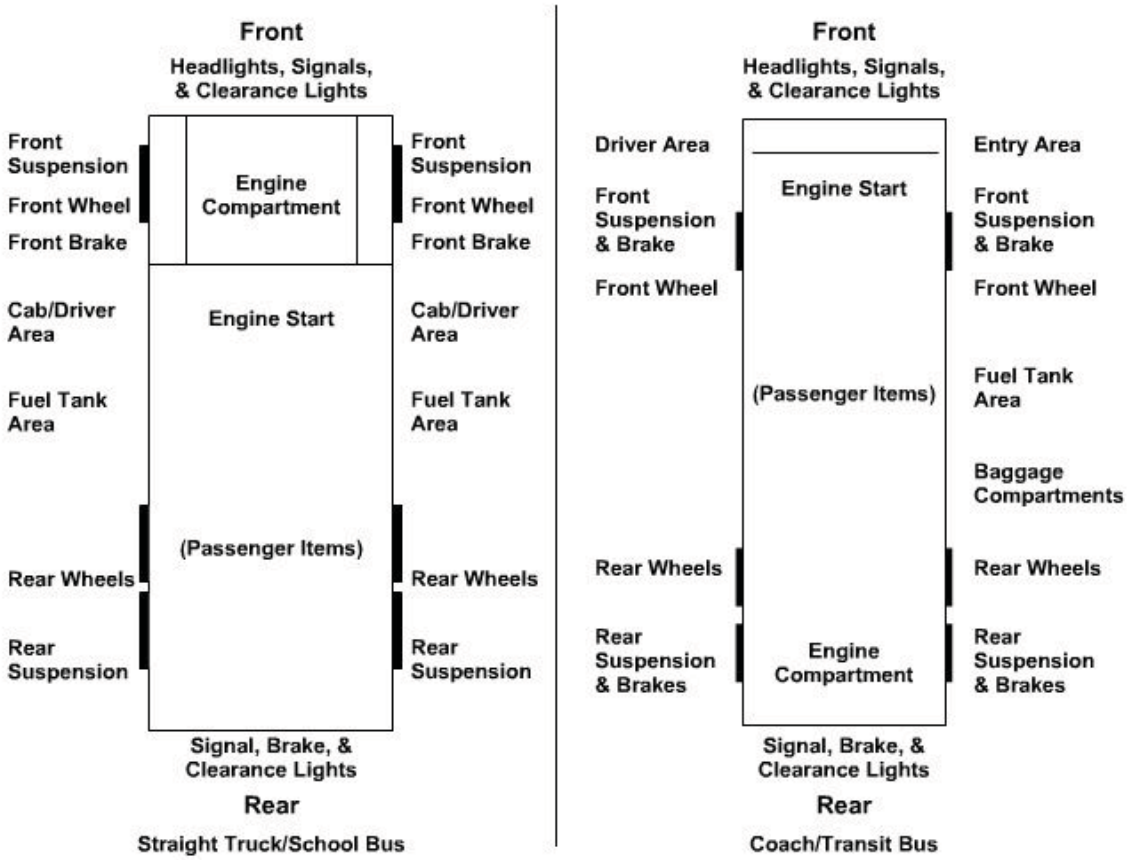


Figure 1-18 – Bus Operator Inspection Memory Aid.

The bus driver is responsible for the orderly behavior and safety of all passengers and cargo. The driver should be neat in appearance and maintain a courteous attitude. The bus driver must comply with the following rules when operating a bus:

1. Do not allow a rider to stand forward of the rear of the driver's seat. Buses designed to allow standing should have a 2-inch line on the floor or some other means showing riders where they cannot stand. This line is called the standee line, and all passengers must stay behind it.
2. Do not put a bus in motion with the doors open, and do not close the doors until all passengers are completely clear of the doors.
3. Pay attention to the road when driving and do not carry on unnecessary conversation with passengers while the vehicle is in motion.
4. Stop, start, and operate buses smoothly and without jerks or sudden changes in acceleration. When making a turn or upon approaching a sharp curve, reduce speed to avoid injuring passengers.
5. While driving, scan the interior of the bus as well as the road ahead, to the sides, and to the rear. If necessary, remind passengers to keep arms and heads inside the bus.
6. Stop the bus between 15 and 50 feet before railroad crossings. Look and listen in both directions for trains. Open the door if it improves the ability to see or hear an approaching train. Before crossing after a train has passed, be sure there is not

another train coming in either direction on other tracks. When it is safe to cross, drive the bus completely across the crossing without changing gears.

While it is not necessary to completely stop, it is important to slowdown and carefully check for other vehicles in the following situations:

- At streetcar crossings
- At railroad tracks used only for industrial switching within a business district
- Where a policeman or flagman is directing traffic
- If a traffic signal shows green
- At crossings marked “exempt crossing”

Adhere to the standards and procedures contained in the Commercial Driver License (CDL) Handbook.

2.7.2 Taxi Service

The taxi service provides a method of transporting personnel to medical appointments, jobsites, airports, and areas directed by the transportation supervisor. The dispatch office is normally the base station for taxi service. A radio is used to communicate with the taxi driver. The driver is responsible for passenger safety.

Test your Knowledge (Select the Correct Response)

8. Which of the following personnel are responsible to the equipment officer for the administration, operations, and operator maintenance of all assigned CESE?

   A. Alpha company operations chief
   B. Transportation supervisor
   C. Senior petty officers
   D. All of the above

9. Which of the following positions is the key equipment management position in a unit?

   A. Collateral equipage custodian
   B. Dispatcher
   C. Wash rack attendant
   D. Master–at–arms

10. Which of the following personnel has the responsibility to know the current status and location of every assigned piece of equipment?

    A. Company commander
    B. Company chief
    C. Dispatcher
    D. Yard boss

11. Which of the following is NOT an area of responsibility of the yard boss?

    A. Equipment yard management
    B. Traffic control enforcement
    C. Tire shop management
    D. Equipment yard maintenance

12. A spare tire and rim is classified as what type of collateral equipage?

    A. Component
    B. Automotive
    C. Construction
    D. Tactical

13. **(True or False)** Attachment storage is maintained so all attachments belonging to one USN number are stored together.

    A. True
    B. False

14. **(True or False)** A bus should stop between 15 and 50 feet before a railroad crossing.

    A. True
    B. False

3.0.0. EMBARKATION

Naval Construction Force units, such as NMCB, Amphibious Construction Battalions (PHIBCBs), Construction Battalion Maintenance Units (CBMUs), are required to maintain a hight state of readiness. The units must be capable of rapidly and efficiently embarking aboard aircraft or shipping to provide contingency support to the Navy, the Marine Corps and other forces. The units must also be ready to perform and participate in disaster recovery operations and field exercises. Detailed procedures for embarkation are outlined in the *Naval Construction Force Embarkation Manual,* COMFIRSTNCDINST 3100.1.

3.1.0 CESE and Material Preparation

Upon notification from higher authority to mount-out and deploy, the battalion re-organizes and sets up a mount-out control center (MOCC). The MOCC is under the direction of the battalion executive officer. The MOCC controls, coordinates, and monitors the movement of all personnel, supplies, and equipment to the marshaling area. The MOCC and the embarkation staff control all aspects of an NMCB mount-out and serve as the coordinating center for all the companies and battalion staff.

The preparation of CESE for embarkation is the responsibility of Alpha company. All vehicles and equipment must be absolutely clean of mud, oil, grease, or any other foreign matter. All leaks must be repaired before equipment is embarked. Embarking on aircraft requires special loading procedures for several types of CESE assigned to the battalion Table of Allowance (TOA). These procedures are outlined in the *NCF Embarkation Manual,* COMFIRSTNCDINST Series. Alpha company is responsible for the following procedures: removal of dump truck headache racks, equipment exhaust

stacks, dozer blades, counter weights, equipment roll over protective structure (ROPS), bows, tarps and side racks, etc.

NOTE

The bolts, nuts, and parts from the disassembled equipment must be placed with the equipment in an easily accessible location.

3.1.1 Mobile Loads

A mobile load is an item on a vehicle not considered to be a secured part of a vehicle. Mobile-loaded items must be secured to the vehicle by a minimum of one-half-inch-thick rope of manila or hemp, from side to side and front to rear.

3.1.2 Onboard Fuel

The amount of fuel in the vehicle fuel tanks must be checked and serviced prior to embarkation. Vehicle fuel tanks must be at least one-fourth full and not more than three-fourths full. If a vehicle is to be placed on an aircraft, fuel tanks should never be more than one-half full.

Fuel in tanks for trailer-mounted and single-axle units must not exceed one-fourth full when these units are disconnected from the prime mover with the tongue resting on the aircraft floor. When positioned on the aircraft ramp, the fuel tanks must be drained but not purged.

3.1.3 Palletized Cargo

Cargo that is to be loaded on an aircraft is palletized on 463-L air certified pallets (*Figure 1-19*). A 463L pallet has the following characteristics:

- Empty weight 290 pounds
- Empty weight with top and side netting 355 pounds
- Outside dimensions 88 X 108 inches
- Usable space dimensions 84 X 104 inches
- Maximum loaded pallet height 96 inches
- Gross maximum weight 10,000 pounds

Figure 1-19 – 463 Air Cargo

A 463L pallet is composed of 22 tie-down rings (six on the long side and five on the short side) that match up with the cargo net fasteners(*Figure 1-20*). 463-L pallets lock into the aircraft by a rail on each side of the aircraft.

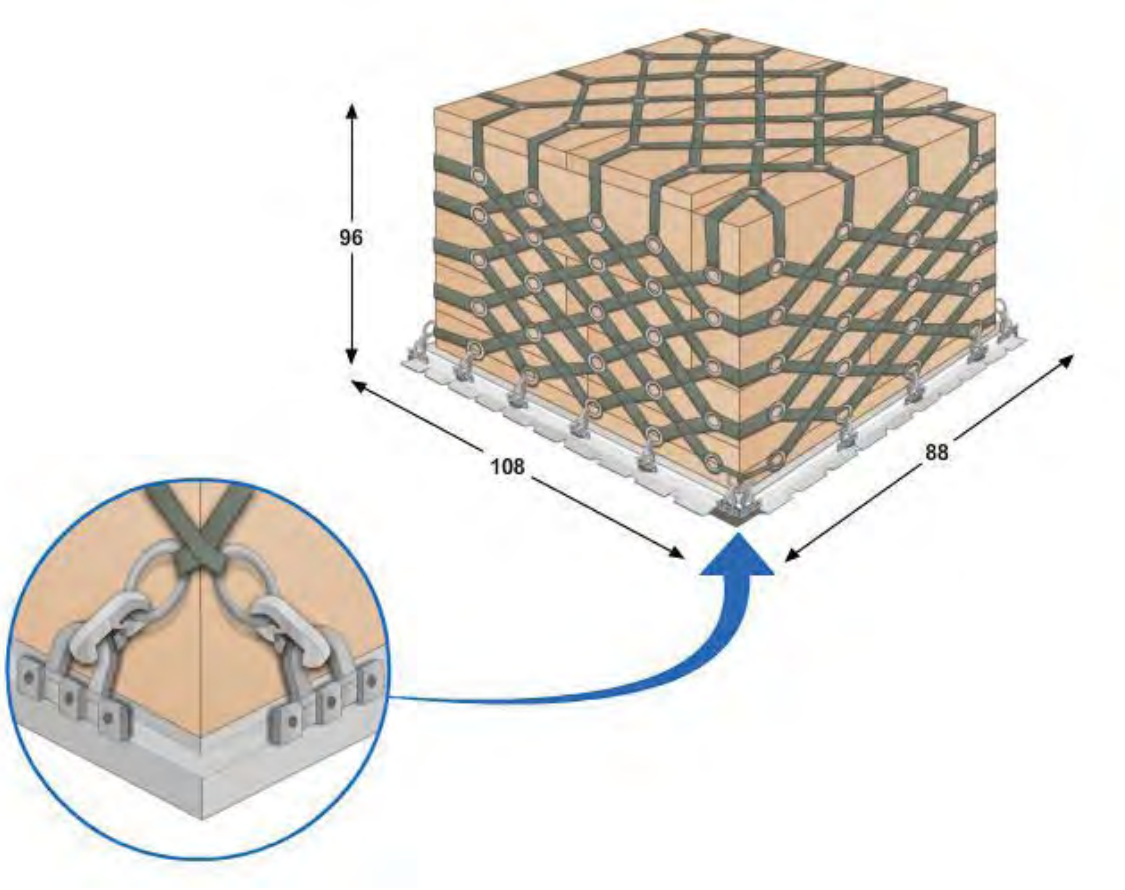


Figure 1-20 – Loaded Cargo Pallet with Outside Dimensions.

A three point dunnage configuration is used to load a pallet. The dunnage should be a least 4X4 by 88-inch timbers (*Figure 1-21*). The timbers should be evenly spaced with one timber in the center and one each on edge of the pallet. This configuration reduces pallet warping and makes material loading safer and handling by forklift possible.

During the pallet-building process (placing cargo on the pallets), place three point dunnage underneath the pallet. Start with the heaviest cargo and distribute the weight out from the center (*Figure 1-22*). Doing so keeps the center of balance in the center of the pallet.

Figure 1-21 – 463L Pallet with Three Point. Dunnage.

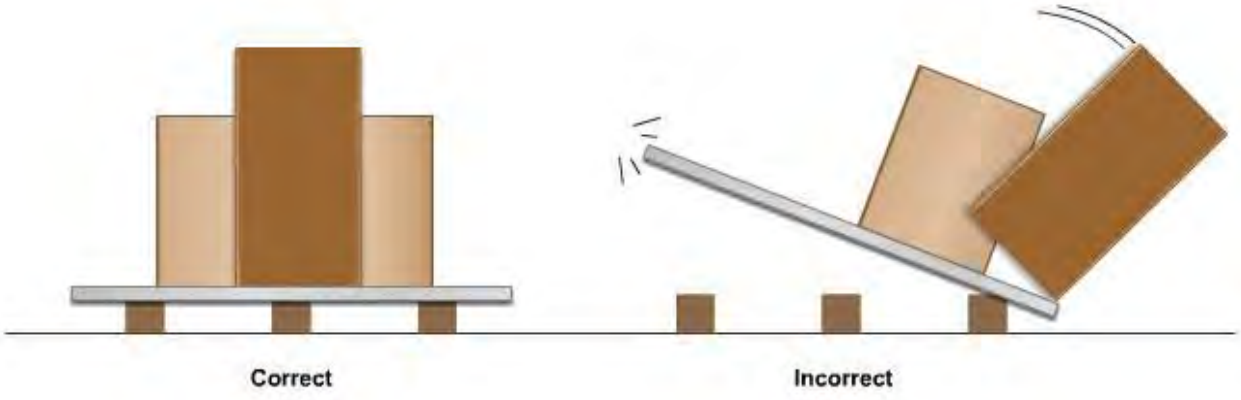


Figure 1-22 – Correct Pallet Weight Distribution.

Load in a square or pyramid shape whenever possible to make the load stable (*Figure 1-23*). All cargo loaded on a 463-L pallet must be placed close together with no open space between them. If space is left between cargo items, it can shift during flight and cause possible damage to or even loss of the aircraft.

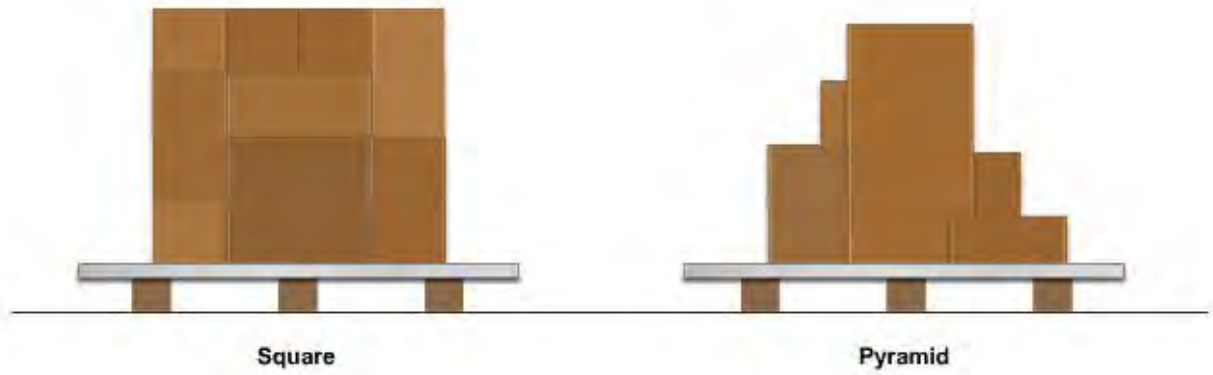


Figure 1-23 – Pyramid and Square Pallet Load Configuration.

To store empty pallets, place one set of three point dunnage down and then stack the pallets no more than 10 high. If more pallets need stacking, place another set of dunnage on top of the first 10 pallets. This sequence can be repeated up to a maximum of 40 pallets. Be sure to stack each pallet with the cargo loading surface facing in an upward direction.

Test your Knowledge (Select the Correct Response)

15. Which of the following units are NOT required to maintain a high state of readiness?

    A. NMCB
    B. PW
    C. PHIBCB
    D. CBMU

16. The MOCC is under the direction of what officer?

    A. Operations
    B. Executive
    C. Equipment
    D. Supply

17. What is the maximum amount of fuel the fuel tank on a vehicle can contain if it is to be placed on the ramp of an aircraft?

    A. One-fourth full
    B. One-half full
    C. Three-fourths full
    D. Topped-off

4.0.0 ADVANCED BASE PLANNING

During World War II, when bases were constructed across the island chains of the Pacific Ocean, it became apparent that significant time and material could be saved by standardization of units of materials, equipment, and personnel required to perform specific functions. This was the beginning of the Advanced Base Functional Components (ABFC) System still in use today. This section briefly covers the ABFC System and the *Facilities Planning Guide,* NAVFAC P-437. Refer to the NAVFAC P-437, Volume 2, for more information.

4.1.0 Advanced Base Functional Components System

The Advanced Base Functional Components System (ABFC) is covered in the *Naval Construction Force (NCF) Manual, NAVFAC* P-315, and in Volume 2 of the *Facilities Planning Guide,* NAVFAC P-437. The overall ABFC System is comprised of a preplanned collection of individual functional components, each designed and organized to perform a specific function at an advanced base.

By using the ABFC System, planners for logistics, facilities, and construction can readily identify the equipment, facilities, materials, construction effort, and other pertinent information needed for each component. The *Facilities Planning Guide,* NAVFAC P-437, identifies all of this information.

4.2.0 NAVFAC P-437

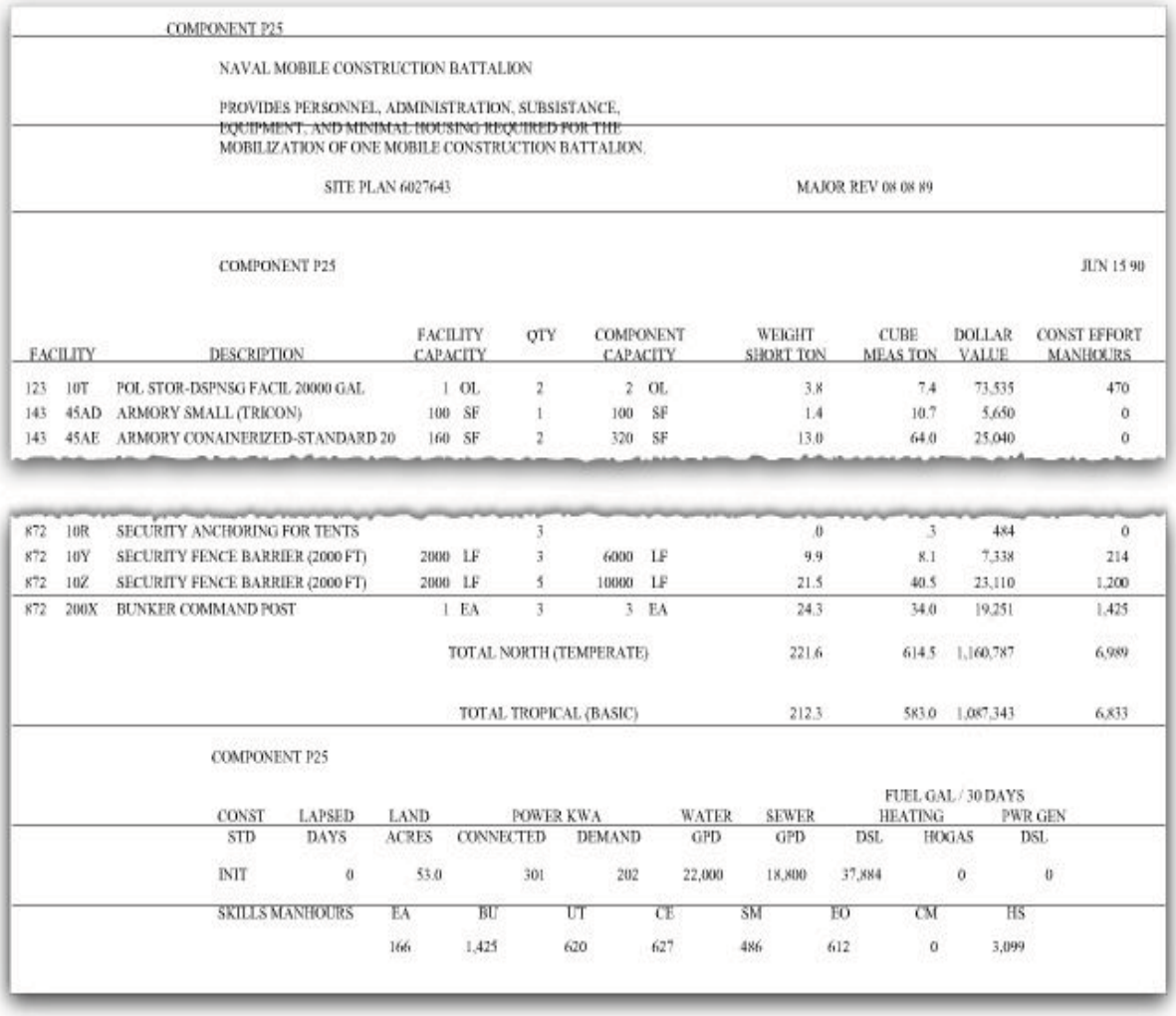
The *Facilities Planning Guide,* NAVFAC P-437, is be used to assist in planning the construction of an advanced base. The document identifies the structures and supporting utilities of the Navy ABFC System. It was developed to make pre-engineered facility designs and corresponding material lists available to planners at all levels. While these designs relate primarily to expected needs at advanced bases and to the Navy ABFC System, they can also be used to satisfy peacetime requirements. Facilities, logistics, and construction planners will find the information required to select and document the material necessary to construct facilities. NAVFAC P-437 consists of two volumes. Volume 2 is addressed first.

4.2.1 NAVFAC P-437(Volume 2)

Volume 2 contains detailed data displays for each Component, Facility, and Assembly in the ABFC System.

Part 1 (Components) contains data displays for each of the ABFC components and is indexed by code number. The data displays list and describe the facilities that make up each ABFC component. *Figure 1-24* is an example of a typical part 1 data display.

Figure 1-24 is for a component P25. The name of the component is Naval Mobile Construction Battalion. The specific function, or purpose, of the component is shown directly below the component name. Listed below the function are all of the facilities that comprise component P25. Each facility has the following; single-facility capacity, total quantity, and total facility capacity required for the component. For example, there is a total of two water-storage facilities (Facility Number 841 40E) required for the complete component. Each of these storage facilities has a capacity of 30,000 gallons, and the total water-storage capacity for the component is 60,000 gallons. Also listed for each facility is the weight, cubic feet, dollar value, and estimated construction effort for the total quantity of each facility. Additional information concerning the complete component is located at the bottom of the sheet. This includes a breakdown, by Seabee rating, of the estimated direct-labor man-hours required to construct the component.



COMPONENT P25

NAVAL MOBILE CONSTRUCTION BATTALION

PROVIDES PERSONNEL, ADMINISTRATION, SUBSISTANCE, EQUIPMENT, AND MINIMAL HOUSING REQUIRED FOR THE MOBILIZATION OF ONE MOBILE CONSTRUCTION BATTALION.

SITE PLAN 6027643 MAJOR REV 08 08 89

COMPONENT P25 JUN 15 90

FACILITY		DESCRIPTION	FACILITY CAPACITY	QTY	COMPONENT CAPACITY	WEIGHT SHORT TON	CUBE MEAS TON	DOLLAR VALUE	CONST EFFORT MANHOURS
123	10T	POL STOR-DSPNSG FACIL 20000 GAL	1 OL	2	2 OL	3.8	7.4	73,535	470
143	45AD	ARMORY SMALL (TRICON)	100 SF	1	100 SF	1.4	10.7	5,650	0
143	45AE	ARMORY CONAINERIZED-STANDARD 20	160 SF	2	320 SF	13.0	64.0	25,040	0
872	10R	SECURITY ANCHORING FOR TENTS		3		.0	.3	484	0
872	10Y	SECURITY FENCE BARRIER (2000 FT)	2000 LF	3	6000 LF	9.9	8.1	7,338	214
872	10Z	SECURITY FENCE BARRIER (2000 FT)	2000 LF	5	10000 LF	21.5	40.5	23,110	1,200
872	200X	BUNKER COMMAND POST	1 EA	3	3 EA	24.3	34.0	19,251	1,425
		TOTAL NORTH (TEMPERATE)				221.6	614.5	1,160,787	6,989
		TOTAL TROPICAL (BASIC)				212.3	583.0	1,087,343	6,833

COMPONENT P25

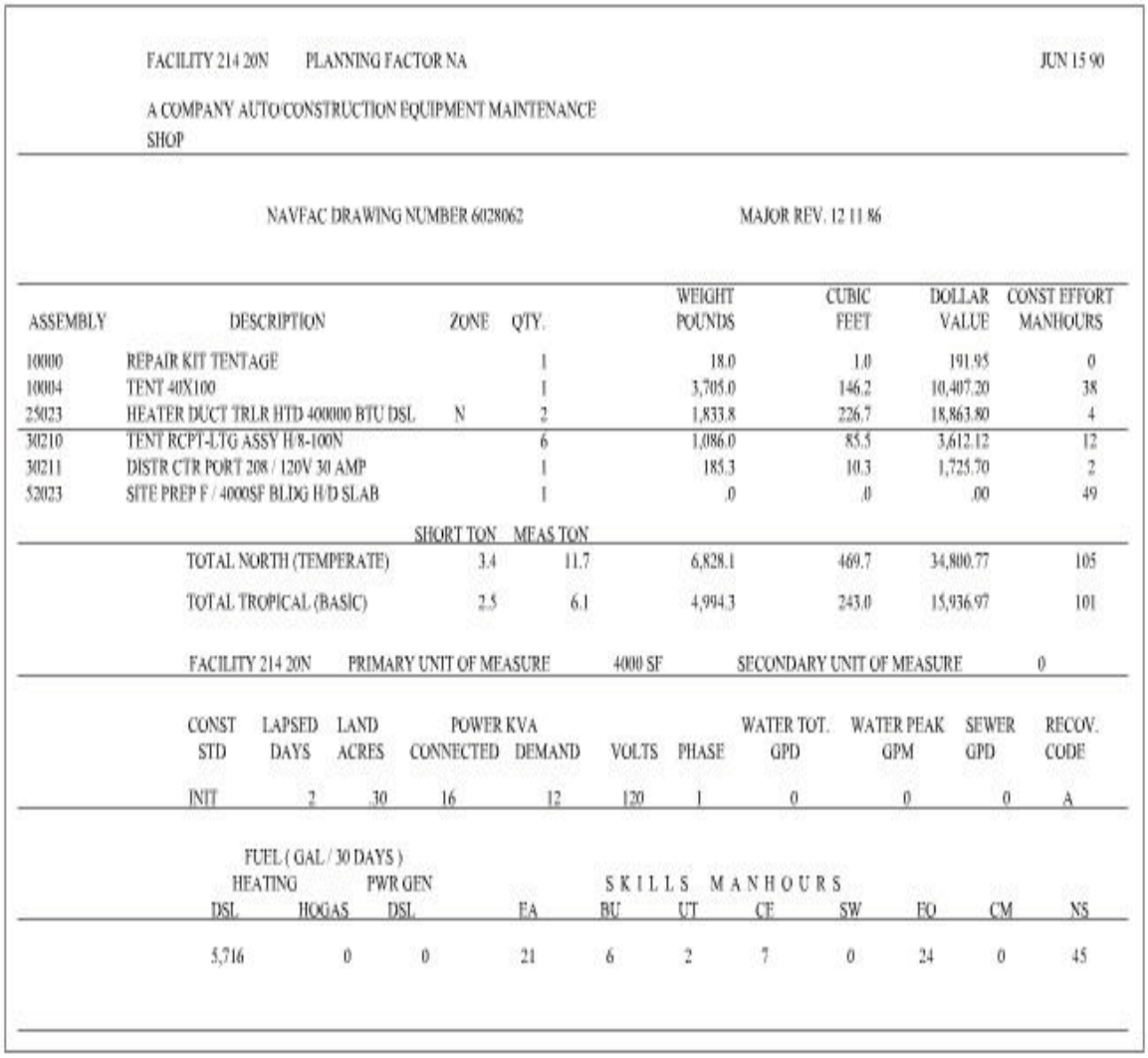
CONST STD	LAPSED DAYS	LAND ACRES	POWER KWA CONNECTED	POWER KWA DEMAND	WATER GPD	SEWER GPD	FUEL GAL / 30 DAYS HEATING DSL	FUEL GAL / 30 DAYS HEATING HOGAS	FUEL GAL / 30 DAYS PWR GEN DSL
INIT	0	53.0	301	202	22,000	18,800	37,884	0	0

SKILLS MANHOURS	EA	BU	UT	CE	SM	EO	CM	HS
	166	1,425	620	627	486	612	0	3,099

Figure 1-24 – Typical Components Data Display.

Part 2 (Facilities), indexed by facility number, identifies the assemblies required for each facility. For the P25 component, look at the data display for Facility Number 214 20N. This data display, found in part 2, is shown in *Figure 1-25*.

At the top of this data display is the facility number and nomenclature of the facility. Below is a listing by assembly number, of all of the assemblies needed for one complete facility. The listing includes the description, quantity, weight, cubic feet, dollar value, and the estimated construction effort required for each assembly. Below the listing of assemblies is information regarding the complete facility; for example, Facility 214 20N requires a land area of .30 acres and the estimated EO direct labor required to install this facility is 24 man-hours.



FACILITY 214 20N PLANNING FACTOR NA JUN 15 90

A COMPANY AUTO/CONSTRUCTION EQUIPMENT MAINTENANCE SHOP

NAVFAC DRAWING NUMBER 6028062 MAJOR REV. 12 11 86

ASSEMBLY	DESCRIPTION	ZONE	QTY.	WEIGHT POUNDS	CUBIC FEET	DOLLAR VALUE	CONST EFFORT MANHOURS
10000	REPAIR KIT TENTAGE		1	18.0	1.0	191.95	0
10004	TENT 40X100		1	3,705.0	146.2	10,407.20	38
25023	HEATER DUCT TRLR HTD 400000 BTU DSL	N	2	1,833.8	226.7	18,863.80	4
30210	TENT RCPT-LTG ASSY H/8-100N		6	1,086.0	85.5	3,612.12	12
30211	DISTR CTR PORT 208 / 120V 30 AMP		1	185.3	10.3	1,725.70	2
52023	SITE PREP F / 4000SF BLDG H/D SLAB		1	.0	.0	.00	49
		SHORT TON	MEAS TON				
	TOTAL NORTH (TEMPERATE)	3.4	11.7	6,828.1	469.7	34,800.77	105
	TOTAL TROPICAL (BASIC)	2.5	6.1	4,994.3	243.0	15,936.97	101

FACILITY 214 20N PRIMARY UNIT OF MEASURE 4000 SF SECONDARY UNIT OF MEASURE 0

CONST STD	LAPSED DAYS	LAND ACRES	POWER KVA CONNECTED	POWER KVA DEMAND	VOLTS	PHASE	WATER TOT. GPD	WATER PEAK GPM	SEWER GPD	RECOV. CODE
INIT	2	.30	16	12	120	1	0	0	0	A

FUEL (GAL / 30 DAYS) HEATING DSL	HOGAS	PWR GEN DSL	SKILLS MANHOURS EA	BU	UT	CE	SW	EO	CM	NS
5,716	0	0	21	6	2	7	0	24	0	45

Figure 1-25 – Typical Facility Data Display.

Part 3 (Assemblies) is indexed by assembly number and contains data displays listing all of the materials required for each assembly. For an example, the data display for Assembly Number 10004, required for Facility 214 20N, is shown in *Figure 1-26*. The display shows the national stock number (NSN), description, unit of issue, quantity, weight, cubic feet, and dollar value for each line item of material required for one complete assembly. The estimated number of man-hours and recommended crew size needed to assemble and install one of the assemblies appears at the bottom of display.

ASSEMBLY 10004 ZONE 10004
TENT 40X100

NAVFAC DRAWING NUMBER NONE MAJOR REVISION DATE 02 09 82

COG	STOCK NUMBER	DESCRIPTION	UI	QTY	HEIGHT POUNDS	CUBIC FEET	DOLLAR VALUE
90	3940-00-272-9285	BLOCK AND TACKLE 3 / 4 F-RP	EA	4	80.00	2.7200	936.76
92	4010-00-171-3115	ANCHOR GUY CABLE H/TRNBKL F/40X100 TENT	EA	12	528.00	9.60000	1,135.44
90	8340-00-062-5738	POLE TENT 8FT3N F/40X80	EA	36	612.00	36.0000	320.40
90	8340-00-241-8183	POLE TENT 21FT F/40X80	EA	4	344.00	4.0000	673.20
90	8340-00-242-7863	CHAIN HOOK-RING TENT	SE	4	26.00	.7200	218.40
90	8340-00-252-2266	LINE TENT	EA	12	480.00	2.2800	156.60
90	8340-00-252-2266	PIN TENT 36N WOOD	EA	45	225.00	.9000	351.00
90	8340-00-266-6780	TENT SECTION END F/60X100	EA	2	300.00	18.0000	1,903.00
90	8340-00-266-6781	TENT SECTION HID F/40X100	EA	3	810.00	30.0000	2,612.10
90	8340-00-266-6782	TENT SECTION HALL F/40X100	EA	6	300.00	42.0000	2,100.30
		ASSEMBLY 10004		TOTAL	3,705.00	146.2200	10,407.20

FUEL (GAL / 30 DAYS)			SKILLS MANHOURS								
HEATING		PWR GEN									CONST EFFORT
DSL	HOGAS	DSL	EA	BU	UT	CE	SW	EO	CM	NS	MANHOURS
0	0	0	0	6	0	0	0	0	0	32	38

NOTE - CREW SIZE: 1 BU, 5 CW

MIL-T-11100

WHEN USING IN HIGH WIND LOCATION, ADD ASSY 10018
KIT TENT ANCHORING.

Figure 1-26 – Typical Assembly Data Display.

4.2.1 NAVFAC P-437(Volume 1)

Volume 1 contains reproducible engineering drawings organized in three parts; Component Site Plans, Facility Drawings and Networks, and Assembly Drawings.

Part 1, Component Site Plans, is indexed by component designation and includes typical site plans for the ABFC components. When a component does not have a site plan, the word "*None"* appears on the data display for the component.

Part 2, Facility Drawings and Networks, is indexed by facility number and contains detailed construction drawings of the ABFC facilities as well as preconstruction networks. A network is a diagram used to guide and manage a construction project. It includes information, such as the sequence of construction activities, start and finish dates of each construction activity, duration of each activity, and other information useful to crew leaders, supervisors, and managers of a project.

Part 3, Assembly Drawings contain working drawings of the ABFC assemblies indexed by assembly number.

Test your Knowledge (Select the Correct Response)

18. The ABFC System is covered in volume 2 of which of the following NAVFAC publications?

    A. P-306
    B. P-404
    C. P-405
    D. P-437

19. **(True or False)**The overall ABFC System comprises of a preplanned collection of individual functional components.

    A. True
    B. False

Summary

This chapter presented information specific to transportation operations including the control and accountability of all CESE. This chapter detailed the mandated operator application forms, licensing test and forms required to operate various types of vehicle and equipment.

This chapter also addressed the different organizational titles and duties affiliated with transportation operations including the dispatcher, yard boss, collateral equipment custodian and attachment custodian.

Finally, the topics of embarkation and Advance Base Planning were discussed. Additional information can be found in the manuals specific to each topic.

Review Questions (Select the Correct Response)

1. Which of the following publications states that all personnel in the Naval Construction Force (NCF) who operate government–owned or rented equipment must have a valid U.S. Government Operator's License in their possession?

   A. NAVFAC P–315
   B. NAVFAC P–300
   C. NRVFAC P–404
   D. NAVFAC P–405

2. Which of the following form numbers is used as an application for a vehicle operator's identification card?

   A. NAVFAC 11240/10
   B. NAVFAC 11260/1
   C. NAVFAC 9-11240/13
   D. NAVFAC 11260/4

3. In the NCF, in what location can you find information particular to a piece of equipment?

   A. The equipment glove box
   B. The equipment toolbox
   C. The dispatch office
   D. The technical library

4. When does the Construction Equipment Operator License expire?

   A. On the birth date of the operator and is valid for 2 years
   B. On the date of issue and is valid for 3 years
   C. On the projected rotation date (PRD) of the operator
   D. At the operator's end of active obligated service (EAOS) date

5. Which of the following information is documented on dispatch forms?

   A. Miles only
   B. Hours only
   C. Maintenance performed only
   D. Miles, maintenance performed, and hours

6. Which of the following numbers is a form number for a hard card?

   A. NAVFAC 9-11240/13
   B. NAVFAC 11240/10
   C. NAVFAC 11260/4
   D. DD Form 518

7. The hard card provides a uniform list of services to be performed on equipment by the operator at which of the following times?

   A. Before operation
   B. During operation
   C. After operation
   D. All of the above

8. Which of the following forms contains a record of an operator's destination, time of departure, time of arrival, and speedometer reading?

   A. Standard Form 91
   B. DD Form 1970
   C. DD Form 518
   D. NAVFAC 11260/4

9. Which of the following forms is used to provide any person involved in a mishap with a Navy vehicle the name and organizational assignment of the Navy operator?

   A. DD Form 518
   B. DD Form 1970
   C. 1250-1
   D. NAVFAC 9-11240/13

10. In an NMCB, what person is designated as the equipment officer?

    A. Alpha company commander
    B. Bravo company commander
    C. Charlie company commander
    D. Delta company commander

11. In an NMCB, at what location are the spare keys for each piece of equipment maintained?

    A. In the dispatch spare key locker
    B. In the yard boss spare key locker
    C. In the equipment history jacket
    D. In the spare key locker maintained at the quarter deck

12. What component provides a means of listing, by USN number, all the equipment assigned to a unit?

    A. Equipment status board
    B. Equipment chalkboard
    C. Equipment log file
    D. Equipment location file

13. NCF dispatcher logs are retained on file for what period of time?

    A. 30 days
    B. 90 days
    C. 180 days
    D. 240 days

14. Equipment in the equipment pool must be maintained in a standby status and cycled at what time periods?

    A. Daily
    B. Weekly
    C. Monthly
    D. Yearly

15. Which of the following personnel maintains the equipment cycle log?

    A. Equipment cycle custodian
    B. Dispatcher
    C. Yard boss
    D. Shop inspector

16. What are the two basic types of collateral equipage?

    A. Component and automotive
    B. Construction and automotive
    C. Component and tactical
    D. Construction and tactical

17. At what location can a list of types and amounts of component collateral equipage for a single piece of equipment be found?

    A. The dispatcher log
    B. The history jacket
    C. The vehicle data plate
    D. The equipment status board

18. What is the number of the form used to reorder lost, damaged, or deteriorated collateral equipage?

    A. 1250-1
    B. 1970
    C. 173/3
    D. 120–A

19. Which of the following personnel has the responsibility for the segregated storage of all attachments and their associated accessories?

    A. Yard boss
    B. PM runner
    C. Attachment custodian
    D. Dispatcher

20. The MOCC and what other staff controls all aspects of an NMCB mount-out?

    A. Embarkation
    B. Security
    C. Medical
    D. Supply

21. When mobile-loaded items are secured to a vehicle by rope, the rope must be what minimum size?

    A. One-fourth inch
    B. One–half inch
    C. Three–fourths inch
    D. Five–eighths inch

22. What is the weight limitation for a 463-L pallet?

    A. 1,000 pounds
    B. 5,000 pounds
    C. 8,000 pounds
    D. 10,000 pounds

23. Before loading a pallet, how many pieces of dunnage must be placed underneath the pallet?

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

24. When stacking pallets, place dunnage at what height intervals?

    A. After every 5 pallets
    B. 10 pallets high
    C. 15 pallets high
    D. 20 pallets high

25. What part of the P-437 contains data displays for each of the ABFC components and is indexed by code number?

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

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.

Cargo Specialists' Handbook, FM 55-17, Department of the Army Headquarters Washington, DC, February 1999.

Embarkation Manual, COMFIRSTNCDINST 3100.1, Naval Construction Division Little Creek, VA, 2008.

Equipment Management, COMFIRSTNCDINST 11200.2A, Naval Construction Division Little Creek, VA, 2008.

NCF Equipment Management Manual, NAVFAC P-404, Naval Facilities Engineering Command, 200 Stovall Street, Alexandria, VA, 1988.

Facilities Planning Guide, NAVFAC P-437, Naval Facilities Engineering Command, 200Stovall Street, Alexandria, VA, 1990.

Federal Motor Carrier Safety Regulations Pocketbook, 7-ORS-A, U.S. Department of Transportation, Federal Highway Administration, Washington, DC, 1990.

MAC Affiliation Training Program, MAC Pamphlet 50-13, Department of the Air Force, Headquarters, Military Airlift Command, Scott Air Force Base, IL, 1987.

Management of Transportation Equipment, NAVFAC P-300, Naval Facilities Engineering Command, 200 Stovall Street, Alexandria, VA, 1992.

Manual for Truck and Bus Drivers, Commercial Drivers License, Florida Department of Highway Safety and Motor Vehicles, Tallahassee, FL, 1989.

Navy Driver's Handbook, NAVFAC MO-403, Naval Facilities Engineering Command, 200 Stovall Street, Alexandria, VA, 1980.

Safety and Health Requirements Manual, EM 385-1-1, U.S. Army Corps of Engineers, Washington, DC, 1987.

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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Description

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Chapter 2

Engine Systems

Topics

1.0.0 Engines

2.0.0 Fuel Injection Systems

3.0.0 Air Intake Systems

4.0.0 Lubrication Systems

5.0.0 Cooling Systems

To hear audio, click on the box. 

Overview

Inspecting and replenishing coolant and oil levels and cleaning air filters are part of operator preventive maintenance. To understand the purpose of these inspections, you must understand the operating principles of automotive and construction equipment.

This chapter covers the basic principles of engines, fuel systems, air intake systems, lubrication systems, and cooling systems on the equipment used by the Navy and the Naval Construction Force (NCF).

Objectives

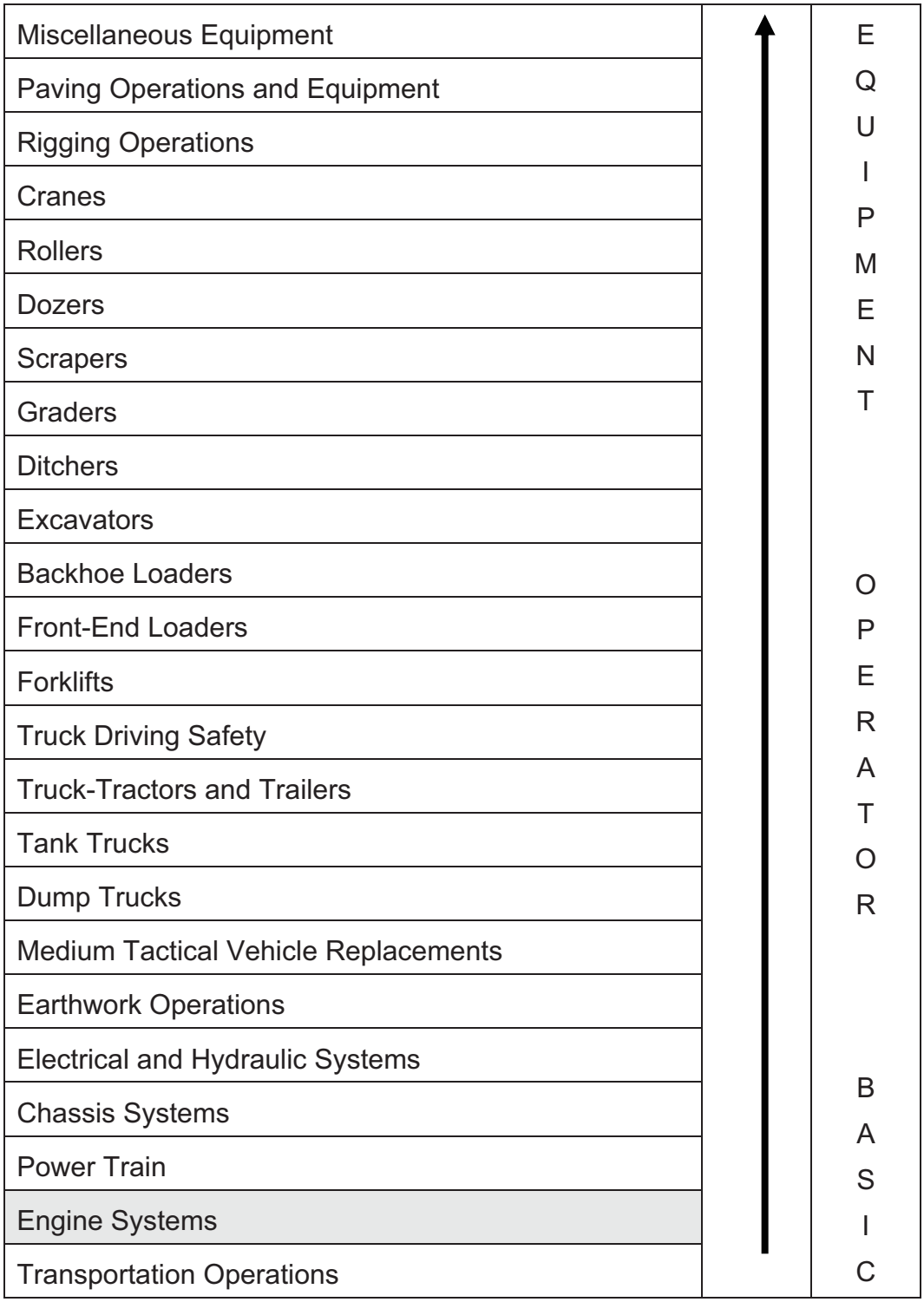
When you have completed this chapter, you will be able to do the following:

1. Understand the principles of engines.
2. Understand the principles of fuel injection systems.
3. Understand the principles of air intake systems.
4. Understand the principles of lubrication systems.
5. Understand the principles of cooling systems.

Prerequisites

None

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



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 ENGINES

An engine (*Figure 2-1*) is a device that converts heat energy into mechanical power which drives the vehicle or equipment. An internal combustion engine is any type of engine that burns fuel within its body.

Fuel and air are needed to produce heat energy. Fuel is broken down into small particles; a process known as atomization. The atomized fuel is evenly mixed with incoming air. This mixture is highly combustible. Combustion is a chemical reaction that occurs when the mixture is ignited in the engine cylinder. The force of the combustion produces mechanical power.

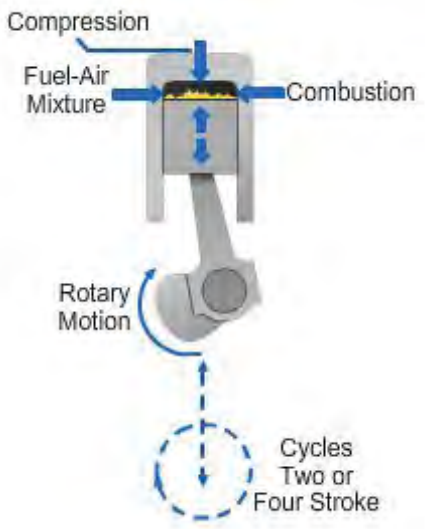


Figure 2-1 – Basic elements of an engine.

A piston, cylinder, connecting rod, and a crankshaft work together to convert ***reciprocating motion*** into ***rotary motion***.

The piston is fitted to glide up and down in the cylinder with little side clearance (*Figure 2-2*). The combustion chamber is located on top of the cylinder. It usually has two valves, an intake valve and an exhaust valve. The connecting rod transmits the piston's reciprocating motion to the crankshaft. The crankshaft has a section offset from the center line of the shaft so that it "cranks" when the shaft is turned (*Figure 2-3*).

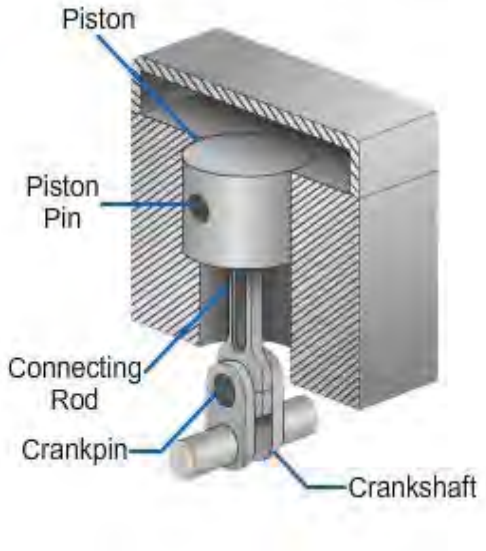


Figure 2-2 – Piston in a cylinder.

Figure 2-3 – Piston to crankshaft relationship.

1.1.0 Engine Cycle

When the piston is at the highest point in the cylinder, it is called top dead center. When the piston is at its lowest point in the cylinder, it is called bottom dead center. *Figure 2-4* shows the position of “top dead center” TDC and “bottom dead center” BDC.

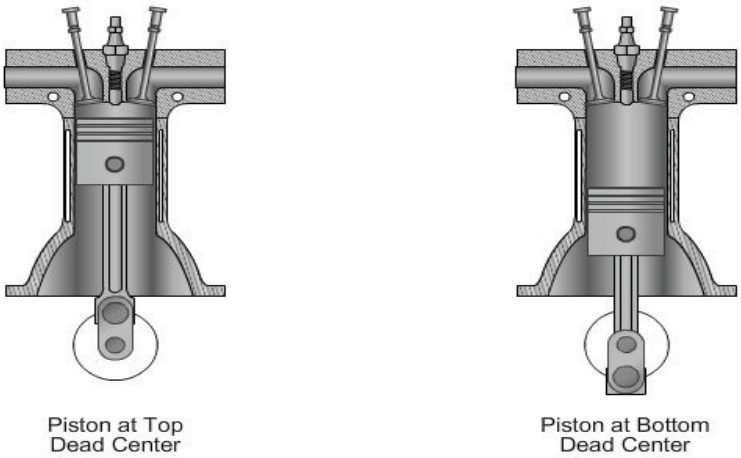


Figure 2-4 – Piston positions.

As the piston moves from top to bottom or from bottom to top, the crankshaft rotates exactly one half of a revolution. Each movement of the piston from top to bottom or from bottom to top is called a stroke; therefore, the piston completes two strokes for every full crankshaft revolution.

The following sequence of events must occur for an engine to operate:

- INTAKE: A combustible mixture is pulled into the cylinder.
- COMPRESSION: The combustible mixture is compressed into a smaller space.
- POWER: The compressed combustible mixture is ignited causing it to expand, producing mechanical power.
- EXHAUST: The burnt gases are removed from the cylinder.

The engine repeats this sequence of events over and over to produce sustainable power. One complete series of these events is called a cycle. Engines have either a four-stroke cycle or a two-stroke cycle. Most engines operate on a four-stroke cycle.

1.1.1 Four-Stroke Cycle Gasoline Engine

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 a spark plug. The spark plug emits 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 2-5* shows the operations of a four-stroke cycle gasoline engine.

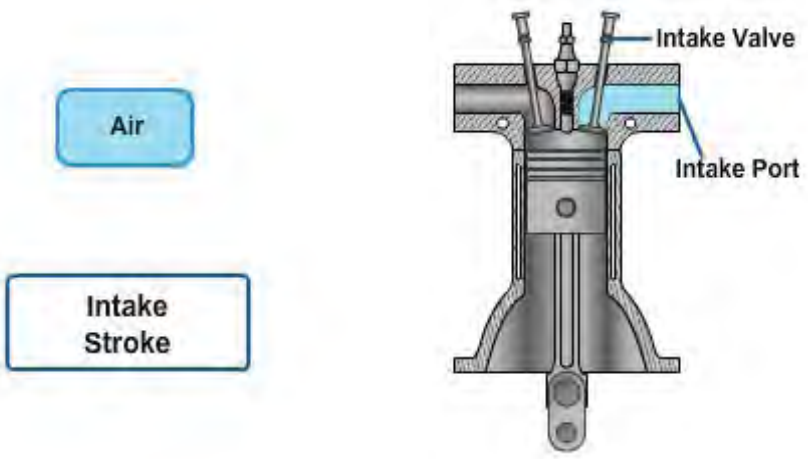


Figure 2-5 – Four-stroke cycle gasoline engine in operation.

1.1.2 Four-Stroke Cycle Diesel Engine

The four-stroke cycle diesel engine (*Figure 2-6*) is similar 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.

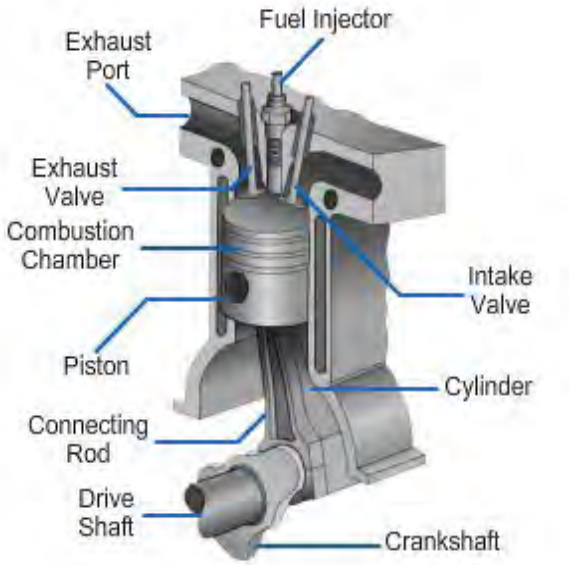


Figure 2-6 – Four-stroke cycle diesel engine.

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 mush as 500 pounds per square inch (psi) at a temperature approximately 1000F°.

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. *Figure 2-7* shows the operation of four-stroke cycle of a diesel engine.

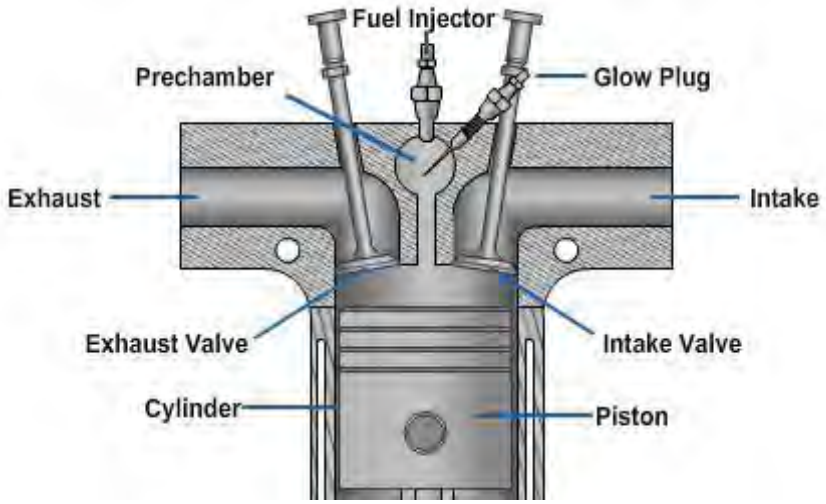


Figure 2-7 – Four-stroke cycle diesel engine in operation.

The primary differences between a diesel engine and a gasoline engine are as follows:

- In a diesel engine, the fuel and air mixture is ignited by the heat generated by the compression stroke, while a gasoline engine uses an ignition system to ignite fuel and air.
- The fuel and air mixture in a diesel engine is compressed to about one twentieth of its original volume, while in a gasoline engine the fuel and air mixture is only compressed to about one eighth of its original volume. A diesel engine must compress the mixture more tightly to generate enough heat to ignite the fuel and air mixture. The contrast between the two engines is shown in *Figure 2-8.*

Figure 2-8 – Diesel and gasoline engines compression strokes.

- A diesel engine takes in only air through the intake port. An injection system delivers fuel directly into the combustion chamber, where it is then mixed with air. A gasoline engine mixes the fuel and air in the intake manifold before it reaches the combustion chamber. This contrast in shown in *Figure 2-9.*

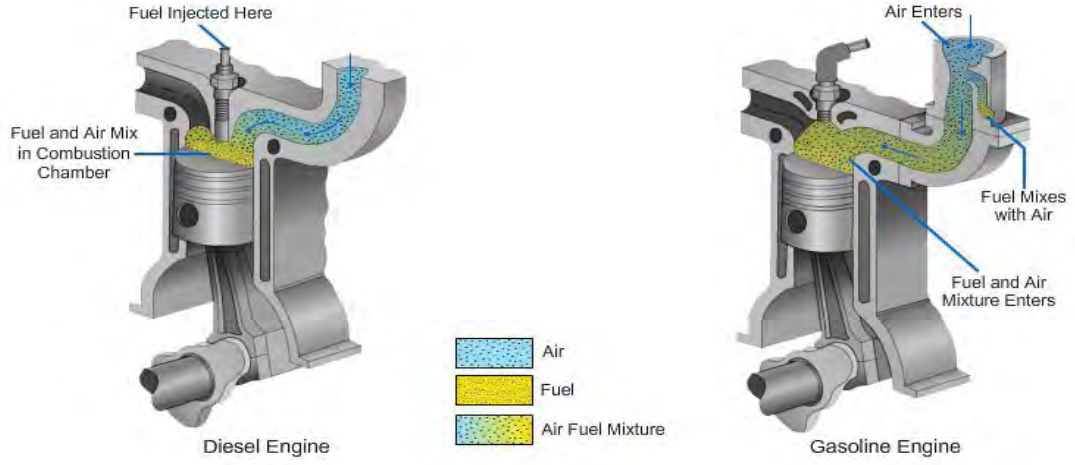


Figure 2-9 – Diesel and gasoline engines intake strokes.

- A diesel engine, controls the engine speed and power output by the quantity of fuel delivered to the combustion chamber. The amount of air is constant. The gasoline engine, regulates the speed and power output by limiting the air and fuel mixture entering the engine.

A diesel engine is more efficient than a gasoline engine. It does not require an ignition system because it generates heat by the higher compression. It is more fuel efficient because it burns fuel completely. A diesel engine also has greater torque because of the power developed by the high-compression ratio.

1.1.3 Two-Stroke Cycle Diesel Engine

The two-stroke cycle diesel engine (*Figure 2-10*) has the same operating principles as any other internal combustion engine. It also has the same advantages that diesel engines have over gasoline engines.

Although, the two-stroke cycle diesel engine does not produce as much power as the four-stroke diesel engine, it runs more smoothly because a two-stroke cycle diesel engine generates a power stroke each time the piston moves downward, once for each crankshaft revolution.

The two-stroke cycle diesel engine also has a less complicated valve train because it does not have an intake valve. Instead, it requires a supercharger to force air in and exhaust gases out of the cylinder. This method is called scavenging.

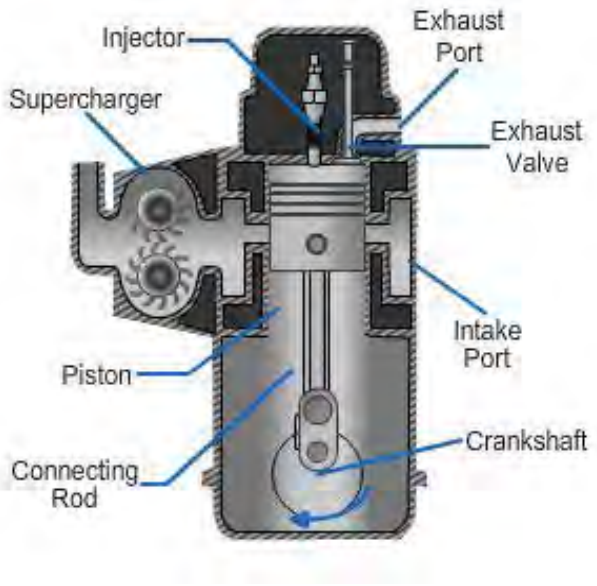


Figure 2-10 – Two-stroke cycle diesel engine.

Scavenging begins when the piston is at bottom dead center, the exhaust valve is open, and the intake ports are uncovered. The supercharger forces air into the cylinder. As the air is forced in, the burnt gases from the previous operating cycle are forced out.

Compression Stroke – As the piston moves towards top dead center, it covers the intake ports. The exhaust valve closes, sealing the upper cylinder. As the piston continues upwards, the air in the cylinder is tightly compressed. As in the four-stroke cycle diesel, the compression generates a tremendous amount of heat.

Power Stroke – As the piston reaches top dead center, the compression stroke ends. The engine's fuel injection system delivers fuel into the cylinder. The heat of the compression ignites the fuel and air mixture. The burning gases push the piston down, giving power to the crankshaft. The power stroke ends when the piston gets down to the point where the intake ports are uncovered and the exhaust valve opens and scavenging begins again. *Figure 2-11* shows the operation of a two stroke cycle of a diesel engine.

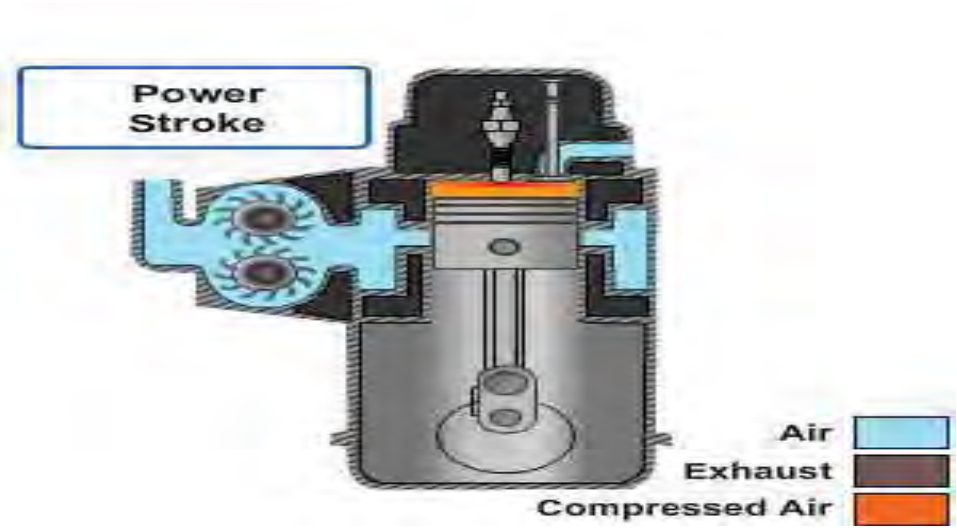


Figure 2-11 – Two-stroke cycle diesel engine in operation.

Valve Train – Valve timing and sequence is critical. If the exhaust valve opens in the middle of the intake stroke, burnt gases will be drawn into the combustion chamber and mixed with fresh fuel and air. This mixture would not be combustible. A two-stroke cycle engine is equipped with a valve train to properly operate the valves (*Figure 2-12*).

The camshaft, shown in *Figure 2-12*, is designed to rotate with the crankshaft through timing gears. As the cam lobe rotates, it pushes up on the lifter. The cam lobe pushes the valve open against the pressure of a spring. As the cam lobe rotates away from the lifter, the valve spring pulls the valve closed. The proper positioning of the cam lobes on the camshaft establishes a sequence for the intake and exhaust valves.

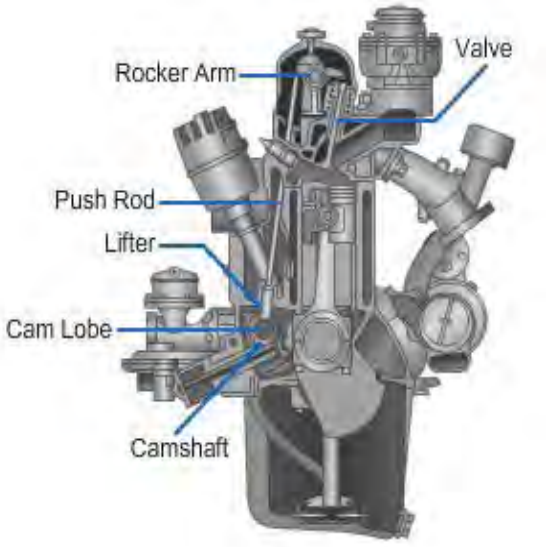


Figure 2-12 – Valve train.

Test your Knowledge (Select the Correct Response)

1. Atomization is the _____.

   A. the process of breaking down fuel into small particles
   B. the process of breaking down air into smaller particles
   C. the chemical reaction that occurs when fuel and air is mixed
   D. the chemical reaction that occurs when fuel and air is ignited

2. 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. a stroke

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

   A. True
   B. False

4. **(True or False)** A diesel engine has an ignition system.

   A. True
   B. False

5. **(True or False)** The two-stroke cycle diesel engine has an intake valve.

   A. True
   B. False

2.0.0 FUEL INJECTION SYSTEMS

The fuel injection system serves three functions: deliver proper amount of pressurized fuel to the engine cylinders, closely control the fuel-air ratio, and atomize fuel so that it will mix with the air to become a combustible mixture. The major components of fuel injection systems are fuel, fuel tank, fuel lines, pumps and injectors.

2.1.0 Fuel

Fuel is defined as any chemical compound that can burn and produce energy. Most fuels are compounds of hydrogen and carbon, called hydrocarbons. The most commonly used fuels in internal combustion engines are gasoline and diesel.

2.1.1 Gasoline

Gasoline is a by-product of petroleum. Two types of gasoline are used: leaded and unleaded.

Leaded gasoline has a higher octane rating than unleaded gasoline. It is also more effective as a valve and valve seat lubricant. Leaded gasoline has almost been discontinued because engines that use it emit a great amount of hydrocarbons that are harmful to the atmosphere.

Engines that use unleaded gasoline emit fewer hydrocarbons and have fewer combustion chamber deposits. In addition, unleaded gasoline provides a longer life for spark plugs, exhaust systems, and fuel injectors. Interestingly, unleaded gasoline engines emits about the same amount of carbon monoxide and nitrogen oxide as leaded gasoline.

NOTE

The octane number is the measurement of gasoline's ability to burn evenly and resist spontaneous combustion. A knocking sound in a gasoline engine is caused by gases burning too rapidly.

Catalysis Converter – A catalytic converter is positioned in the exhaust system, usually between the engine and the muffler. It controls the emission of carbon monoxide and hydrocarbons produced from burning gasoline. As the engine exhaust passes through the converter, carbon monoxide and hydrocarbons are oxidized (combined with oxygen), changing them to carbon dioxide and water. This oxidation causes the outer shell of the converter to operate consistently at temperatures that are several hundred degrees higher than the rest of the exhaust system. The outer shell of the catalytic converter is normally made of stainless steel to cope with the high operating temperatures.

A chemical catalyst is an element or chemical compound that increases the reaction between two other chemicals without reacting with them. In this case, the catalyst in the catalytic converter increases the reaction between oxygen and the harmful carbon monoxide and hydrocarbons to produce harmless carbon dioxide and water emissions.

Platinum and palladium are precious metals often used as catalysts. Small amounts of the catalysts are used to coat the surfaces of the material in the converter. Pellet and monolithic are two common types of catalytic converters (*Figure 2-13*).

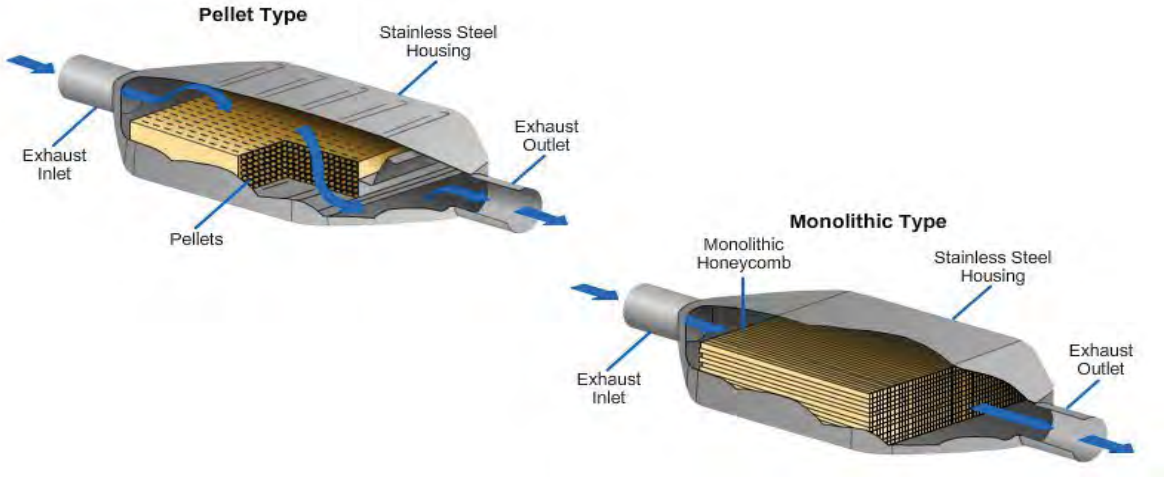


Figure 2-13 – Catalytic converters.

CAUTION

The use of leaded gasoline is destructive to a catalytic converter. The lead in exhaust can coat the catalyst as it passes through the converter. This coating can completely halt the operation of the catalytic converter.

2.1.2 Diesel Fuel

Diesel fuel comes from the residue of crude oil. It is collected during the petroleum refining process, after the more volatile fuels, such as gasoline and kerosene have been removed. As with gasoline, the efficiency of diesel fuel varies with the type of engine. The refining and blending process can produce a suitable diesel fuel for almost any engine operating condition.

Diesel fuel can hold dirt particles in suspension longer than gasoline because it is heavier and thicker. Not all foreign matter can be removed during the refining process.

Harmful matter, such as dirt and water can also get into diesel fuel during handling. Water can rust the injection system, causing it to fail. Dirt can clog fuel injectors, causing an engine to misfire or stop altogether. To be safe, remember to take precautions when refueling and try to prevent foreign matter from entering the fuel tank.

High-cetane diesel fuel allows engines to start at low temperatures. High-centane diesel provides fast warm-ups without misfiring, or producing white smoke. It also reduces the formation of carbon deposits and eliminates engine knocking. However, a too high of a cetane number can lead to incomplete combustion and exhaust smoke, if the delay is too short to allow for proper mixing of fuel and air. Most diesel fuel range from 33 to 64 in cetane number, with 40 the minimum for military grades DF-1 and DF-2.

NOTE

The cetane number is the measurement of diesel's ability to provide fast spontaneous combustion with short ignition delay. A knocking sound in a diesel engine is caused by the fuel igniting too slowly.

Jet Fuel – You may be deployed to some sites at which diesel fuel is not available and you must use JET FUEL. The three major types of jet fuel used by the military are JP-4, JET-A1, and JP-5. DO NOT USE JP-4 IN ANY DIESEL ENGINE. The maintenance supervisor approves the use of JET-A1 and JP-5 and directs the amount of engine oil that must be added to the jet fuel. This must be done to improve the lubricating qualities that prevent the injector pump and injectors from seizing.

2.2.0 Fuel Tank

The fuel tank stores fuel until it is used by the engine. The tank can be located anywhere on the vehicle that is protected from flying debris, shielded from collision, and not likely to bottom out (*Figure 2-14*). Most wheeled vehicles use removable fuel tanks.

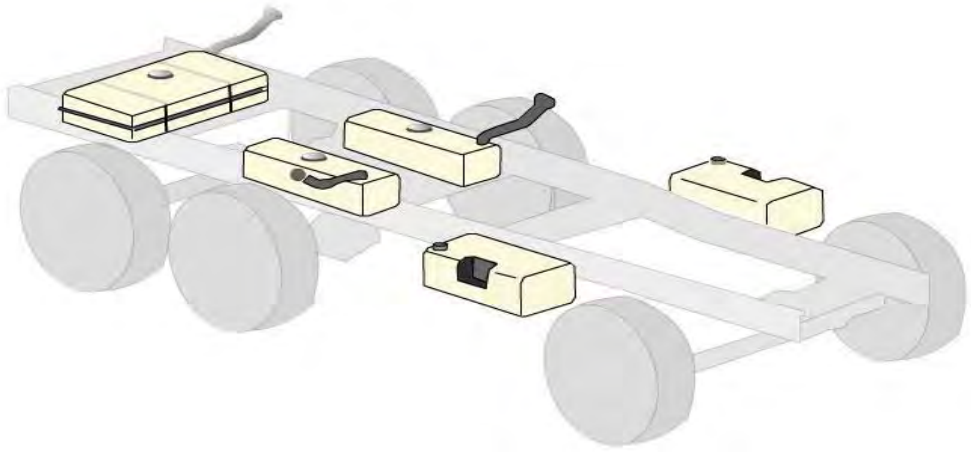


Figure 2-14 – Common fuel tank locations.

Most fuel tanks are made of thin sheet-metal coated with a lead-tin alloy, to prevent corrosion. Fiber glass and a variety of molded plastics are also popular corrosion-resistant materials. The walls of fuel tanks are manufactured with ridges to give them strength and internal baffles that increase internal strength and prevent the fuel from sloshing. The filler pipe offers a convenient opening to fill the tank and prevent fuel from spilling onto the passenger, engine, or cargo compartments. The fuel outlet pipe is located inside the tank and its opening is about one-half inch above the bottom. This location allows sediment to fall to the bottom of the fuel tank without being drawn into the fuel system.

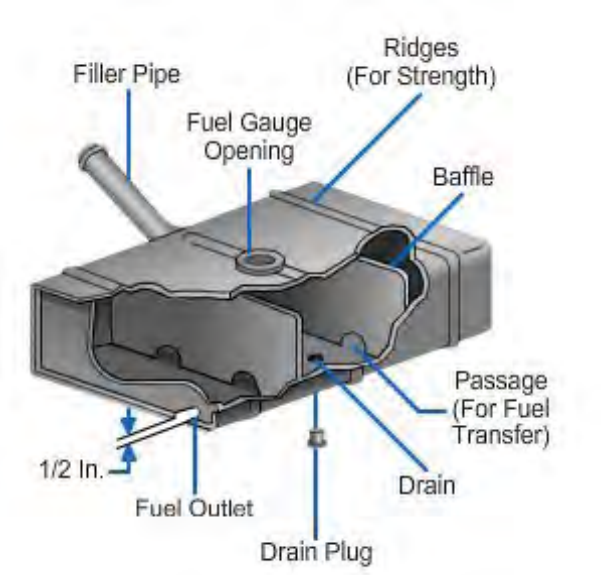


Figure 2-15 – Fuel tank construction.

Most fuel tanks have a location on top to install a fuel gauge sending unit. This is usually a flanged hole. A threaded drain plug is normally located at the bottom of the tank and is used for draining and cleaning the tank. *Figure 2-15* shows the construction of a fuel tank.

2.3.0 Fuel Pump

The fuel pump transfers fuel from the fuel tank. Several types of fuel pumps are used. The most common type is the electric fuel pump.

2.3.1 Electric Fuel Pump

An electric fuel pump (*Figure 2-16*) provides positive fuel pressure. It is usually mounted inside the fuel tank; however, it can be placed in the lines from the tank to the engine.

Some electric pumps are operated by the vehicle electrical system whenever the ignition switch is on. Others types of electric pumps are energized by an ***electronic control module (ECM)*** before the engine has been started.

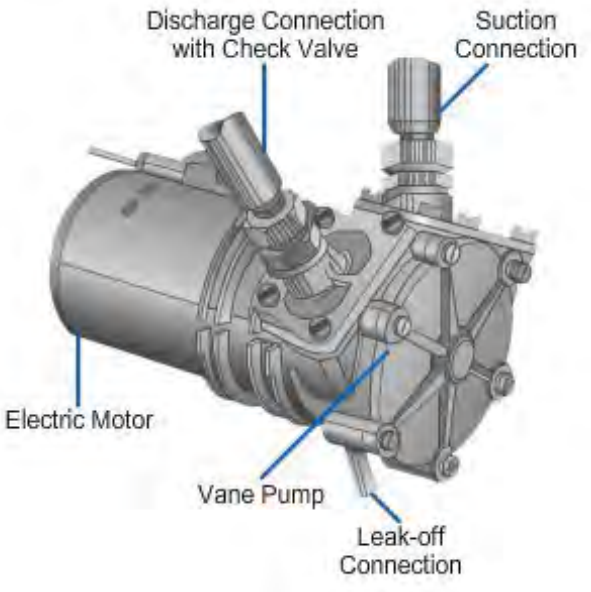


Figure 2-16 – Electric fuel pump.

In gasoline engines, the fuel that is transferred by the electric pump moves through one filter and then to the injectors.

In diesel engines, the fuel that is transferred by the electric pump moves through two filters and then to a fuel injection pump housing manifold.

2.3.2 Fuel Injection Pump

Diesel engines have one or more fuel injection pumps. The primary function of the fuel injection pump is to take fuel from the fuel manifold and deliver it under high-pressure to the injectors.

2.4.0 Fuel Lines

By carrying fuel, fuel lines connect the fuel tank to the rest of the system. Some fuel lines are made of flexible rubber, to move with the engine, or galvanized steel coated internally with a corrosion inhibitor. Other types of fuel lines are made of nylon or plastic to prevent the fuel injectors from clogging and corroding. Fuel lines can be joined by tube fittings or push-on connectors.

2.4.1 Diesel Fuel Lines

Diesel engines have three types of fuel lines: heavyweight, mediumweight, and lightweight (*Figure 2-17*). These fuel lines handle various amount of pressure, are constructed differently, and have specific locations.

Heavyweight Lines – Heavyweight lines handle very high-pressure fuel. They are usually made of copper-coated steel tubing and are located between the injection pump and the injection nozzles.

Mediumweight Lines – Mediumweight lines handle low or moderate fuel pressure. They are made of nylon or neoprene, reinforced with a braided outer casing. They are located between the tank and the injection pump.

Lightweight Lines – Lightweight lines handle little or no fuel pressure. They are used as leak-off lines. Lightweight lines are made of mylar hosing and are located near the nozzles, tank, or fuel pump.

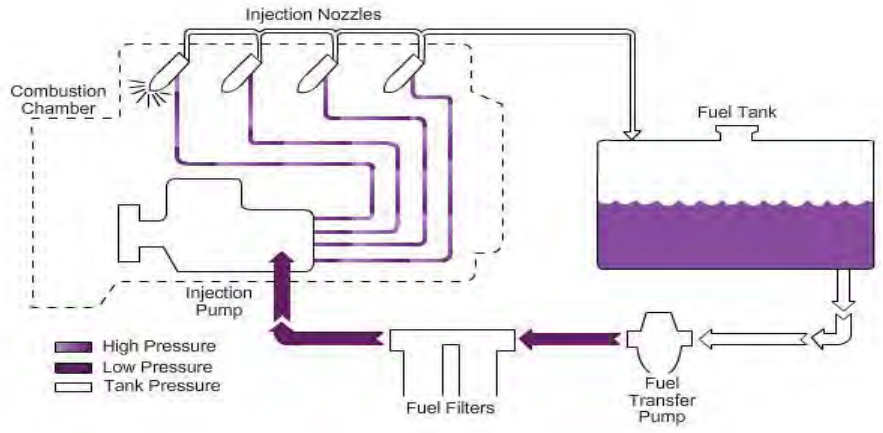


Figure 2-17 – Diesel fuel injection system.

2.5.0 Fuel Filters

The fuel injection system is highly sensitive to foreign particles. Fuel filters prevent water, dirt, and rust particles from entering the system. Contaminated fuel can cause incomplete combustion, smoky exhaust, engine knocking, and difficulties starting the engine. Most heavy equipment has a fuel pressure gauge that indicates when the filters are dirty.

The fuel filter operates by passing fuel through a porous element that removes particles large enough to cause problems in the system. Particles are often measured in microns. A micron is one millionth of a meter.

Some filters serve as sediment bowls. These types of filters separate water and larger particles from the fuel. After separation, the water and particles settle to the bottom of the bowl, where they can be removed through a drain plug (*Figure 2-18*).

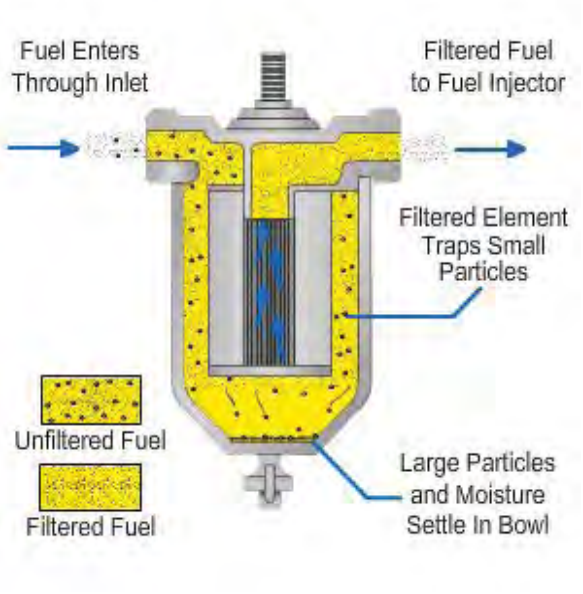


Figure 2-18 – Fuel filter operation.

Filter elements (*Figure 2-19*) can be made of ceramic, treated paper, sintered bronze, or metal screen. Some filter elements are made of laminated disks that are spaced 0.0003 inches apart. Foreign matter is blocked out as the fuel passes between the disks.

Figure 2-19 – Fuel filter elements.

2.5.1 Diesel Fuel Filters

Diesel fuel contains more abrasive particles than gasoline does. For this reason, most diesel engines have a primary filter and a secondary filter (*Figure 2-20*). These filters are not interchangeable. They are usually marked with the letter “P” or “S”.

Primary Filter – The primary filter is made of a coarse metal element. This type of element removes large particles ranging from 20-30 microns in size. Primary filters offer low fuel restriction because they are located between the fuel tank and the fuel pump. The effectiveness of the primary filter increases the life of the secondary filter.

Secondary Filter – The secondary filter is highly effective in removing fine particles ranging from 3-5 microns in size. Secondary filters are made of a pleated-paper element. They are usually located between the fuel pump and the fuel injection pump, where fuel restriction is not a factor. The primary purpose of the secondary filter is to protect the fuel injection pump.

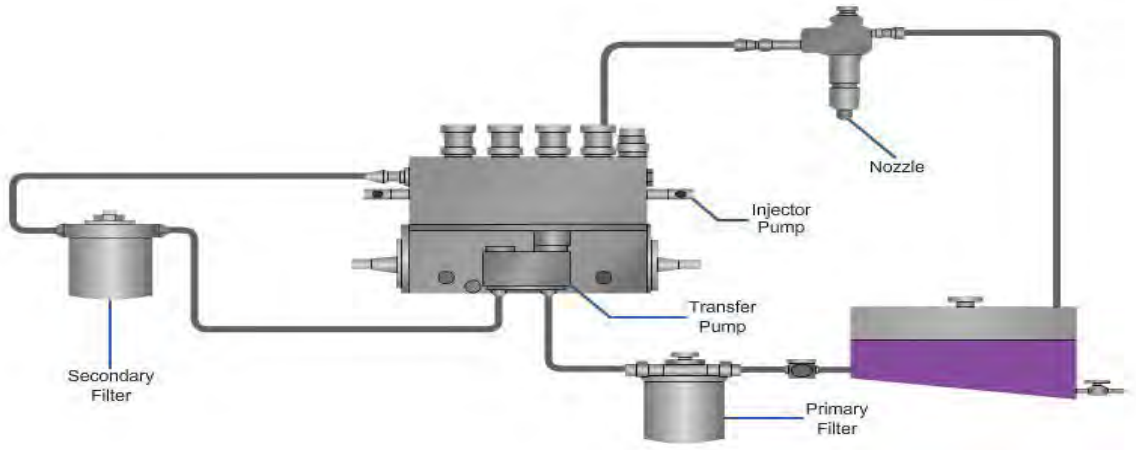


Figure 2-20 – Primary and secondary fuel filters locations.

2.6.0 Fuel Injectors

Fuel injection systems can have one or more fuel supply devices called fuel injectors (*Figure 2-21*). Fuel injectors are controlled by an ECM. The computer system sends an electrical current to activate the solenoid inside the injector. When the solenoid is activated, the injector nozzle opens and squirts atomized fuel in a cone-shaped pattern. The computer system controls the fuel-air ratio by varying the length of time that the injector nozzle remains open.

In gasoline engines injectors squirt fuel into the intake manifold. In diesel engines, fuel is delivered directly into the combustion chamber. Spring pressure closes the injector nozzle when the solenoid is deactivated.

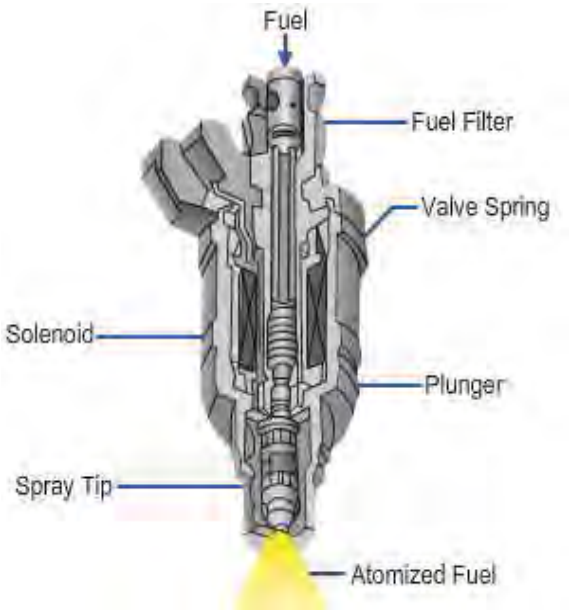


Figure 2-21 – Fuel injector.

2.7.0 Cold Weather Starting Aids

Diesel fuel evaporates much more slowly than gasoline and requires more heat to cause combustion in the cylinders. For this reason, preheaters and starting aids, called glow plugs, are installed on diesel engines.

2.7.1 Preheaters

Preheaters are normally installed in the intake manifold; however, in a two-stroke cycle engine, they are placed in the air passages surrounding the cylinders. The preheater burns a small quantity of diesel fuel in the air before the air is drawn into the cylinders.

This burning process is accomplished by the use of either a glow plug or an ignition coil that produces a spark to ignite a fine spray of diesel fuel. The resulting heat warms the remaining air before it is drawn into the cylinders.

2.7.2 Glow Plugs

Glow plugs (*Figure 2-22*) and the injection nozzle are installed in the precombustion chamber of the cylinder head. The glow plug is turned on when you turn on the ignition switch. On some equipment a light on the dashboard signals that the glow plug is cycling, which signals you to wait between 15 to 30 seconds before cranking the engine. The heat, created by electrical resistance in the glow plug, heats the fuel and air mixture. The heat generated by the glow plug and the heat generated by compression allow the fuel to ignite.

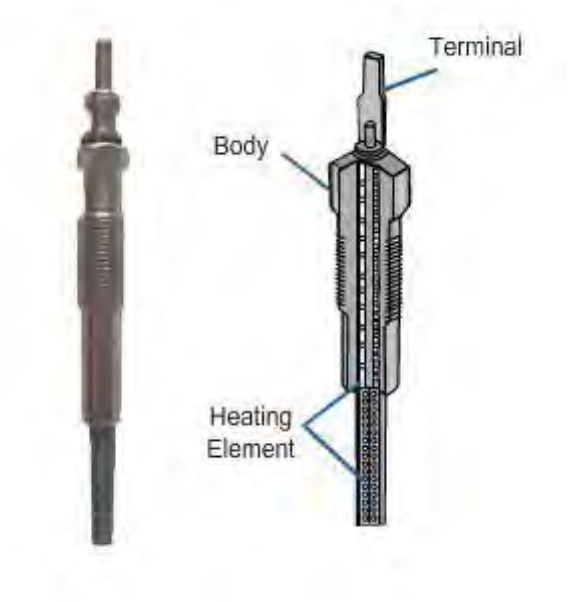


Figure 2-22 – Glow plugs.

Test your Knowledge (Select the Correct Response)

6. Gasoline is a by-product of _____.

   A. crude oil
   B. octane
   C. petroleum
   D. cetane

7. In the diesel engine, what fuel lines handle high-pressure fuel?

   A. Heavyweight
   B. Mediumweight
   C. Lightweight
   D. Leak-off

8. **(True or False)** Glow plugs are needed on gasoline engines because gasoline fuel evaporates slowly and requires heat to cause combustion in the cylinders.

   A. True
   B. False

3.0.0 AIR INTAKE SYSTEMS

The air intake system plays a critical role in supplying and cleaning air. The air intake system also functions as a silencer. Air intake systems consist of force induction systems and air cleaners.

3.1.0 Force Inductions Systems

An engine needs a sufficient amount of air for combustion. In addition, more air in the combustion chamber produces greater engine power. Devices such as blowers, superchargers, and turbochargers are used to increase air inducted.

3.1.1 Blowers

The scavenging process used in the two-stoke cycle diesel engine, is simply a charge of air, forced into the cylinder by a blower. As air is forced into the cylinder, all the burnt gases are swept out. This air also helps cool internal engine parts, particularly the exhaust valves.

Blowers usually have two rotors, closely fitted in housing, bolted to the engine (*Figure 2-23*). The rotary motion of the rotor lobes provides continuous and uniform displacement of air. Depending on the type of blower, rotors can have two or three lobes.

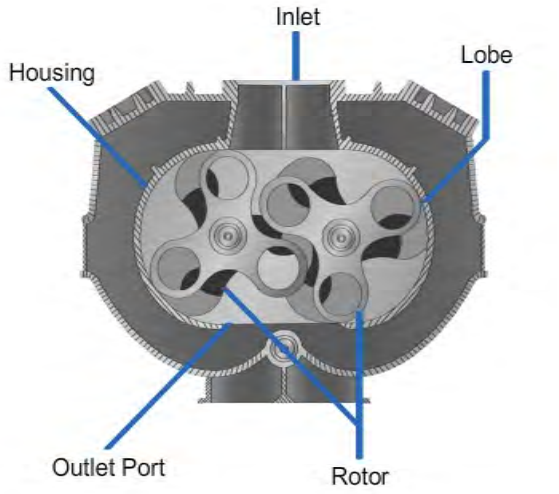


Figure 2-23 – Blower.

3.1.2 Superchargers

Superchargers are engine-driven air pumps that force air and fuel mixture into the engine. The most common type of supercharger is the ***centrifugal*** supercharger.

Centrifugal Supercharger –
The centrifugal supercharger (*Figure 2-24*) has an impeller equipped with curved vanes. The impeller draws air into its center and throws it off at its rim. The air is then pushed along the inside of the circular housing. The diameter of the housing gradually increases to the outlet where the air is pushed out to the engine intake system.

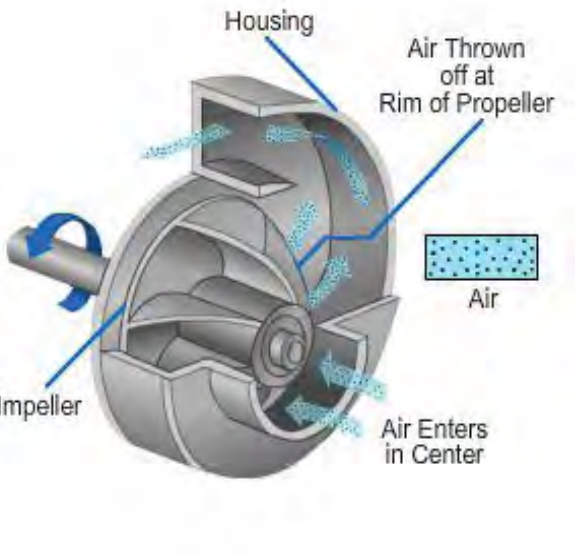


Figure 2-24 – Centrifugal supercharger.

3.1.3 Turbochargers

The four-stroke cycle engine uses two methods of air induction: naturally aspirated and turbocharged.

The naturally aspirated system depends on atmospheric pressure to keep a constant supply of air in the intake manifold.

The turbocharger (*Figure 2-25*), installed on the exhaust manifold, is designed to force air into the cylinder and aid in scavenging exhaust gases. The turbocharger differs from a supercharger because it uses the energy from the exhaust gases to drive a turbine wheel, where as the supercharger is engine-driven.

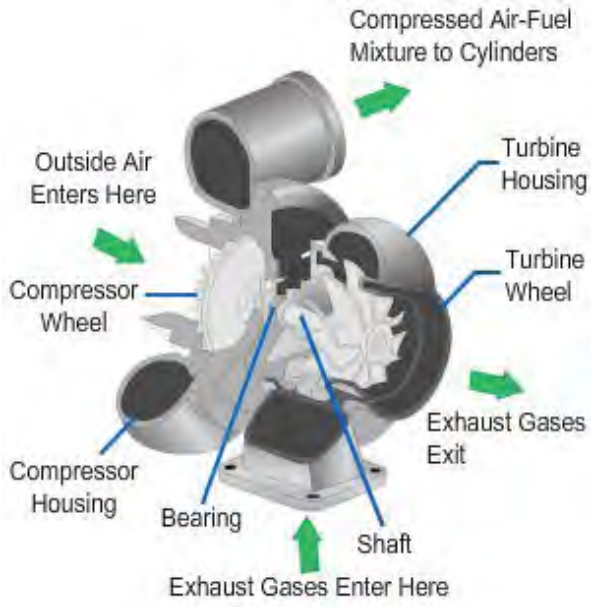


Figure 2-25 – Turbocharger.

The hot exhaust gases from the engine go through the exhaust inlet, across the turbine wheel, and out the exhaust outlet. The force of the exhaust turns the turbine wheel and shaft. This rotates the compressor wheel (impeller) that is attached to the opposite end of the turbine shaft. As the impeller rotates it draws air into the housing, the air is compressed and forced into the intake manifold.

3.2.0 Air Cleaners

Air cleaners are used to prevent foreign matter, such as sand, dust, and lint from entering the intake system. Contaminated air in the intake system can cause engine wear, poor combustion, and engine breakdown. In addition to supplying clean air, air cleaners reduce vibration sounds and other noises caused by air entering the intake system.

The most common types of air cleaners are: pre-cleaners, dry air cleaners, dry element air cleaners, and oil bath air cleaners.

3.2.1 Pre-Cleaners

Pre-cleaners (*Figure 2-26*) remove large particles of dirt and foreign matter from the air before it enters the main air cleaner. This alleviates most of the work for the main air cleaner. Pre-cleaners are used on equipment operating under medium to heavy dusty conditions. They are normally installed at the end of a pipe that extends upward into the air. This location keeps them in an area relatively free of dust.

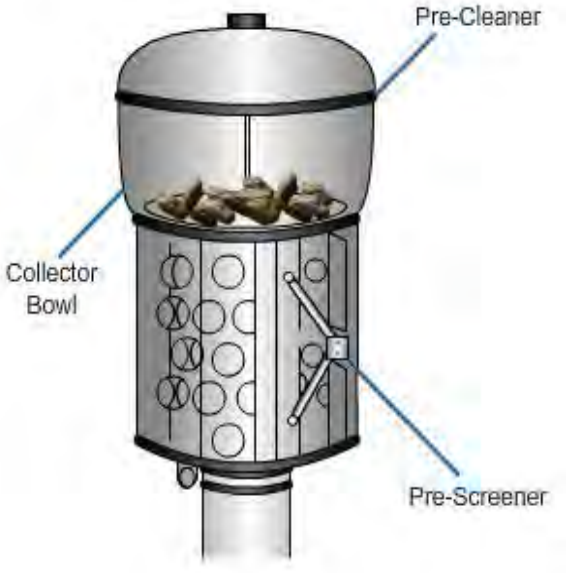


Figure 2-26 – Pre-cleaner.

3.2.2 Dry Air Cleaners

Dry air cleaners (*Figure 2-27*) remove large dirt particles by passing air through layers of cloth and felt. Dry air cleaners are directly attached to the intake system on engines that require a small amount of air.

Figure 2-27 – Dry air cleaner.

3.2.3 Dry-Element Air Cleaners

Dry-element air cleaners provide two stages of cleaning: pre-cleaning and filtering. The two most commonly used dry-element air cleaners are the cleaner with an unloading valve and the cleaner with a dust cup.

Cleaner with a Dust Unloading Valve – The cleaner with a dust unloading valve (*Figure 2-28*) directs air into its pre-cleaner assembly. When the air enters, it strikes a side of a metal shield, which creates a centrifugal force. The air is pushed across the far end of the cleaner housing. Heavier dirt particles continue downwards and are collected in the dust unloader valve.

The dust unloader valve is held closed by the engine suction while the engine is running. When the engine is shut down, the weight of the accumulated dirt helps open the flaps so the dirt can drop out.

Figure 2-28 – Dry air cleaner with unloading valve.

Cleaner with the Dust Air Cup –
The cleaner with the dust air cup (*Figure 2-29*) directs air in and past tilted fins, which creates a centrifugal force. The air is pushed across the far end of the cleaner housing. The force of the air pushes dirt through a slot on the top of the cleaner, where it enters the dust cup.

Both types of pre-cleaners remove over 80 percent of the dirt particles. The remaining dirt particles are removed after the air is redirected and filtered through a pleated-paper element.

Figure 2-29 – Dry air cleaner with dust cup.

As part of preventive maintenance, operators are responsible for inspecting and cleaning air cleaners. The dust unloading valve should be inspected for cracks, clogging, and deterioration. The dust cup should be removed and wiped clean with a rag.

Tapping and rotating a filter on the heel of your hand can remove dust. Avoid tapping the filter on a hard surface. This can damage the filter element.

When tapping does not remove the dust, you can use a compressed air gun to clean a filter. When using compressed air, move the clean air up and down the pleats, blowing from inside to outside (*Figure 2-30*). To prevent rupturing the filter, do not allow the air pressure to exceed 30 psi.

Water can also be used to clean filters. Begin by blowing out the dust with compressed air. Then, flush out the remaining dust from inside to outside with water. Do not allow the water pressure to exceed 40 psi. After flushing is complete, allow the filter to dry.

Figure 2-30 – Cleaning an air filter with low-pressured air.

For an extremely oily filter, first, clean the filter with the compressed air or flush it with clean water. Then, soak and gently agitate the filter in a cleaning solution and lukewarm water. Rinse the filter thoroughly with clean water. Shake the excess water from the filter and allow it to air-dry. Remember to protect the filter from freezing. Keep a spare filter to use while the washed one is drying.

After the filter is clean and dry, inspect it for damage. Before installing the filter, thoroughly clean the inside of the air cleaner body with a clean, damp rag.

NOTE

Consult the Maintenance Supervisor before washing any filter element with water. Additionally, never wash a dry element in fuel, oil, or solvent and never use compressed air to dry the element.

3.2.4 Oil Bath Air Cleaners

Oil bath air cleaners (*Figure 2-31*) draw air down a center tube. At the bottom of the tube is an oil cup. As air is drawn in and redirected upwards, larger particles come in contact with the oil and become trapped. Smaller particles that were able to bypass the oil continue upward into a filter element where they are removed from the air.

The filter element is effective because it is made of metal-wool screen, soaked with oil that has been sprayed by the air as it passed the oil cup.

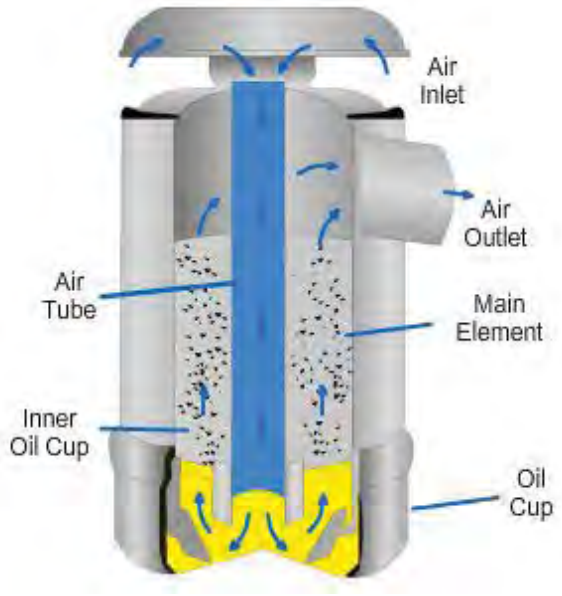


Figure 2-31 – Oil bath air cleaner.

Operators are responsible for keeping the oil cup filled to the proper level. They are also responsible for documenting when the oil is dirty and thick, therefore unable to clean particles from the air.

Test your Knowledge (Select the Correct Response)

9. Which of the following air cleaners has a metal shield that creates centrifugal force?

   A. Cleaner with a dust unloading valve
   B. Cleaner with a dust cup
   C. Dry air cleaner
   D. Oil bath air cleaner

4.0.0 LUBRICATION SYSTEMS

Engines need a proper amount of lubrication to properly operate. The lubrication system (*Figure 2-32*) supplies engine oil throughout the entire engine. Engine oil reduces friction, absorbs heat, cleans, and seals.

As part of preventive maintenance, operators are responsible for inspecting the lubrication system before operating a piece of equipment. The effort to inspect is easier

than explaining to the chain of command why an engine or part of the power train locked up or seized.

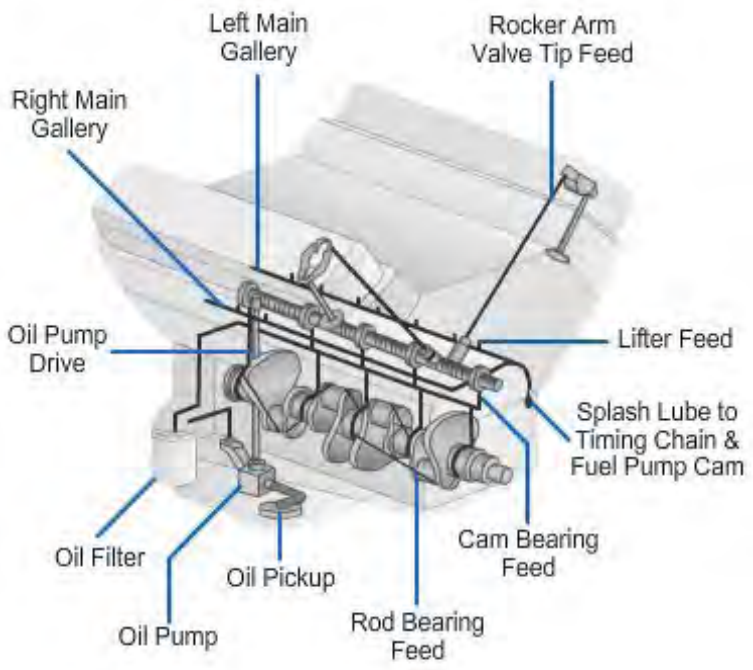


Figure 2-32 – Typical engine lubrication system.

4.1.0 Engine Oil

Engine parts are constantly moving and creating friction by metal-to-metal contact. Engine oil, also known as motor oil help reduces friction by serving as thin cushion between moving parts. Engine oil can also absorb heat from pistons, cylinder walls, and other engine parts that are not cooled by the cooling system.

In addition, engine oil is a sealing agent. A thin film of oil between the piston rings and cylinder wall can help seal in engine compression.

Engine oil is a great cleaning agent. It has additives to make it clean more effectively. As oil circulates the engine, it traps impurities that can cause overheating and premature wear. Foreign matter at the bottom of the crankcase is evidence that the engine oil is cleaning.

4.1.1 Oil Level Indicator

The oil level indicator is a rod known as a dipstick. The dipstick extends through a tube into the crankcase (*Figure 2-33*). Marks on the dipstick indicate when the crankcase is full or, if low, how much oil is needed. You should perform the following procedure to take oil level readings:

NOTE

Before performing these steps, ensure that the vehicle is parked on a flat surface.

Step 1. Pull the dipstick out.

Step 2. Wipe the dipstick with a rag.

Step 3. Stick the dipstick back in.

Step 4. Pull the dipstick out once again. Viewing it flat across from you, note how high the oil level is on the dipstick.

Figure 2-33 – Oil level indicator.

Some engines must cycle a few minutes before the oil level can be accurately measured. However, it is a good practice to check and make sure there is oil in the crankcase, then follow the manufacturer's recommendations.

4.1.2 Full-Flow Filtering System

The full-flow filtering system allows all the oil to flow through a filter before it reaches the engine (*Figure 2-34).* Full-flow filter systems are equipped with a bypass valve. When the filter element becomes clogged, this relief valve allows oil to bypass the element and circulate the system. This prevents the engine from being deprived of oil.

4.1.3 Oil Filters

Oil filters remove most of the impurities trapped by oil. Cartridge filters and sealed "spin-on" filters are commonly used.

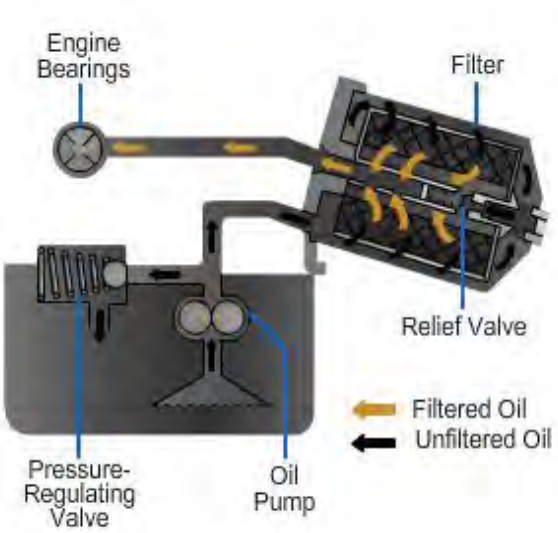


Figure 2-34 – Full-flow system.

Cartridge Filter – The cartridge filter (*Figure 2-35*) is a removable pleated-paper element supported by a center tube. It fits into a metal housing bolted onto the engine. Oil enters from the outside of the filter element and passes through the center tube, where it exits.

Sealed “Spin-On” Filter – The sealed “spin-on” filter (*Figure 2-35*) is directly attached to the engine by a threaded fitting. The term “spin-on” refers to the way it is installed. The spin-on filter operates in the same manner as cartridge filter; however, it is deposed of as a whole unit.

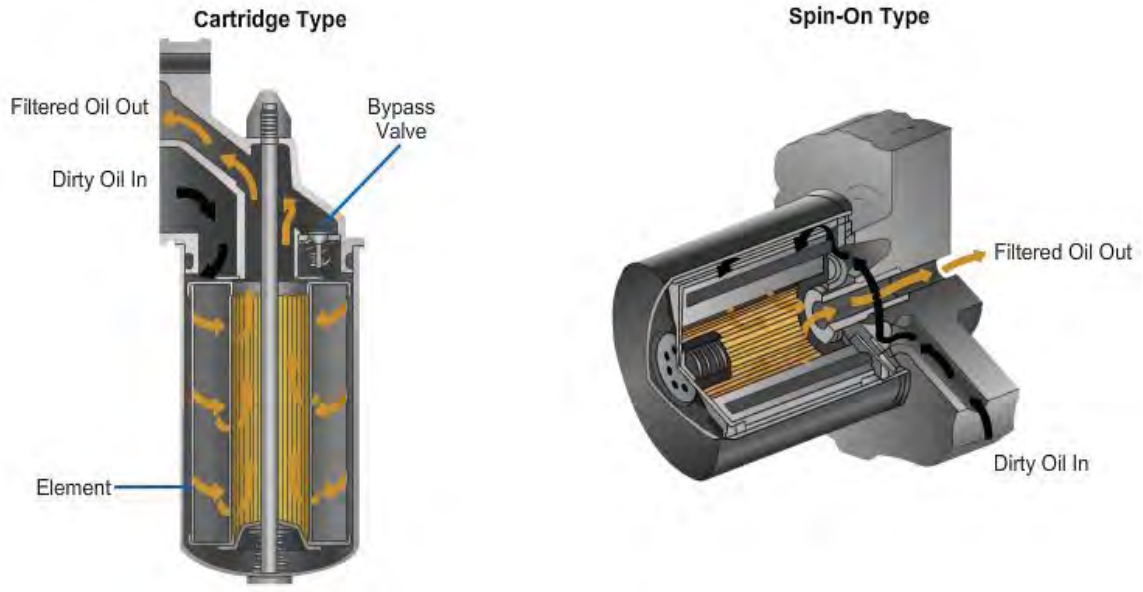


Figure 2-35 – Oil filters.

4.2.0 Hydraulic Fluid

Hydraulic systems need lubrication as well. Hydraulic fluid is used on parts that steer, lift, and push. Most hydraulic fluids are water-based, petroleum-based, or synthetic-based.

CAUTION

Consult the operator’s manual for the correct type of hydraulic fluid before applying. The incorrect type can contaminate the hydraulic system, requiring the system to be drained, flushed, and refilled with the correct fluid.

4.3.0 Gear Oil

Gear oil is used on transmissions, the system of gears that provide the mechanical advantage that drives the vehicle. Gear oil reduces friction and does not breakdown at high temperatures.

CAUTION

Consult the operator’s manual for the correct type of gear oil before applying. Mixing gear oils may cause the oil to breakdown, leaving gears unprotected.

4.4.0 Grease

Grease is used to lubricate fittings, such as bearings, bushings, and pivot points. It can also be used to seal out dirt and water.

Lithium-based grease is commonly used on equipment. It is water-resistant and has a specific heat capacity.

Grease lube charts are usually mounted on equipment or found in the operator's manual. They identify the location of fittings and how frequently they should be lubricated.

Appling an excessive amount of grease on a piece of equipment can cause seals to blow. It can also attract dirt, which can act as grinding compound on surfaces. Applying too little grease allows metal-to-metal contact, causing hotspots and excessive wear.

Grease guns, like the one shown in *Figure 2-36*, are used to apply grease to inaccessible fittings. Basic issue items on Medium Tactical Vehicles include a grease gun and a flexible adapter. The operator is responsible for greasing equipment. Take care to maintain greasing equipment and keep grease free from debris.

Figure 2-36 – Hand-operated grease gun.

Test your Knowledge (Select the Correct Response)

10. **(True or False)** The sealed filter is deposed of as a whole unit.

    A. True
    B. False

11. **(True or False)** Applying too much grease on a piece of equipment can cause seals to blow.

    A. True
    B. False

5.0.0 COOLING SYSTEMS

Internal combustion engines are equipped with a cooling system because of the heat they generate during operation. The temperature in the combustion chamber can be greater than the melting point of iron. Without a cooling system, valves can burn, lubricant oils can breakdown, and bearing and pistons can overheat. At the same time, the engine must not run too cold. A cold engine does not burn all the fuel taken into the combustion chamber, which can cause the formation of carbon deposits, reducing engine power and fuel mileage.

The cooling system removes unwanted heat, helps the engine warm-up to its normal operating temperature as soon as possible, and keeps the engine at a constant temperature. There are two types of engine cooling systems: liquid-cooling and air-cooling.

5.1.0 Liquid-Cooling System

The liquid-cooling system is the most popular type of cooling system on vehicles. It consists of coolant, a radiator, water pump, hoses, fan and shroud, thermostat, and a system of jackets and passages in the cylinder head and block. Engine parts are cooled by keeping coolant circulating and in contact with metal surfaces (*Figure 2-37*). The water pump draws coolant from the bottom of the radiator, forces it through the jackets and passages, and ejects it into the upper tank of the radiator. The coolant then passes through a set of tubes and fins, until it gets to the bottom of the radiator, where the cooling cycle begins. The radiator is situated in front of a fan that is driven by a water pump or an electric motor. The fan ensures airflow to the radiator when the vehicle is not in motion. A thermostat controls the amount of coolant that enters the radiator.

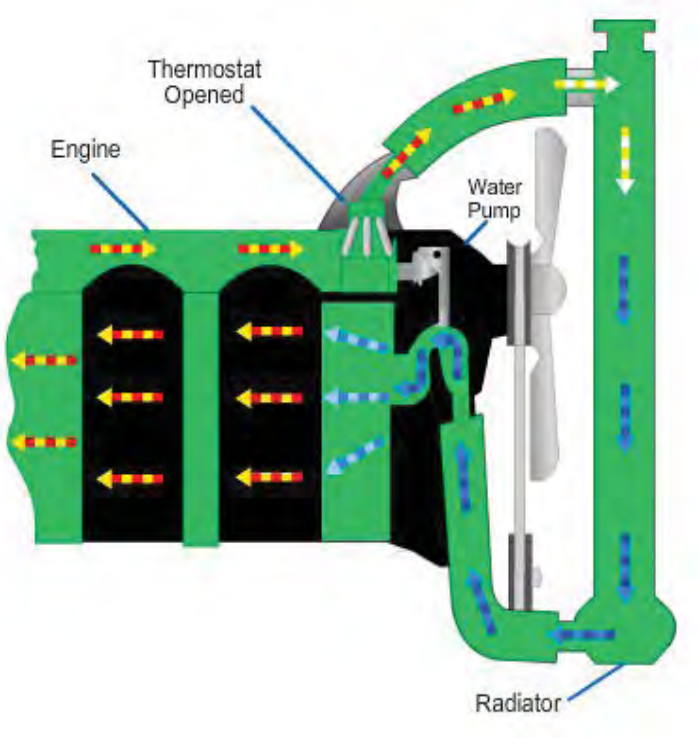


Figure 2-37 – Liquid-cooling system.

5.1.1 Coolant and Antifreeze

Water has served as a basic coolant for years because it is cheap, easily obtained, and has the ability to transfer heat; however, the physical properties of water limit its usefulness as a coolant. These physical properties include water's boiling point, freezing point, and natural corrosive action on metal. Antifreeze is added to water to counteract these properties.

Antifreeze is manufactured under many different trade names. The most commonly used type of antifreeze is ethylene glycol, a chemical compound of ethylene and glycerin derivatives. Ethylene glycol is an ideal coolant because it is nonflammable, has a very high boiling point, and does not evaporate easily. Maximum freezing protection is achieved by mixing 60% ethylene glycol with 40% water. This mixture protects the cooling system from temperatures as low as minus 62°F.

WARNING

Coolant is highly toxic when ingested. It should be properly disposed of to prevent poisoning children and animals.

5.1.2 Radiator

The radiator (*Figure 2-38*) is a heat exchanging device mounted on the front end of vehicles. Most are designed with a top and bottom tank. The top tank has an outside pipe, known as the inlet, directly connected to the engine. The bottom tank has outside pipe, known as the outlet, connected to the water pump. Between the tanks is a heat exchanging core consisting of thin tubes and fins.

On a vertical flow radiator, coolant enters the inlet on the top tank, flows down the exchanging core, and exits the radiator at the bottom tank.

Figure 2-38 – Radiator.

Radiator Pressure Cap – The radiator pressure cap is used on nearly all modern engines. It allows a certain amount of pressure to develop within the cooling system. The pressure raises the coolant's boiling point, approximately 3 degrees for every 1 pound of pressure. This allows the engine to operate at a higher temperature without the loss of coolant from boiling.

The radiator pressure cap has two spring-loaded valves. The larger is called the pressure valve. The smaller is called the vacuum valve. When the cooling system exceeds a maximum amount of pressure, usually identified by the manufacturers on the cap, the pressure valve opens and allows coolant to flow through the overflow pipe and into the recovery tank (*Figure 2-39*).

The vacuum valve opens when the pressure in the cooling system drops below the outside air pressure. The vacuum valve draws coolant back into the radiator, preventing the radiator and hoses from collapsing due to atmospheric pressure as the coolant cools (*Figure 2-39*).

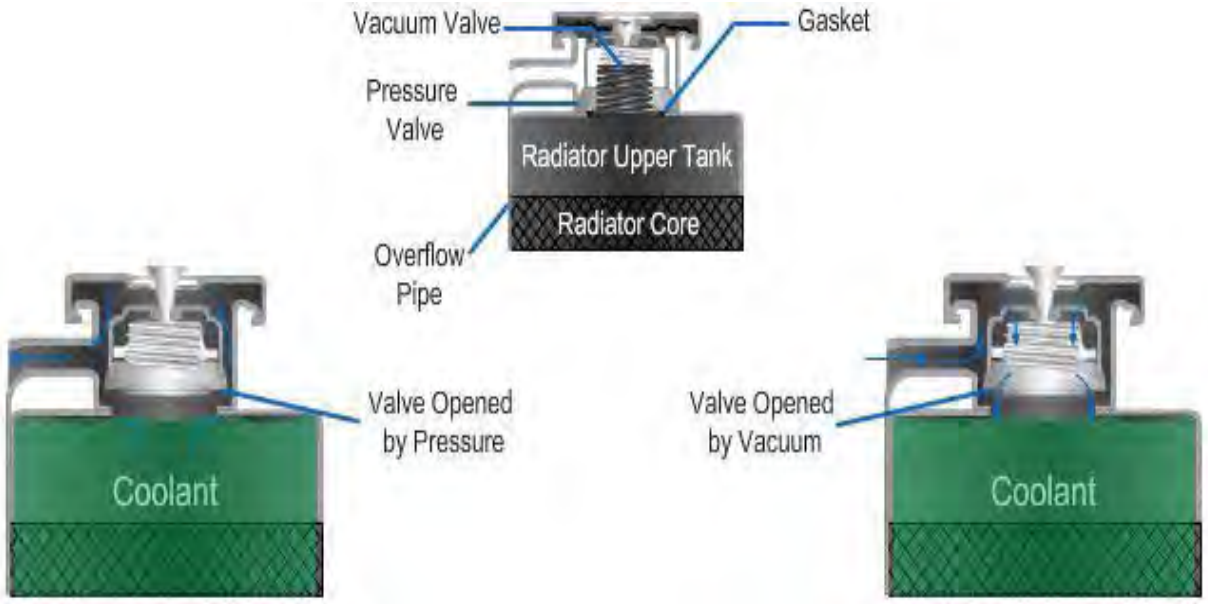


Figure 2-39 – Radiator pressure cap operation.

WARNING

Always remove the radiator cap slowly and carefully. Removing the cap from a hot, pressurized radiator can cause serious burns from escaping steam and coolant.

When performing a pre-start check, inspect the radiator for leaks, particularly where the tanks are soldered to the core. The vibration from pressure can cause fatigue of soldered joints or seams. Bent fins should be straightened, and the radiator core should be inspected for any obstructions that would clog it and reduce its cooling efficiency.

An air hose can be used to clean air passages on a radiator. When using an air hose, apply air in the opposite direction of ordinary airflow. Low-pressured water can also be used to soften obstructions before applying air.

CAUTION

Spraying high-pressured water can cause damage to radiator fins and core.

Radiator hoses and tubing should be inspected for leaks and general condition. In some cases, leaks can be repaired by tightening or replacing the hose clamps. Deteriorated hoses should be replaced to prevent future problems. Hoses can rot from inside, allowing tiny fragments to flow through the system and become lodged in the radiator. For this reason, all old, cracked, or spongy hoses should be replaced as soon as the condition is discovered.

5.1.3 Recovery Tank

The recovery tank serves as a receptacle for coolant forced out of the radiator overflow pipe and provides for its return to the system. As the engine cools, the balancing of pressures causes the coolant to siphon back into the radiator. Cooling systems using a recovery tank are known as closed cooling systems.

5.1.4 Water Pump

The water pump, (*Figure 2-40*) also known as the coolant pump, is the heart of the cooling system. They are cast iron or aluminum housings bolted to the engine block.

As a water pump rotates, coolant is drawn to the center of the pump by suction. The water pump uses centrifugal force created by an impeller with curved blades to push coolant outwards to the engine. The impeller is belt-driven from the crankshaft, and is supported by two sealed bearings.

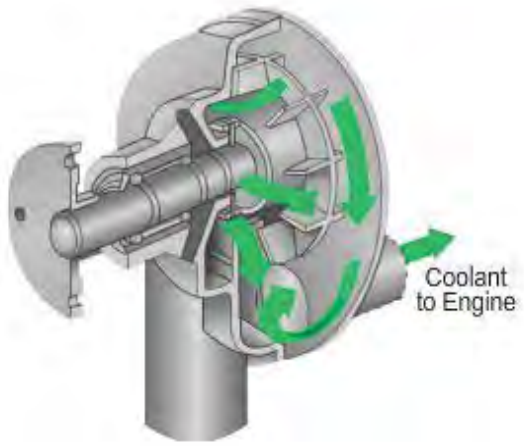


Figure 2-40 – Water pump.

5.1.5 Fan and Shroud

The engine fan is usually mounted on the end of the water pump shaft, so that the same belt that drives the pump also drives the fan. The fan pulls a large volume of air through

the radiator to aid in heat transfer at low speed. In addition to transferring the heat, the fan also cools the engine.

On some construction equipment, such as dozers and track loaders, the fan blows air through the radiator vice pulling the air. Besides cooling the water, the blowing of air keeps sand, dirt, and debris out of the radiator. Some engines are equipped with a shroud that improves fan efficiency by assuring that all the air handled by the fan passes through the radiator.

Fan blades are spaced at intervals around the fan hub to aid in controlling vibration and noise. They are often curled at the tip to increase their ability to move air. Except for differences in location around the hub, most blades have the same pitch and angularity.

Bent fan blades are a common problem. They cause noise, vibration, and excess wear on the water pump shaft. Visual inspection of the fan blades, pulleys, pump shaft end play, and drive belts are part of preventive maintenance. A bent or distorted fan or one with a loose blade should be replaced. When the fan is merely loose on its mounting, tightening is in order. Loose fan belts can be adjusted for proper tension, usually by adjusting the generator or alternator on its mounting (*Figure 2-41*).

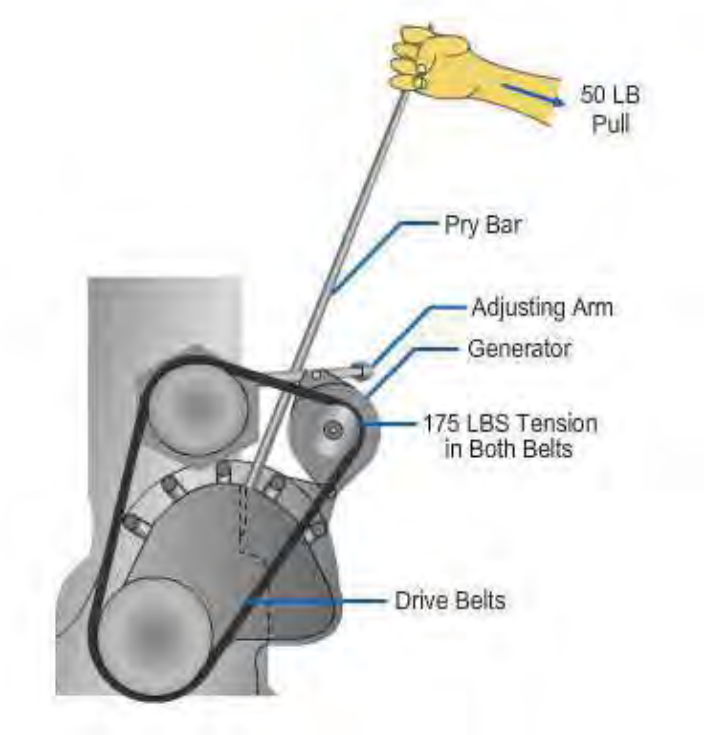


Figure 2-41 – Drive belt adjustment.

A common method for measuring belt tension is to press down on the belt at a point midway between the generator or alternator and the fan pulley, and measure the amount of deflection. The amount of deflection varies and should be set to the manufacturer's specification. A ***rule of thumb*** used in the NCF for belt tension is no more than a one-half inch deflection.

5.1.6 Water Jacket

The passages in the cylinder block and head are referred to as a water jacket. The water jacket does not carry water. Instead, it controls the circulation of coolant and provides proper cooling throughout the engine. The engine's hottest parts, such as the valves and cylinder walls, are surrounded by a water jacket.

5.1.7 Thermostat

Automatic control of the temperature of an engine is necessary for efficient engine performance and economical operation. Since all engine parts are in a contracted state when cold, the engine temperature should be brought to normal as quickly as possible. The water pump starts coolant circulating the moment the engine is started, which is undesirable during cold weather operations. Coolant circulation is restricted by the installation of a thermostatically controlled valve, or thermostat, between the cylinder head and the radiator top tank. This valve allows coolant to circulate freely only within the block until the desired temperature is reached. This shortens the warm-up period. A bypass is used to direct the water from the block to the pump when the passage to the radiator is blocked by the closed thermostat (*Figure 2-42*).

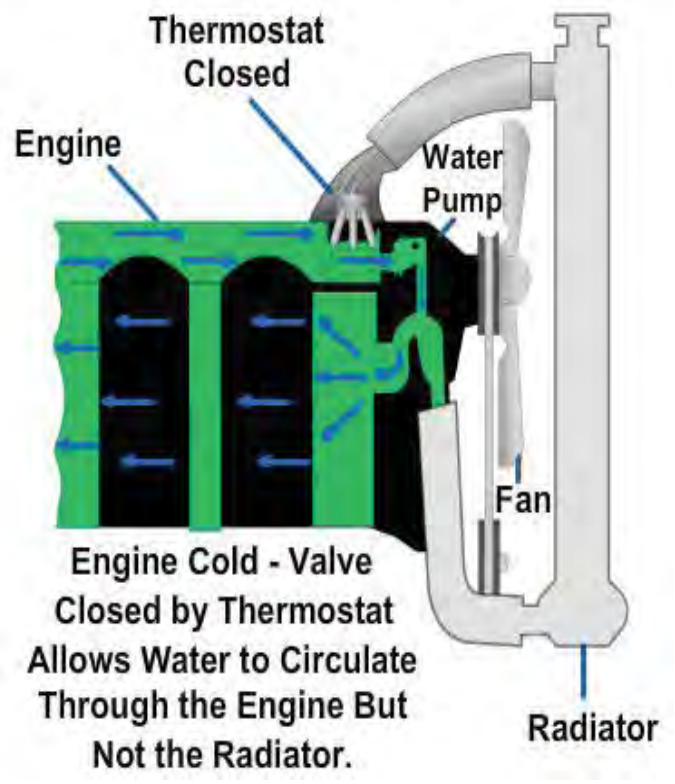


Figure 2-42 – Closed thermostat.

Some stationary engines and large trucks are equipped with shutters that supplement the action of the thermostat in providing faster warm-up and maintaining proper operating temperatures. When the engine coolant is below a predetermined temperature, between 185°F to 195°F, the shutters, located in front of the radiator, remain closed and restrict the flow of air through the radiator. As the coolant reaches proper temperature, the shutters start to open.

5.1.8 Expansion Tank

Some engines use an expansion tank in their cooling system (*Figure 2-43*). The expansion tank is mounted in series with the upper radiator hose and is used to supply extra room for coolant expansion and generally takes the place of the upper radiator tank. The pressure cap and the overflow line are also mounted on the expansion tank.

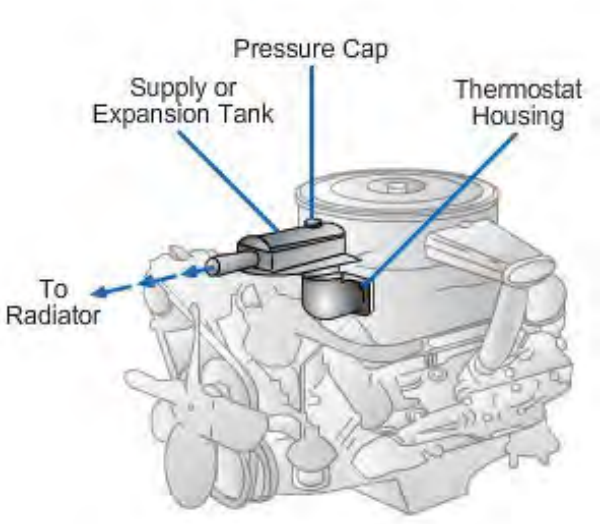


Figure 2-43 – Expansion tank.

5.2.0 Air-Cooling System

The air-cooling system is the simplest and quickest way to cool an engine. Air is supplied by forward vehicle movement. A

fan is also used to cool the engine by drawing off heat.

The rate of cooling depends on many factors, such as the area exposed to the cooling air, the heat conductivity of the engine metal, the amount of airflow, and the difference in temperature between the engine metal and the incoming airflow. Some heat must be retained for efficient operation. This is accomplished by the use of thermostatic controls and mechanical linkage that open and close shutters to control the volume of cooling air. Air-cooled engines generally operate at a higher temperature than liquid-cooled engines, whose operating temperature is largely limited by the boiling point of the coolant used. Consequently, greater clearances must be provided between the moving parts of air-cooled engines to allow for the increased expansion.

In air-cooled engines, the cylinders are mounted independently to the crankcase so that an adequate volume of air can circulate directly around each cylinder. The circulating air absorbs excessive amounts of heat from the cylinders and maintains enough cylinder head temperatures for satisfactory operation. The cooling action is based on the simple principle that the surrounding air is cooler than the engine heat.

The primary components of an air-cooled system are the fan and shroud and the baffles and fins. A typical air–cooled engine is shown is *Figure 2-44*.

Figure 2-44 – Air-cooled engine.

5.2.1 Fan and Shroud

Most air-cooled engines must have fans or blowers to circulate a large volume of air over and around the cylinder. These fans are built into the engine flywheel (*Figure 2-44*). When the engine is assembled, a shrouding, or cowling forms a compartment around the engine so that the cooling air is properly directed for effective cooling. Some air-cooled engines, such as those used on motorcycles and outboard engines do not require the use of fans or shrouds. Their engines are adequately cooled by the airflow created by forward movement.

5.2.2 Baffles and Fins

Some engines use baffles to redirect cool air towards engine parts that are not in the direct path of airflow. Most baffles are made of light metal and are semicircular with one edge in the stream of air.

Other types of air-cooled engines use fins. Fins are thin, raised projections on the cylinder barrel and head. They provide more cooling area and aid in directing airflow. Heat, resulting from combustion, passes by conduction from the cylinder walls and cylinder head to the fins and is carried away by the passing air.

Test your Knowledge (Select the Correct Response)

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

    A. True
    B. False

13. 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

14. What is the function of the water jacket?

    A. Control the circulation of coolant
    B. Control the circulation of water
    C. Control the temperature of the coolant
    D. Decrease the temperature of the coolant

Summary

This chapter not only described engine systems, it also explained the harsh effects that can occur if they not routinely cared for. By simply inspecting and replenishing coolant and oil levels, applying an adequate amount of grease, and inspecting a radiator, an operator can prevent major engine problems and extend the life of a piece of equipment.

Review Questions (Select the Correct Response)

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

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

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

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

3. **(True or False)** The connecting rod transmits the reciprocating motion of the cylinder to the crankshaft.

   A. True
   B. False

4. **(True or False)** Most engines operate on a four-stroke cycle.

   A. True
   B. False

5. 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

6. In a diesel engine, to what volume is the fuel and air mixture compressed?

   A. One eight
   B. One fifteenth
   C. One twentieth
   D. One twenty-fifth

7. In a four-stroke diesel engine, where does air and fuel mix?

   A. In the combustion chamber
   B. In the injection chamber
   C. In the catalytic convert
   D. In the intake manifold

8. **(True or False)** A diesel engine has a greater torque than a gasoline engine because of the power developed from the low-compression ratio.

   A. True
   B. False

9. The two-stroke diesel engine uses what method to force air in, and exhaust gases out of the cylinder?

   A. Supercharging
   B. Turbocharging
   C. Scavenging
   D. Blowing

10. **(True or False)** In a two-stroke cycle diesel engine, if the exhaust valve opened in the middle of the intake stroke, the piston would draw burnt gases into the combustion chamber.

    A. True
    B. False

11. In a two-stroke cycle diesel engine, what part of the camshaft contacts the bottom of the lifter?

    A. Cam bearing
    B. Cam valve tappet
    C. Cam timing gear
    D. Cam lobe

12. Which of the following is NOT a function of the fuel injection system?

    A. Deliver proper amount of pressurized fuel
    B. Control the fuel-air ratio
    C. Atomize fuel
    D. Automatically refuel

13. Most fuels are compounds of _____ and _____.

    A. hydrogen/carbon
    B. sodium/aluminate
    C. hydrogen/sulfide
    D. carbon/dioxide

14. What type of pollution is emitted into atmosphere by engines using leaded gasoline?

    A. Hydrocarbons
    B. Sodium aluminate
    C. Hydrogen sulfide
    D. Carbon dioxide

15. What number designator is used to identify gasoline's ability to burn evenly and resist spontaneous combustion?

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

16. As exhaust passes through the catalytic converter, what chemical compounds are produced?

    A. Nitrates and ketones
    B. Hydrogen sulfide and carbon monoxide
    C. Carbon dioxide and water
    D. Sulfur dioxide and acetones

17. **(True or False)** Catalytic converters are designed to convert the exhaust gases formed from the combustion of leaded gasoline.

    A. True
    B. False

18. **(True or False)** Diesel fuel can hold dirt particles in suspension longer than gasoline because it is heavier and thicker.

    A. True
    B. False

19. What supervisor approves the use of Jet-A1 and JP-5 as fuel?

    A. Maintenance
    B. Transportation
    C. Project
    D. Light Shop

20. When jet fuel is used in a diesel engine, what ingredient is added to improve lubricating qualities?

    A. Hydraulic fluid
    B. Engine oil
    C. Power steering fluid
    D. Drive line oil

21. **(True or False)** In diesel engines, the fuel that is transferred by the electric pump moves through a filter and then to the fuel injection housing manifold.

    A. True
    B. False

22. **(True or False)** The fuel filter operates by passing fuel through a porous element.

A. True
B. False

23. What is the purpose of the primary fuel filter on a diesel engine?

A. Remove all foreign matter
B. Remove fine particles
C. Remove the air deposits
D. Remove large particles

24. Which of the following is NOT a function of the air intake system?

A. Supply air
B. Control the fuel-air mixture
C. Clean air
D. Function as a silencer

25. What drives the turbine wheel on a turbocharger?

A. Exhaust gases
B. A drive belt
C. A pump
D. Fuel-air mixture

26. Dry-element air cleaners provide _____ and _____.

A. dry-cleaning and filtering
B. pre-cleaning and filtering
C. wet-cleaning and filtering
D. pre-cleaning and discharging

27. What creates the centrifugal force in the air cleaner with a dust cup?

A. A metal shield
B. Titled fins
C. A pump
D. A propeller

28. Who is responsible for inspecting and cleaning air cleaners?

A. The Mechanic
B. The Washrack Custodian
C. The Yard Boss
D. The Operator

29. Which of the following procedures is used to clean an air filter element?

A. Apply high-pressured air
B. Tap the filter on the heel of your hand
C. Apply high-pressured water
D. Tap the filter on the tire of a vehicle

30. What supervisor approves the washing of filter elements?

A. Transportation
B. Maintenance
C. Light Shop
D. 5000 Shop

31. What happens to the larger dirt particles that are drawn through an oil bath cleaner?

A. Remains trapped in the filter element
B. Remains trapped in the dust cup
C. Remain trapped in the oil
D. Remain trapped in the dust unloading valve

32. Which of the following is NOT a function of the lubrication system?

A. Reduce friction
B. Absorb heat
C. Clean engine
D. Strengthen engine parts

33. **(True or False)** The bypass valve prevents the engine from being deprived of grease.

A. True
B. False

34. What oil filter fits into a metal housing that is bolted onto the engine?

A. Pre-cleaner filter
B. Cartridge filter
C. Sealed filter
D. Spin on filter

35. Which of the following is NOT a common type of hydraulic fluid?

A. Water-based
B. Petroleum-based
C. Lithium-based
D. Synthetic-based

36. **(True or False)** Grease lube charts identify the location of grease fittings and how frequently they should be lubricated.

A. True
B. False

37. Who is responsible for greasing equipment?

A. The Yard Boss
B. The Operator
C. The Grease Rack Custodian
D. The Company Clerk

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

A. True
B. False

39. Which of the following is NOT a property of water that limits its usefulness as a coolant?

A. Boiling point
B. High surface tension
C. Freezing point
D. Natural corrosive action on metal

40. The pressure in the cooling system raises the coolant's boiling point how many Fahrenheit degrees for every 1 pound of pressure?

A. 12
B. 9
C. 3
D. 6

41. In the NCF, what is the rule of thumb for fan belt tension?

A. No more than 1 inch defection
B. No more than ¾ inch defection
C. No more than ½ inch defection
D. No more than ¼ inch defection

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

A. The shutter
B. The overflow tank
C. The water jacket
D. The thermostat

43. **(True or False)** The expansion tank is mounted in series with the lower radiator hose and is used to supply extra room for coolant expansion.

A. True
B. False

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

A. The incoming airflow is cooler than the engine metal.
B. The incoming airflow is cooler than the coolant.
C. The incoming airflow is easier to control than coolant.
D. The engine metal is easier to control by the use of surrounding air.

45. Which of the following provides more cooling area and aids in directing airflow?

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

Trade Terms Introduced in This Chapter

Centrifugal	An outward force exerted by a body moving in a curved line. It is the force that tends to tip a car over in going around a curve.
Electronic control module (ECM)	A computer in a vehicle, used for specific systems.
Reciprocating motion	An up and down or back-and-forth motion.
Rotary motion	A circular motion.
Rule of thumb	A statement or formula that is not exactly correct but is accurate enough for use in rough figuring.

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.

Auto Engine Performance and Driveability, The Goodheart-Willcox Company, Inc., Tinley Park, Illinois, 2004.

Construction Mechanic Basic, Volume 1, NAVEDTRA 14264, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1999.

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Principles of Automotive Vehicles, TM 9-8000, Headquarters, Department of the Army, Washington, DC, 1988.

Principles of Gasoline and Diesel Fuel Systems, Subcourse OD1620, U.S. Army Correspondence Course Program, USA Ordnance Center and School, Aberdeen Proving Ground, MD, 1991.

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Chapter 3

Power Train

Topics

1.0.0 Transmissions

2.0.0 Propeller Shaft Assemblies

3.0.0 Final Drives

To hear audio, click on the box. 

Overview

On vehicles and construction equipment, the power train transmits engine power to the wheels or tracks. In a simple application, such as a stationary engine-powered ***hoist***, a set of gears could perform this task. However, the vehicles and construction equipment that you operate were designed for rigorous applications. They were designed to provide pulling power, move at high speed, travel in reverse as well as forward, and operate on rough terrain as well as smooth roads. For these applications, power trains are equipped with a variety of components, including transmissions, propeller shaft assemblies, and final drives. This chapter covers the basic principles of such components.

Objectives

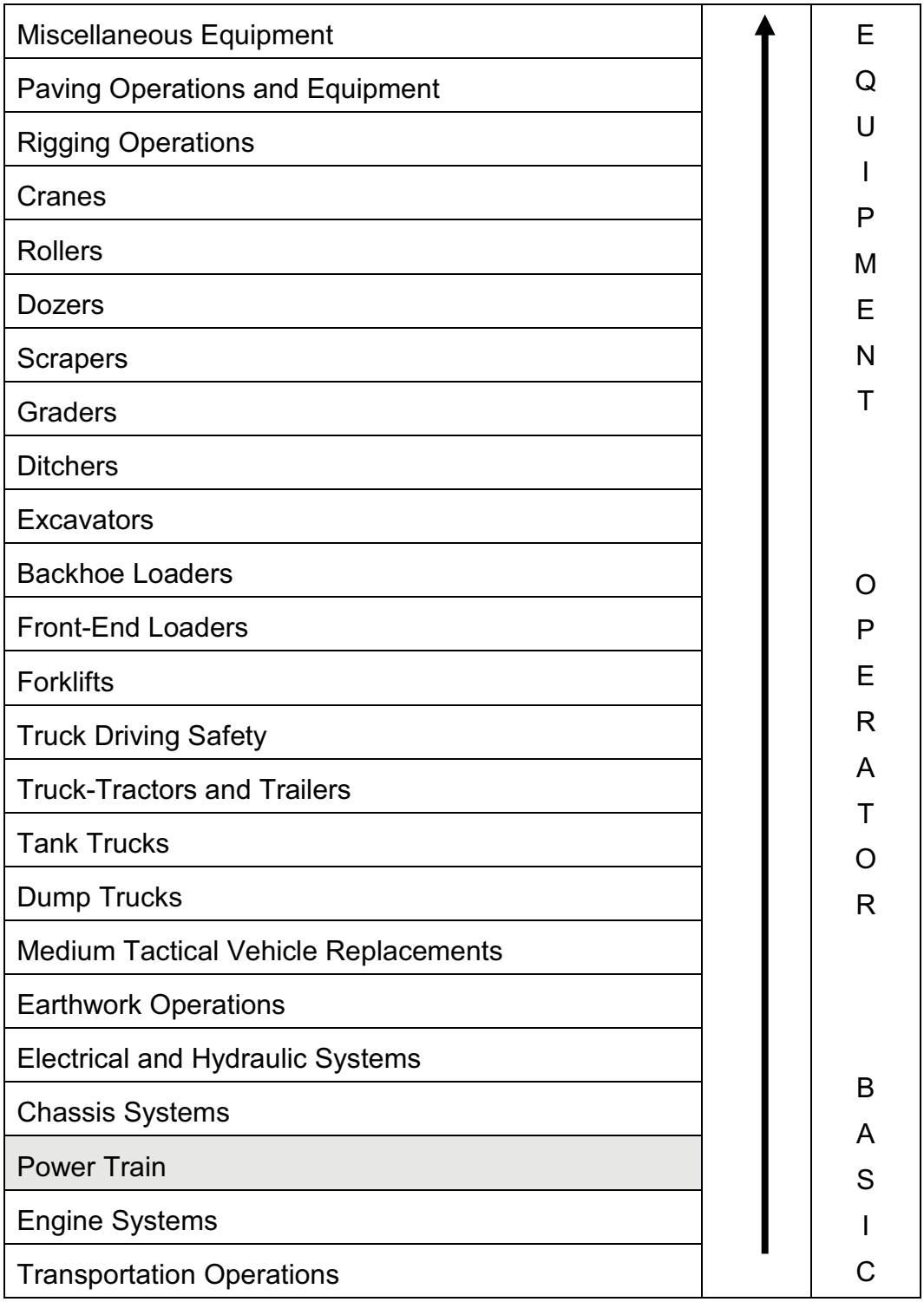
When you have completed this chapter, you will be able to do the following:

1. Understand the principles of transmissions.
2. Understand the principles of propeller shaft assemblies.
3. Understand the principles of final drives.

Prerequisites

None

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



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 TRANSMISSIONS

The transmission, also known as the “gearbox”, is a major part of the power train (*Figure 3-1*). It is a system of gears located behind the engine between the clutch housing and the propeller shaft. The transmission provides the mechanical advantage that enables the engine to drive the vehicle. It also allows the operator to control the engine power and speed of the vehicle.

The Naval Construction Force (NCF) has vehicles and construction equipment equipped with manual and automatic transmissions. In addition, some of these vehicles and construction equipment have auxiliary transmissions.

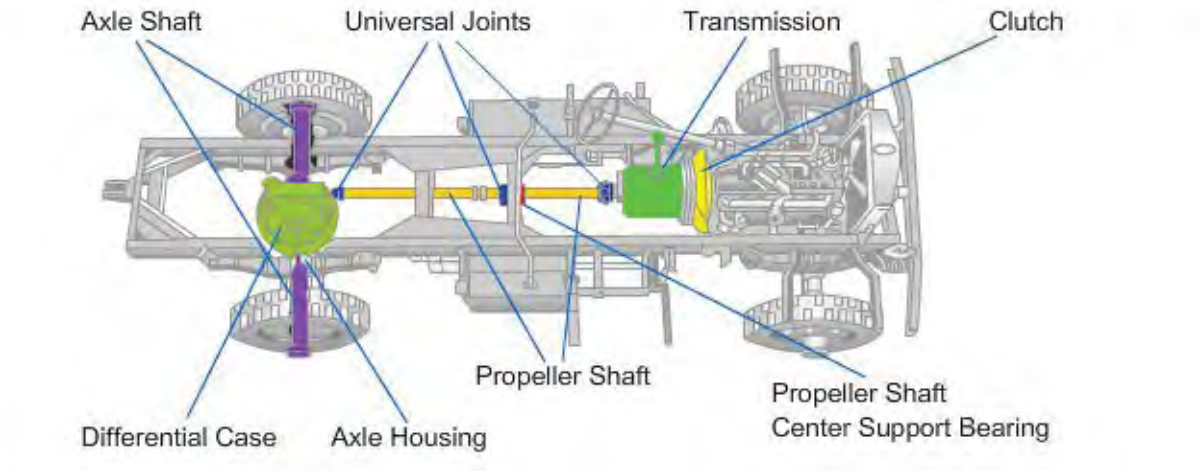


Figure 3-1 – Typical power train.

1.1.0 Manual Transmission

The manual transmission is designed with two purposes in mind. One is to provide the operator the option of maneuvering the vehicles in either forward or reverse direction. This is a basic requirement of all vehicles. Almost all vehicles have multiple forward gear ratios but, in most cases, only one reverse gear ratio. Gear ratio is the number of times a driving gear must rotate to turn the driven gear.

Another purpose of the manual transmission is to provide the operator a selection of gear ratio between the engine and wheels, so that the vehicle can operate under a variety of operating conditions and loads. If in a proper operating condition, a manual transmission should do the following:

- Increase ***torque*** going to the rear wheels for quick acceleration.
- Supply different gear ratios to match different engine load conditions.
- Have a reverse gear ratio for moving the vehicle backwards.
- Provide the operator an easy means of shifting transmission gears.
- Operate quietly with minimum engine power loss.

The manual transmission is often referred to as “stick shift” because the operator shifts gears using a manual control lever, called a gear-shift lever, and a clutch pedal.

1.1.1 Clutch

The clutch is the first power train component. As shown in *Figure 3-1*, the clutch is located between the engine and the transmission. When an operator shifts gears, it is used to temporarily disconnect the engine and the transmission. After shifting, it re-connects the engine and the transmission.

Single-Disc Clutch – The single disc clutch is common in NCF's vehicles and construction equipment. It is called a dry clutch because instead of using oil like other types of clutches, it uses friction to operate.

The driving members of the single-disk clutch consist of the flywheel and the pressure plate. The pressure plate is spring loaded and bolted to the engine flywheel. The driving members are attached to the engine crankshaft and transfer engine power to the driven member.

The driven member consists of a clutch disc, faced on both sides with friction material and ***splined*** to the clutch shaft. *Figure 3-2* shows the driving and driven members of a single-disc clutch.

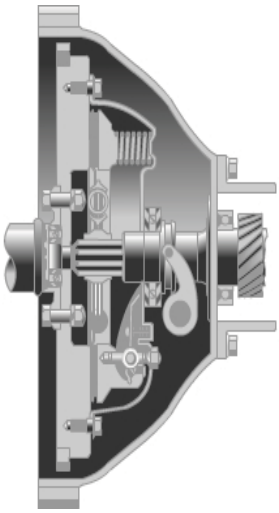


Figure 3-2 – Single-disc clutch.

When there is no pressure on the clutch pedal, the spring action of the pressure plate firmly clamps and holds the clutch disc against the flywheel. This results in a direct, non-slipping connection between the driving and driven clutch members. The clutch disc rotates the clutch shaft which is attached to the transmission input shaft. In this position, the clutch is fully "engaged"; the transmission transfers power flow to the wheels.

When there is pressure on the clutch pedal, the pressure plate pulls away from the clutch disc, releasing the disc from the flywheel. This results in a disconnection between the driving and driven clutch members. The engine crankshaft is able to turn without rotating the driven members. Because of the disconnection, the transmission is no longer transferring power flow to the wheels. In this position, the clutch is "disengaged", and the operator is able to shift gears. *Figure 3-3* shows the operation of a clutch.

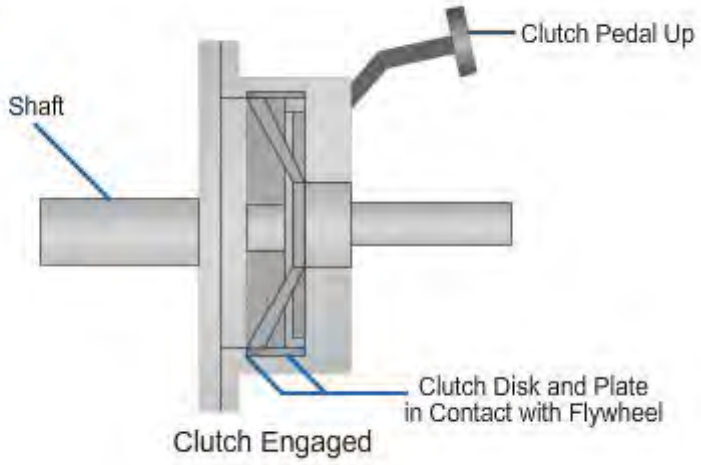


Figure 3-3 – Clutch in operation.

During vehicle operation, several clutch troubles may occur, including:

- clutch slipping, ***clutch chatter***, or grabbing when engaging;
- spinning or dragging when engaged;
- clutch noises, ***stiff clutch pedal***, and ***mushy shift***.

These troubles must be documented and reported to maintenance for repairs.

1.1.2 Synchromesh Transmission

The synchromesh transmission (*Figure 3-4*) is the most common type of manual transmission. It has parallel shafts with gears in constant mesh. Shifting is done by locking free-running gears to their shaft by using sliding collars. This type of manual transmission has an extra device, called a synchronizer. The synchronizer accelerates or slows down the rotation of the shaft and gear, until both are rotating at the same speed and can be locked together without a gear clash. The synchronizer is used in most manual transmissions and is common in equipment that requires shifting while moving.

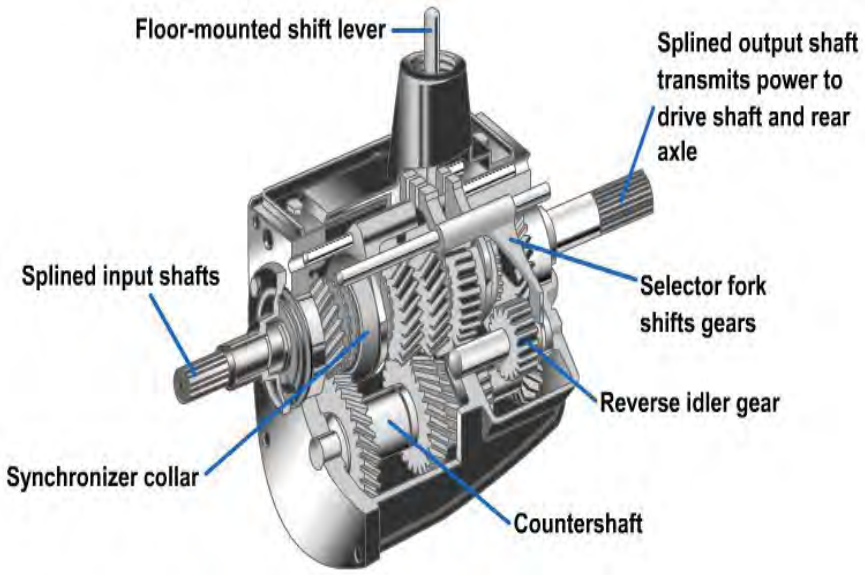


Figure 3-4 – Synchronizer transmission.

1.1.3 Non-Synchronized Transmission

The non-synchronized transmission is commonly seen in older vehicles. This type of manual transmission brings the teeth of the driving and driven gears to the same speed. Vehicles with non-synchronized transmissions require double-clutch shifting to permit proper engagement of the gears and prevent momentum loss.

1.1.4 Manual Shift Operation

To be a great Equipment Operator, you must be able to manual shift properly. Poor manual shifting can cause poor vehicle performance and vehicle damage.

The following are proper steps for clutch shifting and double-clutch shifting.

Clutch Shifting – After you have performed a pre-start check on the vehicle and you are acquainted with its instruments and controls, warm the engine with the transmission in neutral. Follow the steps below to move the vehicle.

Step 1. With your left foot, depress the clutch pedal and shift into low or first gear.

Step 2. Check the mirrors, check blind spots, and give signals as required.

Step 3. Begin to release the clutch pedal, pausing at the friction point (approximately the halfway point between the clutch being fully depressed and being released) or when you feel it taking hold. Recheck the mirrors for traffic.

Step 4. Release the parking brake and slowly release the clutch pedal, at the same time, slightly depress the accelerator.

Step 5. When driving operation is under way, remove your foot completely from the clutch pedal.

Double-Clutch Shifting – Follow these steps to shift to a higher gear.

Step 1. Release the pressure on the accelerator as you begin depressing the clutch pedal.

Step 2. When the clutch pedal is fully depressed, move the gear-shift lever to the neutral position.

Step 3. Release the clutch pedal.

Step 4. When the proper rpm for the next higher gear is reached, depress the clutch pedal again.

Step 5. While the pedal is depressed, move the gear-shift lever to the next higher gear.

Step 6. Release the clutch pedal and, at the same time, depress the accelerator

Double-Clutch Shifting – Follow these steps to shift to a lower gear.

Step 1. Release the pressure on the accelerator as you begin depressing the clutch pedal.

Step 2. When the clutch pedal is fully depressed, move the gear-shift lever to the neutral position.

Step 3. Release the clutch pedal and, at the same time, depress the accelerator to speed up the engine.

Step 4. Let up on the accelerator and depress the clutch pedal.

Step 5. While the pedal is depressed, move the gear-shift lever to the next lower gear.

Step 6. Release the clutch pedal and, at the same time, depress the accelerator to maintain engine speed as the engagement of the clutch again connects the load to the engine.

NOTE

The steps for shifting to a lower gear is the same as shifting to a higher gear; except, when shifting to a lower gear the engine is accelerated while the transmission is in neutral.

Figure 3-5 shows the elements of shifting.

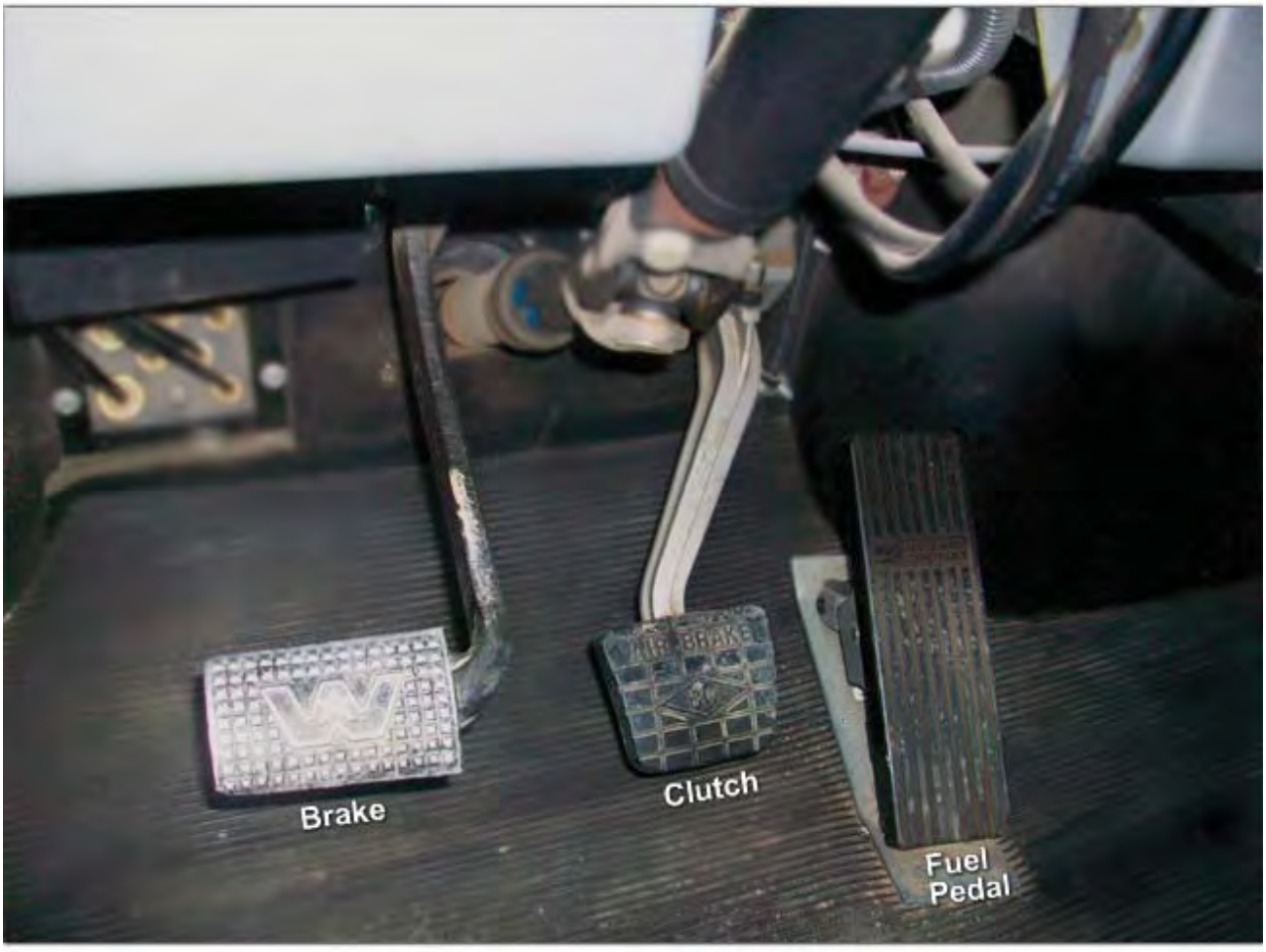


Figure 3-5 – Elements of shifting.

When performing the steps provided above, you should know the vehicle's shift pattern so well that you can shift gears without looking at the gear-shift lever. The shift pattern is usually shown in the vehicle or operator's manual. Remember to move the gear-shift lever only when you have fully depressed the clutch pedal. To shift gears smoothly and quietly, keep the pedal fully depressed until the shift has been completed.

In addition, learn when to disengage the clutch and the amount of free play in the clutch pedal. Free play is the amount of pedal movement possible at the top of the stroke without engaging or disengaging the clutch.

Recognizing any changes in free play is important. As the clutch surfaces wear, free play diminishes, until the clutch cannot fully engage, resulting in slippage, overheating

and rapid wear. Routine inspection of free play is necessary to ensure full engagement of the clutch.

Remember to keep your foot off the clutch pedal at all times except when starting, stopping, or shifting gears. Slight constant pressure on the clutch pedal can cause excessive wear. For this reason, when stopped on a hill, you should use the brakes to keep from rolling backwards.

While waiting for a long traffic light or halted for other reasons, depressed the clutch pedal and shift the transmission gear-shift lever into neutral. After shifting into neutral, release the clutch pedal.

When slowing your vehicle to stop or make a turn, always downshift as you stop. Coasting at a high speed rate with the clutch pedal depressed is dangerous and abusive to the vehicle. This practice makes controlling the vehicle difficult and can damage to the clutch.

CAUTION

When you are shifting gears in rough terrain and on hills, never let your vehicle slow down to the point the engine begins to labor or jerk before shifting into a lower gear ratio. Always anticipate the need for extra engine power and shift gears accordingly. When descending a hill, with or without a heavy cargo load, always drive with your vehicle in gear and the clutch pedal out.

NOTE

You may encounter vehicles that may have complicated transmissions, such as multi-gear ranges, dual-speed axles, or other special features. You are responsible for reading and understanding the operator's manual before operating any vehicle or equipment.

Provided are some manual transmission troubles that you may encounter and must report to maintenance:

- Hard shifting
- Slipping out of gear
- No engine power through the transmission
- Transmission noisy when in gear
- Gear clash when shifting
- Oil leaks

1.2.0 Automatic Transmission

Like the manual transmission, the automatic transmission (*Figure 3-6*) is designed to match the load requirements a vehicle to the engine power and speed range of its engine. However, unlike the manual transmission, the automatic transmission does not have to be shifted manually. It shifts automatically, depending on throttle position, vehicle speed, and position of the selector lever. Automatic transmissions are used in vehicles that have two to five forward speeds and in some vehicles that are equipped with overdrive. Operator control is limited; the operator selects gear range by moving a transmission selector.

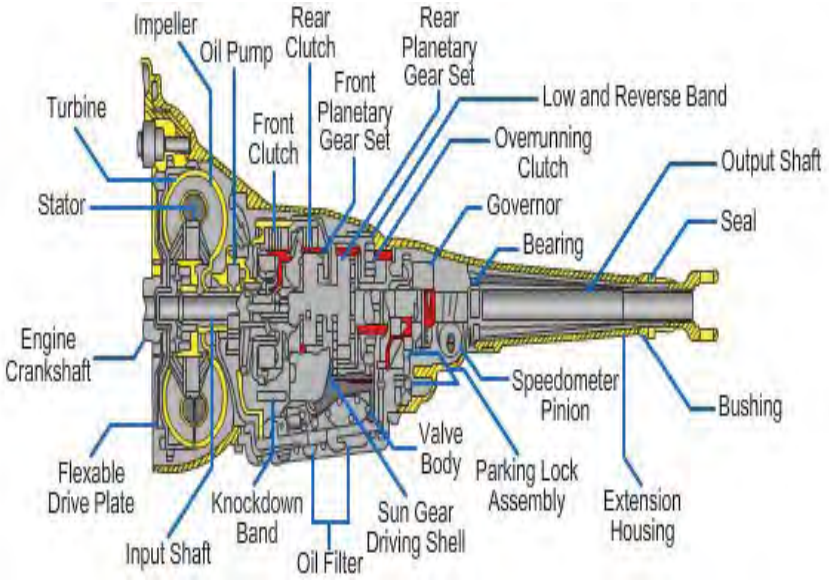


Figure 3-6 – Automatic transmission.

1.2.1 Fluid Coupling

The automatic transmission is coupled to the engine by a torque converter, a type of fluid coupling. A fluid coupling, a device that uses oil to transmit rotating mechanical power, is used as an alternative to the mechanical clutch. It functions by slipping at idling speeds and by holding to increase power as engine speed increases.

The principle of fluid coupling is shown in *Figure 3-7*. As two fans face each other, the speed of rotation of one fan makes the other fan rotate. When the speed of driving fan changes from medium to low, the driven fan loses speed; but, if the fan speed increases from medium to high, the speed of the driven fan picks up.

Figure 3-7 – Principle of fluid coupling.

Torque Converter – The torque converter (*Figure 3-8*) is a modified fluid coupling. It performs the same function as the dry clutch on a manual transmission. Like the dry clutch, the torque converter is located between the engine flywheel and the transmission.

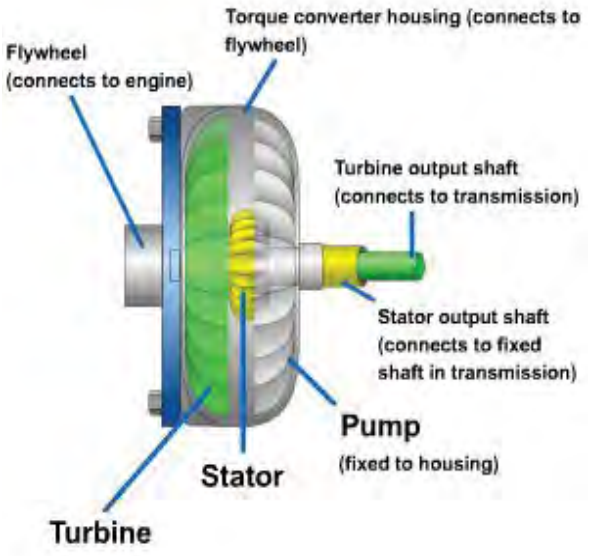


Figure 3-8 – Torque converter.

As shown is *Figure 3-8*, a torque converter has four basic parts:

- Outer housing, normally made of two pieces of steel welded together in a doughnut shape, housing the impeller, stator, and turbine. The housing is filled with transmission fluid (oil).
- Impeller, a driving member that produces oil movement by use of curved vanes, inside the torque converter when the engine is running. It is also called the converter pump.
- Turbine, a driven fan with curved vanes, splined to the input shaft of the automatic transmission. Inside the outer housing, it is located in front of the stator and impeller. It is not fastened to the impeller but instead, free to rotate independently. Oil is the only connection between the two.
- Stator, designed to improve oil circulation inside the torque converter. It increases efficiency and torque by causing the oil to swirl around the inside of the housing. Secured in the outer housing, the stator is located between the impeller and turbine. It acts as a fulcrum (pivot) with curved vanes.

The primary action of the torque converter results from the action of the impeller passing oil at an angle into the blades of the turbine. The oil pushes against the faces of the turbine vanes, causing the turbine to rotate in the same direction as the impeller. When the engine is idling, the impeller spins slowly throwing only a small amount of oil into the stator and turbine. This small amount of oil does not develop enough force inside the torque converter to spin the turbine. The vehicle remains stationary with the transmission in gear. During acceleration, the engine crankshaft, the outer housing, and the impeller begin to move faster. More oil is thrown out by ***centrifugal force***, rotating the turbine. As a result, the transmission input shaft and vehicle start to move, but with some slippage.

At cruising speeds, the impeller and turbine spins at almost the same speed with very little slippage. When the impeller spins fast enough, centrifugal force throws oil out almost hard enough to lock the impeller and turbine. After the oil has imparted its force to the turbine, the oil follows the contour of the turbine shell and vanes, leaving the center section of the turbine spinning counterclockwise. Because the turbine has absorbed the force required to reverse the direction of the clockwise spinning of the oil, it now has greater force than is being delivered by the engine. The process of multiplying engine torque has begun.

The stator is mounted on a one-way clutch that allows it to rotate clockwise but not counterclockwise. The purpose of the stator is to redirect the oil returning from the turbine and change its rotation back to that of the impeller. Stator action is needed only when the impeller and turbine are turning at different speeds. The one-way clutch locks the stator when the impeller is turning faster than the turbine. This causes the stator to route oil flow over the impeller vanes properly. Then, when turbine speed almost equals impeller speed, the stator can freewheel on its shaft so it does not obstruct flow. *Figure 3-9* shows the operation of a torque converter.

Figure 3-9 – Torque converter in operation.

1.2.2 Planetary Gears

A planetary gear system (*Figure 3-10*) is the heart of the automatic transmission. It enables the automatic transmission to use torque efficiently. The planetary gear system consists of three members: the sun gear, ring gear, and planetary pinion with carrier, which holds the planetary gears in proper relation to the sun and ring gear.

The sun gear is in the center of the system. The term planet fits these pinions and gears because they rotate round the sun gear, as shown in *Figure 3-11*. The ring gear, or internal gear, is so-called because of its shape and internal teeth.

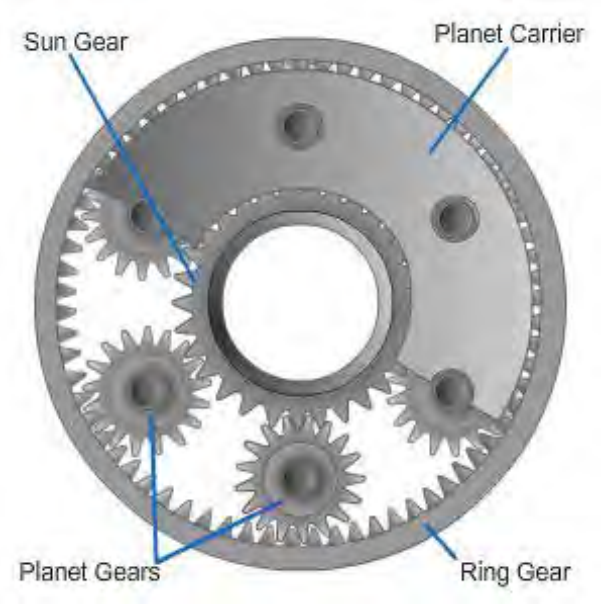


Figure 3-10 – Planetary gear system.

Figure 3-11 – Planetary gear system in operation.

Hydraulic servos and spring pressure hold and release the components of the planetary gear system. By doing so, they make it is possible to do the following:

- Reduce output speed and increase torque (gear reduction).
- Increase output speed while reducing torque (overdrive).
- Reverse output direction (reverse gear).
- Serve as a solid unit to transfer power (one to one ratio).
- Freewheel to stop power flow (park or neutral).

An advantage of the planetary gear system is that it is compact. Additionally, the planetary gear system has more teeth to make contact and carry the load. Usually, each planetary gear meshes with at least two other gears. None of the teeth are damaged as a result of teeth clashing or a partial mesh because the gears are always in mesh. Another advantage is the ease of shifting gears. Planetary gears, set in automatic transmissions, are shifted without any special skill required by the operator.

Power can be transmitted through the planetary gear system in various ways. A shaft from the engine may be connected to drive the sun gear. It may be connected to drive the planet carrier or connected to drive the ring gear. The propeller shaft may also be connected to any one of these members; however, power can be transmitted in the planetary gear system only when:

- The engine is delivering power to one of the three members.
- The propeller shaft is connected to one of the other members, and
- The remaining member is held against rotation.

All three of these conditions must be satisfied for power to be transmitted in the system.

1.2.3 Automatic Transmission Operation

Most automatic transmissions function in the same way. They combine a torque converter with a planetary gear system and control the shifting of the planetary gear with an automatic hydraulic control system. The torque converter is attached to the engine crankshaft and serves as the engine flywheel. This design means that when the engine runs, engine power flows into the converter and drives the converter output (turbine) shaft. There is no neutral in the torque converter. Neutral is provided in the planetary gear system by the release of bands and clutches.

The transmission automatically multiplies and transmits engine torque to the propeller shaft as driving conditions demand. The operator partially controls the speed of coupling and gear shifting. The operator only has partial control in the drive position, because the transmission shifts the planetary gear system into the higher gears to prevent engine overspeeding regardless of throttle position.

The operation of automatic shift vehicles is quite simple; however, professional operators must learn to operate them smoothly and properly.

In vehicles equipped with automatic transmissions, the initial gear selection is controlled by the transmission selector. Most vehicles at least four of the five following selector positions.

Park (P) Position – On smaller vehicles, such as sedans and pickup trucks, the park position is used to lock the transmission so the vehicle cannot roll while parked. On some larger vehicles, the park position does not lock the transmission. Vehicles with a park position should be started in this position.

Neutral (N) Position – Vehicles not equipped with a park position are started from the neutral position. In this position, the engine is disengaged from the vehicle’s propeller shaft.

Drive (D) Position – With the selector in the drive position, the vehicle moves forward as you depress the accelerator. After starting the engine in the park or neutral position, step on the brake and change the selector to “D” or “DR” to move forward. To avoid premature forward movement, keep foot pressure on the brake pedal while positioning the selector. The transmission will automatically shift to higher gears as speed increases without any further operator action.

Low (L) or Power Position – When the selector is in the low position, the transmission will not shift automatically to higher gear ratios. The low position is used when negotiating steep grades and rough terrain, or when braking power is required. When low range is no longer needed, release the accelerator temporarily and move the selector to the drive position for normal gear progression. In the drive position, the low range engages

automatically when engine speed decreases. If the accelerator is suddenly fully depressed, the low range becomes engaged. (This procedure may be used to provide a sudden burst of speed for passing.) When a predetermined engine speed has been attained, the transmission automatically returns to driving range.

Reverse (R) Position – Some selectors must be raised slightly to move to the reverse position. Others may require the operator to press down on button on the end of the selector before moving in reverse.

Before operating a vehicle or piece equipment, become familiar with its instruments, controls, and selector positions. The location of the reverse position may vary. When moving the selector, the operator must be aware of the reverse position of the operated vehicle in order to avoid moving in an unintended direction.

1.3.0 Auxiliary Transmission

The auxiliary transmission provides two additional gear ratios in the power train: high (H) range and low (L) range. These gears are shifted by a separate gear-shift lever in the operator's cab. The auxiliary transmission is installed behind the main transmission and engine power flows directly to it from the main transmission (*Figure 3-12*).

When the operator shifts the auxiliary transmission into the high range position, engine power flows directly through the transmission and is controlled only by the main transmission.

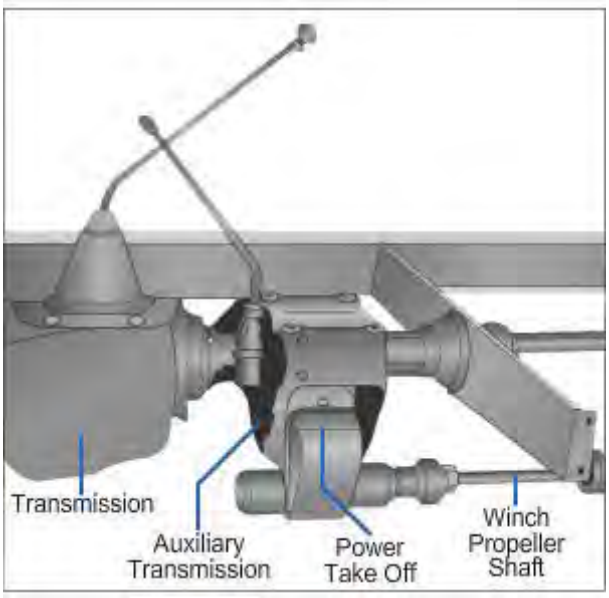


Figure 3-12 – Auxiliary transmission.

When the auxiliary transmission is shifted into the low range, vehicle speed is decreases and torque increases. This range is ideal for hard pulls. When the low range is used with the lowest speed of the main transmission, the engine drives the wheels very slowly and with less engine horsepower.

1.3.1 Transfer Case

The transfer case, also known as the "transfer box" (*Figure 3-13*) is used on all-wheel drive vehicles to divide engine torque between the front and rear driving axles. The transfer case also allows the front driving axle to be disengaged, to prevent undue wear on the power train components during highway operation.

Another purpose of the transfer case is to move the propeller shaft for the front driving axle off to the side so that it can clear the engine. This arrangement is necessary to allow adequate ground clearance and to allow the body of the vehicle to remain at a practical height.

Transfer cases in heavier vehicles have two-speed positions and a de-clutching device for disconnecting the front-driving wheels. Two-speed transfer cases also serve as auxiliary transmissions.

Transfer cases are quite complicated. They can be larger than the main transmission when they have speed-changing gears, declutching devices, and attachments for three or more propeller shafts.

Some transfer cases have an overrunning sprag unit (or units) on the front output shaft. A sprag unit is a form of an ***overrunning clutch***; power can be transmitted through it in only one direction.

During normal operation, the rear wheels drive the vehicle. The front wheels turn at the same speed as the rear wheels. However, when the rear wheels lose traction and begin to slip, they turn faster than the front wheels. When this occurs, the sprag unit engages the front wheels to drive the vehicle for more traction.

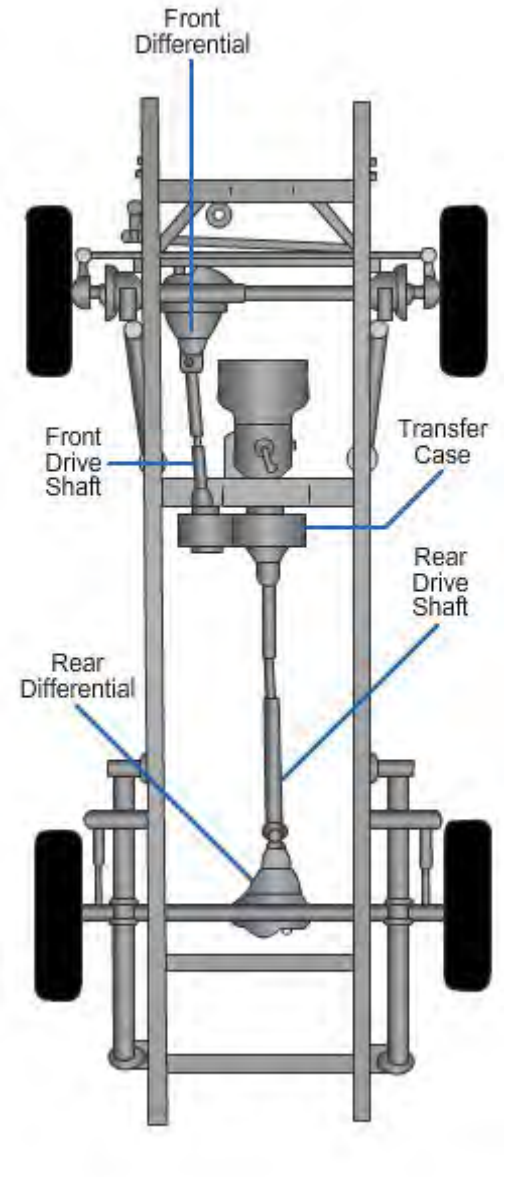


Figure 3-13 – Transfer case location.

1.3.2 Power Takeoff

A power takeoff (PTO) is an attachment for connecting the engine to power-driven auxiliary equipment. It can be attached to the transmission, auxiliary transmission, or transfer case. *Figure 3-14* shows a PTO installed at the left side of a transmission. This PTO is used to drive a ***winch*** at the front of a truck through a universal joint and propeller shaft.

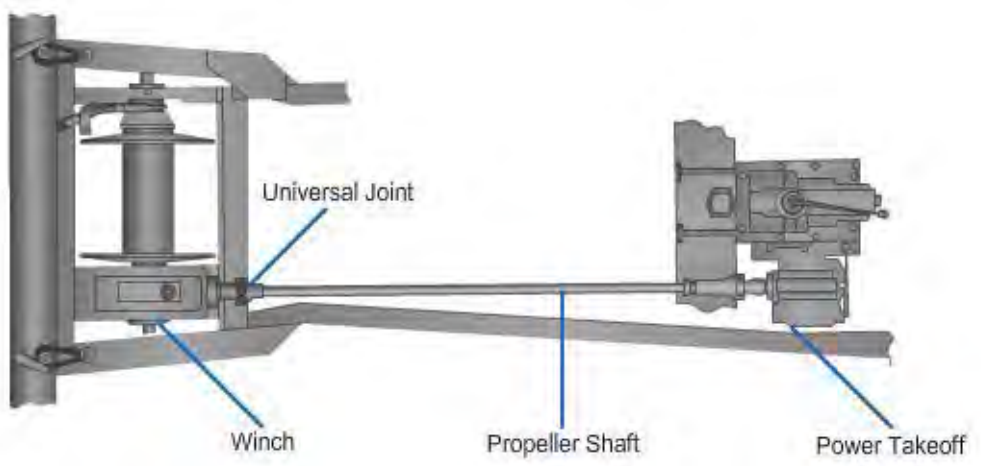


Figure 3-14 – Power takeoff and winch installation.

The simplest type of PTO is the single-speed, single-gear shown in *Figure 3-15*. This type of unit may be bolted onto the side of a transmission case.

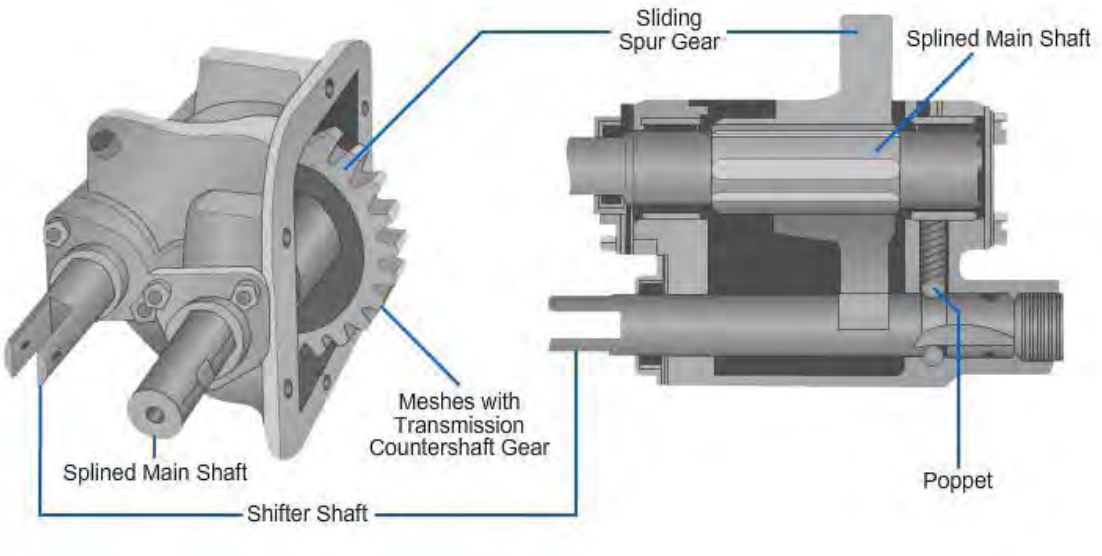


Figure 3-15 – Single-speed, single gear power takeoff.

The sliding gear of the PTO meshes with the transmission countershaft gear. Shims or spacers are often used maintain proper contact is maintained between the teeth of the two meshing units. The operator moves a shifter shaft lever to slide the gear in and out of mesh with the countershaft gear. A spring-loaded ball (poppet) holds the shifter shaft in position.

Some vehicles have PTOs with gear arrangements for two forward speeds and one reverse speed. This arrangement is used to operate winches and hoists. The operation of this type of PTO is similar to that of the single-speed unit.

Damaged or broken linkage can cause faulty operation of a PTO. To prevent this, you must exercise care when shifting. You must also be aware that trying to engage the unit with the transmission gears turning can damage the gear teeth and rapid clutch engagement can break the housing.

The linkage can be bent or damaged by rapid shifting and forcing the control lever.

WARNING

During the operation of a PTO, you must exercise caution. Operators can be harmed if their clothing becomes entangled in the revolving PTO components. Follow the instructions provided by the operator's manual.

Test your Knowledge (Select the Correct Response)

1. **(True or False)** A manual transmission should increase torque going to the front wheels for quick acceleration.

   A. True
   B. False

2. **(True or False)** The driving members of the clutch are attached to the engine crankshaft and transfer engine power to driven member.

   A. True
   B. False

3. The fluid coupling uses _____ to transmit rotating mechanical power.

   A. water
   B. gasoline
   C. diesel
   D. oil

4. Which of the following is NOT a component of the torque converter?

   A. Generator
   B. Impeller
   C. Turbine
   D. Stator

5. **(True or False)** By holding and releasing the components of the planetary gear system, the hydraulic servos and spring pressure can increase output speed while reducing torque.

   A. True
   B. False

6. **(True or False)** The high range on the auxiliary transmission is ideal for hard pulls.

   A. True
   B. False

7. **(True or False)** The transfer case connects the engine to power-driven auxiliary equipment.

   A. True
   B. False

8. **(True or False)** The power takeoff automatically slides the gear in and out of mesh with the countershaft gear.

   A. True
   B. False

2.0.0 PROPELLER SHAFT ASSEMBLIES

The propeller shaft assembly consists of a propeller shaft, commonly known as a drive shaft, a slip joint, and one or more universal joints. It provides a flexible connection through which power is transmitted from the transmission to the rear axle assemblies or auxiliary equipment. Long-wheel base vehicles are equipped with a propeller shaft that extends from the transmission to a center support bearing. From that center support bearing another propeller shaft extends to the rear axle, as shown earlier in *Figure 3-1*.

The propeller shaft may be solid or tubular. A solid shaft is stronger than a hollow or tubular shaft of the same diameter, but a hollow shaft is stronger than a solid shaft of the same weight. Solid shafts are used inside a shaft housing that encloses the entire propeller shaft assembly. These are called torque tube drives.

A slip joint is at one end of the propeller shaft. It provides fluctuation, known as end play. The rear axle, attached to the springs, is free to move up and down, while the transmission is attached to the frame and cannot move. Any upward or downward movement of the axle, as the springs flex, shortens or lengthens the distance between the axle assembly and the transmission. The slip joint allows the propeller shaft to function despite the changing distance.

2.1.0 Universal Joints

A universal joint (*Figure 3-16*) acts as a flexible coupling between two shafts. It permits one shaft to drive the other, even though they are at an angle from each other. The universal joint is flexible in the sense that it permits power to be transmitted, while the angle of the shaft continually changes.

Figure 3-16 Universal joint.

A simple universal joint is composed of three fundamental units, a journal (cross) and two yokes. The two yokes are set at right angles to each other, and their open ends are connected by the journal. This construction permits each yoke to pivot on the axis of the journal and also permits the transmission of rotary motion from one yoke to the other. As a result, the universal joint can transmit power from the engine through the shaft to the rear axle, even though the engine is mounted in the frame at a higher level than the rear axle, which is constantly moving up and down in relation to the engine. *Figure 3-17* show the operation of a universal joint.

Universal joints need little, if any, maintenance other than lubrication. Universal joints with grease fittings and should be lubricated according to the operator's manual.

Figure 3-17 – Universal joint in operation.

2.2.0 Center Support Bearings

When two or more propeller shafts are connected in tandem, their alignment is maintained by a rubber bushed center support bearing (*Figure 3-18*). The center support bearing is a ball or roller bearing unit secured to a cross member of the frame. It supports the center of the power train where the two propeller shafts come together, as shown in *Figure 3-1*.

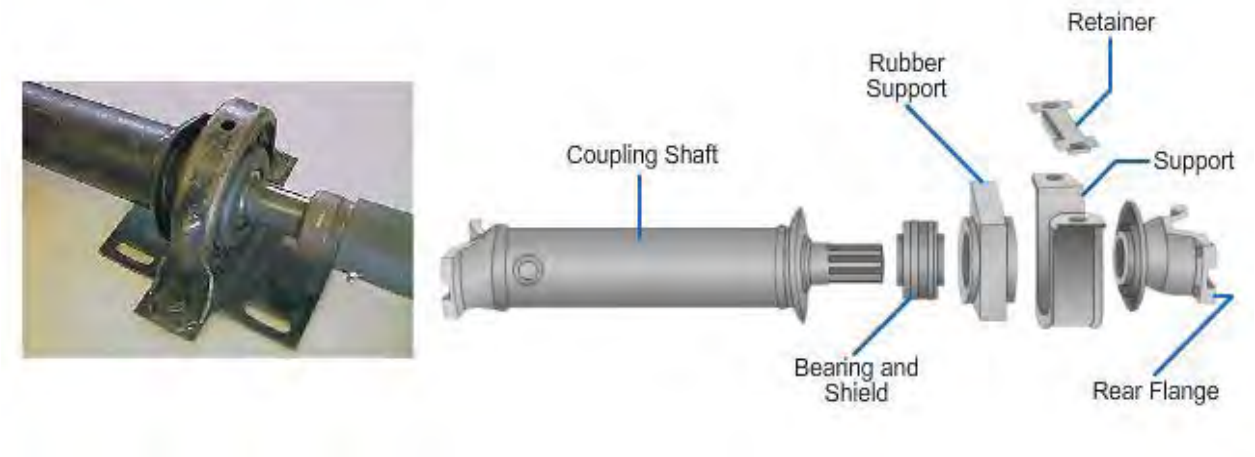


Figure 3-18 – Center support bearing.

The standard bearing is pre-lubricated and sealed and requires no further lubrication; however, some support bearings on heavy-duty vehicles and equipment have lubrication fittings. The first indication of support bearing failure is excessive vehicle vibration at low speed, caused by the bearing turning with the shaft in the rubber support.

Test your Knowledge (Select the Correct Response)

9. Which of the following is NOT a component of the propeller shaft assembly?

   A. Slip joint
   B. Universal joints
   C. Drive shaft
   D. Final drive

10. **(True or False)** The universal joint is a ridgid coupling between two shafts.

   A. True
   B. False

11. The alignment between two or more propeller shafts is maintained by a _____.

   A. universal joint
   B. slip joint
   C. center support bearing
   D. coupling

3.0.0 FINAL DRIVES

A final drive transmits the power delivered from the propeller shaft to the driving wheels or to the ***sprockets*** on tracked equipment. The final drive is usually identified as a part of the rear axle assembly because it is located in the rear axle housing. It consists of two gears: the ring gear and pinion. They are beveled gears mounted on shafts that are 90 degrees apart. They may be worm, spiral bevel, spur bevel, or hypoid, as shown in *Figure 3-19.*

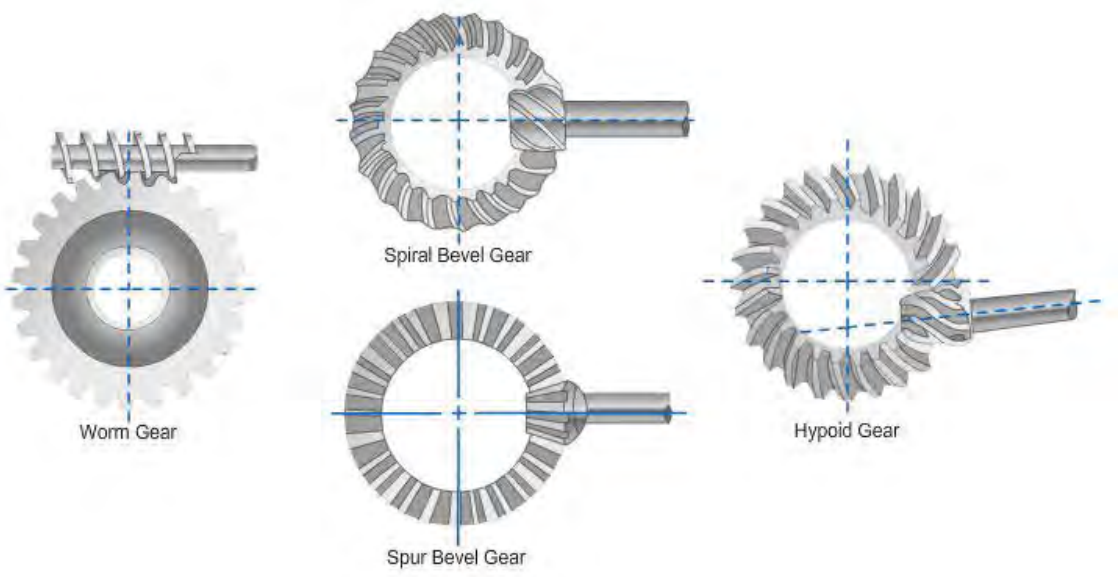


Figure 3-19 – Gears used in final drives.

The function of the final drive is to change by 90 degrees the direction of the power transmitted through the propeller shaft to the driving axles. It also provides a fixed reduction between the speed of the propeller shaft and the axles driving the wheels. In passenger cars, this reduction varies between 3 to 1 and 5 to 1. In trucks, it can vary from 5 to 1 to as much as 11 to 1.

The gear ratio of a final drive with bevel gears is found by dividing the number of teeth on the driven or ring gear by the number of teeth on the pinion. In a worm gear final drive, the gear ratio is found by counting the number of revolutions of the worm gear for one revolution of the driven gear.

Most final drives are gear type. Hypoid differential gears permit a lower body design. They permit the bevel-driven pinion to be placed below the center of the ring gear, thereby lowering the propeller shaft, as shown in *Figure 3-19*. Worm gears allow a larger speed reduction and are sometimes used on large trucks. Spiral bevel gears are similar to hypoid gears and are used in both passenger cars and trucks to replace spur gears that are too noisy.

3.1.0 Differentials

Another important unit in the power train is the differential (*Figure 3-20*). It is driven by the final drive. The differential is located between the axles. Its housing resembles a pumpkin.

The differential is an assembly of gears that permits one axle shaft to turn at a different speed than another while at the same time transmitting engine power from the transmission or transfer case to both axle shafts. The variation in axle shaft speeds is necessary when the vehicle turns a corner or travels over uneven ground

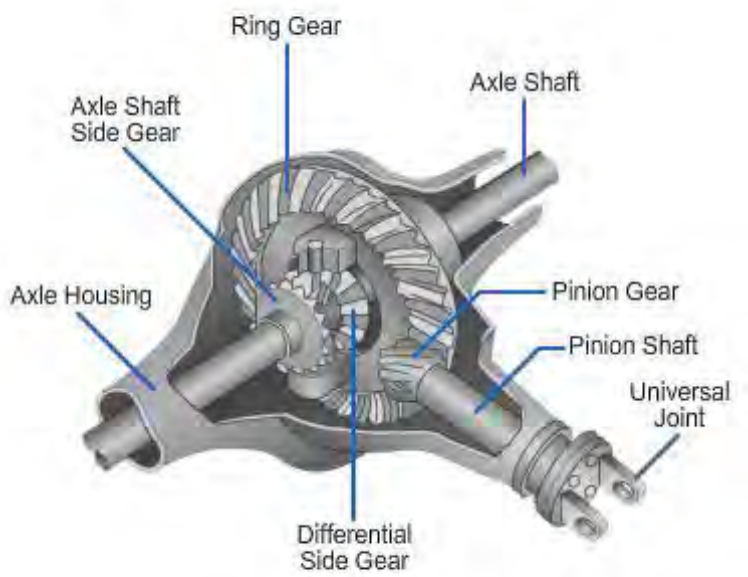


Figure 3-20 – Differential.

As a vehicle turns a corner, the outer wheel must travel faster and farther than the inner wheel. Without the differential, one rear wheel would be forced to skid when the vehicle turns. This skidding would cause excessive tire as well as making the vehicle more difficult to control.

Some trucks are equipped with a differential lock to prevent one wheel from spinning. This lock is a simple ***dog clutch***, controlled manually or automatically, that locks one axle shaft to the differential case and bevel drive gear. This device forms a rigid connection between the two axle shafts and makes both wheels rotate at the same speed. Drivers seldom use it, however, because they often forget to disengage the lock after using it.

3.2.0 Driving Axles

Axles are classified as either live or dead. Live axles transmit power. Dead axles only support part of the vehicle weight and provide a mounting for the wheel assembly.

On rear-wheel drive vehicles, the front axle is a dead axle and the rear axle is a live axle. On four-wheel drive vehicles, both the front and rear axles are live axles. On six-wheel drive vehicles, all three axles are live axles; the third axle is part of a ***bogie drive***, joined to the rearmost axle by a trunnion axle, as shown in *Figure 3-21*. The trunnion axle is attached rigidly to the frame. Its purpose is to distribute the load between the two live axles that it connects.

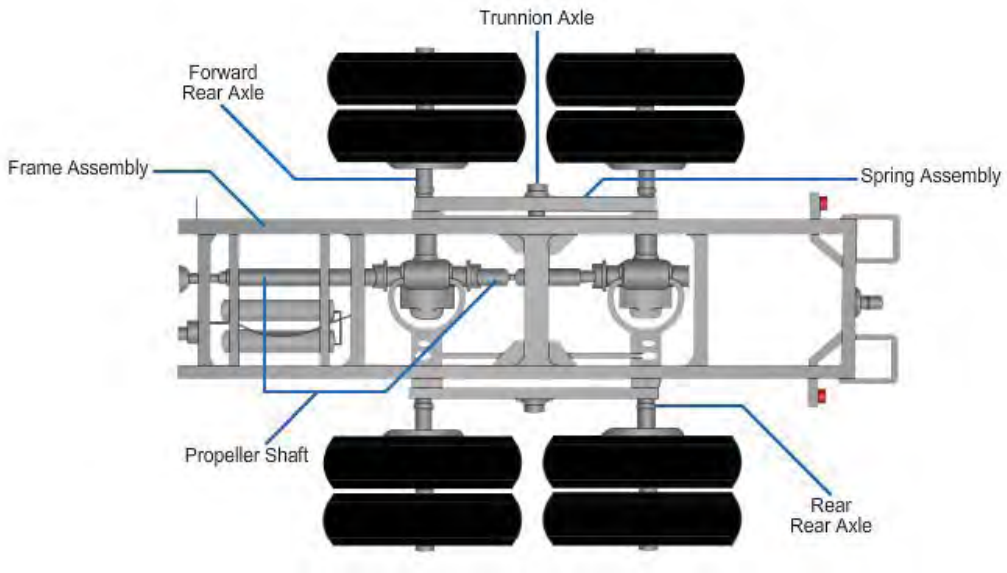


Figure 3-21 – Bogie drive.

Semi-floating and full-floating are two common types of live axles. Semi-floating axles are used on passenger vehicles and light trucks, the shaft and axle housing supports the weight of the vehicle.

Full-floating axles are used on many heavy–duty trucks. The axle housing supports the full weight of the vehicle and absorbs all stresses or end thrust caused by turning, skidding, and pulling. All wheel-drive vehicles have a full-floating axle that provides power to the front wheels.

3.3.0 Driving Wheels

Wheels attached to live axles are called driving wheels because they drive the vehicle. Wheels attached to the outside of the driving wheels are called dual wheels. Dual wheels provide more traction and distribute vehicle weight evenly.

The number of wheels is sometimes used to identify the vehicle. For example, a passenger car with four wheels, two of which are driving wheels, is identified as a 4 by 2. A truck with four wheels, all of which are driving wheels, is identified as a 4 by 4. On this vehicle, power is delivered to the transfer case where it is divided between the front and rear axles, allowing all four wheels to drive (*Figure 3-22*).

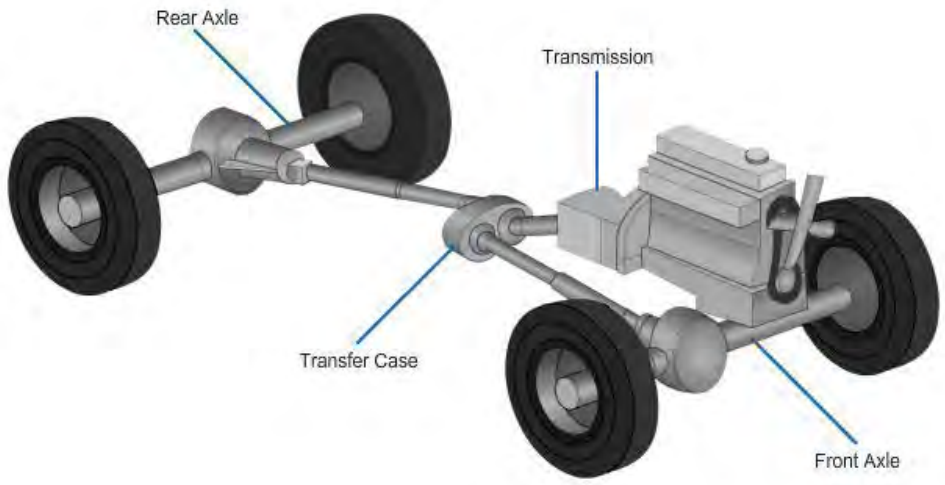


Figure 3-22 – Four-wheel drive transmission.

A truck with six wheels, two of which are dual wheels at the rear, is identified as a 6 by 4. When a live axle is in front, like on the Medium Tactical Replacement Vehicles (MTVRs), the truck becomes a 6 by 6 (*Figure 3-23*), in which all six wheels drive the vehicle.

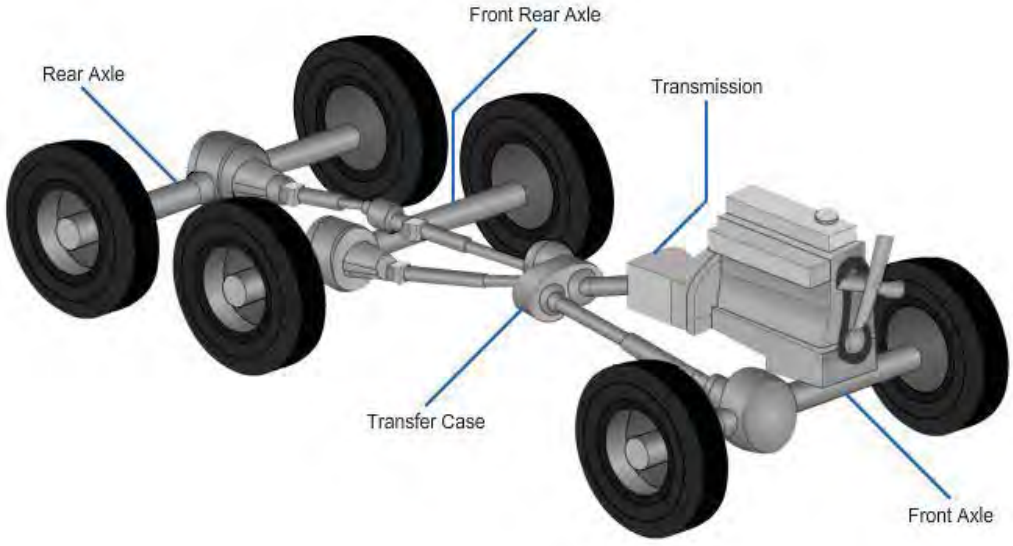


Figure 3-23 – Six-wheel drive transmission.

Test your Knowledge (Select the Correct Response)

12. **(True or False)** The final drive changes the direction of the power transmitted through the propeller shaft to the driving axles.

    A. True
    B. False

13. Which of the following permits a variation in axle shaft speeds?

    A. Transmission
    B. Differential
    C. Transfer case
    D. Dog clutch

14. **(True or False)** Live axles transmit power.

    A. True
    B. False

15. **(True or False)** On a 6 by 6 truck, the front axle is a live axle.

    A. True
    B. False

Summary

This chapter provided the knowledge you must have to operate vehicles and construction equipment equipped with sophisticated power trains.

In this chapter, you were introduced to the principles and operations of shifting gears using a clutch on a manual transmission as well as the principles and operations of an automatic transmission. You learned how the additional gears provided by the auxiliary transmission are used to operate winches and hoists.

You learned how the propeller shaft assembly and its components, including a propeller shaft and universal joints, transmit power from the transmission to the rear axle assemblies and auxiliary equipment.

Additionally, you learned how the final drive plays a part in delivering power from the propeller shaft to the driving wheels, or on tracked equipment, to the sprockets.

Review Questions (Select the Correct Response)

1. **(True or False)** The transmission allows the operator to control the engine power and speed of the vehicle.

   A. True
   B. False

2. What is the definition of gear ratio?

   A. The number of times a driving gear must turn to rotate the driven gear
   B. The number of times a driven gear must turn to rotate the driving gear
   C. The number of teeth the driven gear has
   D. The number of teeth the driving gear has

3. What component of the clutch is bolted to the engine flywheel?

   A. Clutch disc
   B. Pressure plate
   C. Friction facing
   D. Clutch release shoe

4. What device is added to the manual transmission to equalize the speed of the shaft and gear before they are locked together?

   A. A countershaft
   B. A synchronizer
   C. An equalizer
   D. A planetary gear system

5. While operating a manual transmission, what action should an operator take when waiting at a long traffic light?

   A. Depress the clutch pedal until the light turns green.
   B. Depress the clutch pedal, shift the transmission to neutral and continue with the clutch depressed until the light turns green.
   C. Depress the clutch pedal, shift the transmission to neutral, and release the clutch pedal after shifting into neutral.
   D. Depress the clutch pedal, shift the transmission to first gear and continue with the clutch depressed until the light turns green.

6. During double-clutch shifting, what technique is performed when shifting to a lower gear but NOT performed when shifting to a higher gear?

   A. The engine is accelerated when the transmission is in neutral.
   B. The clutch pedal is fully depressed twice.
   C. The accelerator pedal is released before depressing the clutch.
   D. When the clutch is fully depressed, the gear-shift lever is placed in the neutral position.

7. Which of the following factors does NOT affect the shifting of an automatic transmission?

   A. The throttle position
   B. The vehicle speed
   C. The engine temperature
   D. The position of the selector lever

8. Which component of the torque converter absorbs the force required to reverse the direction of the clockwise spinning oil?

   A. Outer housing
   B. Impeller
   C. Turbine
   D. Stator

9. **(True or False)** The stator is allowed to rotate counterclockwise.

   A. True
   B. False

10. Besides the sun gear and ring gear, the planetary gear system includes what other component?

    A. Planet pinions with carrier
    B. Throw-out bearings
    C. Star with carrier gears
    D. Moon pinions

11. What component of the planetary gear system has internal teeth?

    A. Planet pinion
    B. Ring gear
    C. Sun gear
    D. Throw-out bearing

12. Which of the following is NOT an advantage of the planetary gear system?

    A. More teeth to make contact to carry the load
    B. Gears are always in mesh
    C. Ease of shifting
    D. Its simplicity

13. **(True or False)** Vehicles with a park (P) transmission position should be started in this position.

    A. True
    B. False

14. When negotiating steep grades and rough terrain, what position should the transmission selector be placed in?

    A. Low (L) position
    B. Drive (D) position
    C. Neutral (N) position
    D. Reserve (R) position

15. When placing the transmission selector in the drive (D) position, an operator should take what action to avoid the premature forward movement of a vehicle?

    A. Place wheel chocks in front of the rear wheels.
    B. Engage the parking brake.
    C. Maintain pressure on the foot break pedal.
    D. Slowly engage the selector.

16. What is the function of an auxiliary transmission?

    A. Replace the main transmission
    B. Replace the main transmission during fording operations
    C. Provide additional gear ratios
    D. Provide front axle power

17. What condition causes the sprag to automatically engage?

    A. The rear wheels slipping and turning faster than the front wheels
    B. The operator shifting to low gear
    C. The front wheels slipping and turning faster than the rear wheels
    D. High-speed operation

18. What component of the power train is used to drive auxiliary equipment?

    A. Final drive
    B. Transfer case
    C. Planetary gear system
    D. Power takeoff

19. What assembly provides a path through which power is transmitted from the transmission to the drive axle?

    A. Final drive
    B. Propeller shaft
    C. Differential
    D. Dog clutch assembly

20. What component sits between and supports two propeller shafts on vehicles with a long wheel base?

    A. Center support bearing
    B. Auxiliary support transmission
    C. Propeller support casing
    D. Universal support joint

21. What component of the propeller shaft assembly provides end play?

    A. Leaf springs
    B. Universal joints
    C. Sprag unit
    D. Slip joint

22. **(True or False)** The universal joint has three yokes that are set at right angles to each other.

    A. True
    B. False

23. What technique should you use to determine the gear ratio on a worm gear final drive?

    A. Divide the number of teeth on the worm gear by the number of teeth on the pinion.
    B. Multiply the number of teeth on the worm gear by the number of teeth on the pinion.
    C. Count the number of teeth on the worm gear for the number of teeth of the driven gear.
    D. Count the revolutions of the worm gear for one revolution of the driven gear.

24. On the final drive, which of the following type of gear permits a larger speed reduction?

    A. Hypoid
    B. Worm
    C. Spur bevel
    D. Spiral bevel

25. **(True or False)** Without a differential, one rear wheel would be forced to skid when the vehicle turns.

    A. True
    B. False

26. On a truck axle assembly, what component prevents one wheel from spinning?

    A. Propeller shaft
    B. Countershaft lock
    C. Anti-skid lock
    D. Differential lock

27. Which of the following component supports part of the vehicle weight and provides a mounting for the wheel assembly?

    A. Dead axle
    B. Live axle
    C. Trunnion axle
    D. Final drive

28. Which of the following components distribute the load between the two live axles that it connects?

    A. Dead axle
    B. Live axle
    C. Trunnion axle
    D. Final drive

29. Which of the following type of live axle is used on passenger vehicles and light trucks?

    A. Semi-floating
    B. One-half floating
    C. Three-quarters floating
    D. Full-floating

30. On a 4 x 4 drive vehicle, what component divides power between the front and rear axle?

    A. The power takeoff
    B. The differential case
    C. The center support housing
    D. The transfer case

Trade Terms Introduced in this Chapter

Bogie drive	Two or more axles, mounted to a frame so as to distribute the load between the axles and permit vertical oscillation of the axles.
Centrifugal force	The outward force exerted by a body moving in a curved line.
Clutch chatter	A condition in which the clutch severely vibrates as the vehicle accelerates.
Dog clutch	A device that forms a rigid connection between two axle shafts and makes both wheels rotate at the same speed.
Hoist	A machine used for lifting loads.
Mushy shift	A condition when the transmission changes too slowly.
Overrunning clutch	Device that locks a pinion gear in one direction and releases it in the other.
Splined	Meshed by series of ridges.
Sprockets	Gears that meshes with a chain or a crawler track.
Stiff clutch pedal	A condition caused by binding or other restriction in the clutch mechanism, making the pedal hard to depress.
Torque	The twisting force exerted by or on a shaft (without reference to the speed of the shaft).
Winch	A drum that can be rotated so as to exert a strong pull while winding in a line.

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.

Construction Mechanic Basic, Volume 2, NAVEDTRA 14273, NAVEDTRA 14081, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1999.

Equipment Operator, Basic, NAVEDTRA 14081, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1994.

Fundamentals of Service, Power Trains, Deere & Company, Moline, IL, 2005.

Principles of Automotive Vehicles, TM 9-8000, Headquarters, Department of the Army, Washington, DC, 1988.

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Chapter 4

Chassis Systems

Topics

1.0.0 Steering Systems

2.0.0 Suspension Systems

3.0.0 Tires

4.0.0 Brake Systems

To hear audio, click on the box. 

Overview

The chassis systems on vehicles and equipment provide the operator a means of controlling the direction of travel. These systems also allow the vehicle to travel over rough terrain by reducing the amount of shock felt by the operator and in the cargo area. This chapter covers the basic principles of the chassis systems, which include the steering system, suspension system, tires, and brake system.

Objectives

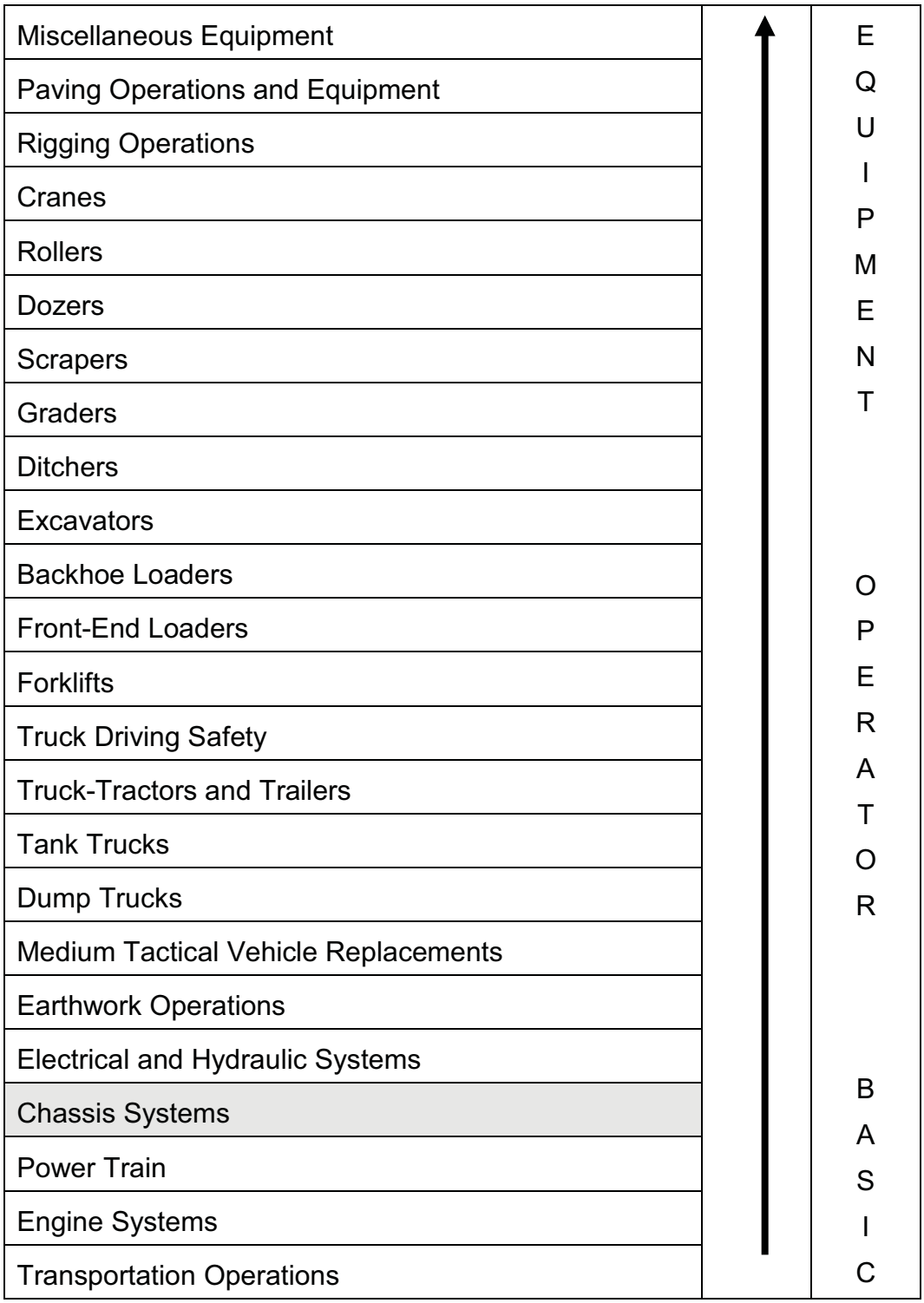
When you have completed this chapter, you will be able to do the following:

1. Understand the principles of steering systems.
2. Understand the principles of suspension systems.
3. Understand the principles of tires.
4. Understand the principles of brake systems.

Prerequisites

None

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



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 STEERING SYSTEMS

The steering system allows the operator to guide the vehicle along the road and turn the vehicle left or right as desired. A steering linkage assembly controls the direction of the vehicle. Vehicle steering systems are classified as either manual or power. The arrangement and function of the steering linkage assembly is similar in both systems. Some wheeled construction equipment have other types of steering systems called articulated steering or front-and-rear steering.

1.1.0 Steering Linkage Assembly

The steering linkage assembly (*Figure 4-1*) ties the front wheels together and connects them to the steering gear case, which is at the lower end of the steering column. The steering column is connected to the steering wheel. All steering linkage assemblies have the same basic components: a pitman arm, a center link, an Idler arm, ball sockets, and two tie rod assemblies.

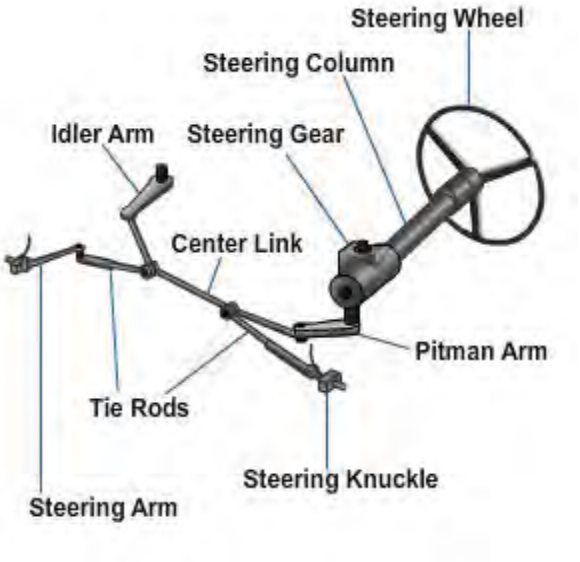


Figure 4-1 – Steering linkage assembly.

1.1.1 Pitman Arm

The pitman arm transfers steering mechanism motion to the steering linkage (*Figure 4-1*). The pitman arm is splined to the steering mechanism's output shaft, called the pitman arm shaft. A large nut and lock washer secure the pitman arm to the output shaft. The outer end of the pitman arm normally uses a ball-and-socket joint to connect to the center link.

1.1.2 Center Link

The center link (*Figure 4-1*) is simply a steel bar that connects the steering arms, pitman arm, tie-rod ends, and idler arm together. The turning action of the steering mechanism is transmitted to the center link through the pitman arm. The center link is hinged on the opposite end of the pitman arm by means of an idler arm.

1.1.3 Idler Arm

The idler arm (*Figure 4-1*) supports the free end of the center link and allows it to move left and right with ease. The idler arm is bolted to the frame.

1.1.4 Ball Sockets

Ball sockets are like small ball joints. Between two connected components, they allow motion in all directions. Ball sockets prevent the steering linkage from bending and sustaining damage when the wheels turn or move up and down over rough roads.

Ball sockets are filled with grease to reduce friction and wear. Some have a grease fitting that allows chassis grease to be inserted with a grease gun. Others are sealed by the manufacturer and cannot be serviced.

1.1.5 Tie Rod Assemblies

Two tie-rod assemblies (*Figure 4-1*) keep the front wheels in proper alignment by fastening the center link to the steering knuckles. Ball sockets are located on both ends of the tie-rod assemblies.

Preventive maintenance includes inspecting and servicing the steering linkage assembly. You will need someone to assist you by turning the steering wheel back and forth through the free play while you inspect for lubrication and wear. You should closely inspect areas containing ball sockets, such as the idler arm and tie-rod ends. These areas are subject to damage from extreme movements and dirt.

1.2.0 Manual Steering

Manual steering is entirely adequate for smaller vehicles. It is tight, fast and accurate in maintaining steering control; however, manual steering requires more effort from the operator when the engine is larger and heavier, when there is greater overhang on the vehicle, and when the vehicle has wide tread tires.

When performing a pre-start check on a vehicle equipped with manual steering system, refer to operator's manual for instructions for inspecting the steering gear case lubricant. If lubricant is needed, add the type of lubricant recommended by the manufacturer.

1.3.0 Power Steering

With the following components added to the steering linkage assembly, the power steering system (*Figure 4-2*) reduces steering efforts: a hydraulic pump, a fluid reservoir, hoses, and a pressure cylinder also known as a steering assist unit, which is normally powered by a belt that runs from the engine crankshaft. The steering assist unit can be mounted on the linkage or incorporated in the steering gear assembly.

When you perform a pre-start check on a vehicle equipped with a power steering system, the engine must be cool, the transmission in park and the parking brake set.

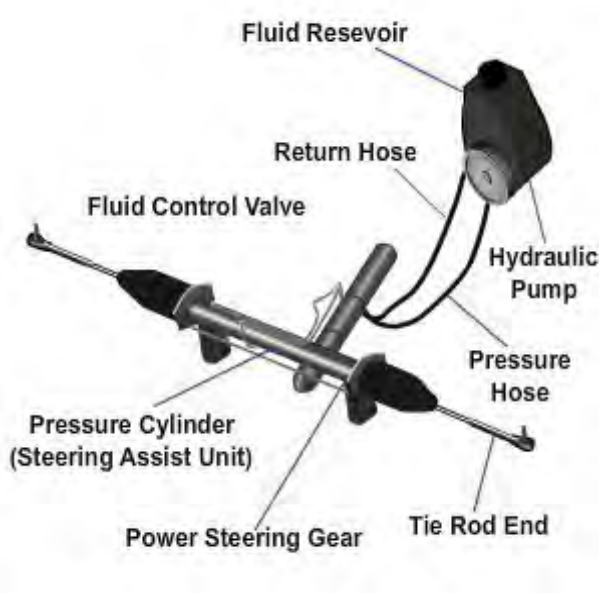


Figure 4-2 – Power steering system.

During the pre-start, closely inspect the belt tension. Improper belt tension can cause low oil pressure and hard steering.

Additionally, inspect the power steering fluid. If the fluid level is low, add fluid to bring it up to the recommended level and only use the type of power steering fluid recommended by the manufacture. If the level is low, there may be a leak; therefore, inspect hoses and power steering connections for signs of leaks. The connections may only need tightening to eliminate leaks; however, if the seals are defective, leakage may

occur at various points in the power steering unit. Document the conditions and report them to the maintenance shop for replacement.

1.4.0 Articulated Steering

Some construction equipment, such as the 4K rough terrain forklift, is equipped with articulated steering (*Figure 4-3*). Hydraulic power is used to turn a whole section of the equipment on a vertical hinge. Articulated steering is controlled by a steering wheel, a hydraulic control valve, and hydraulic cylinders located on both sides of the equipment.

In articulated steering, when the steering wheel is turned in one direction, the cylinder on the turning side retracts while the cylinder on the opposite side extends. The pivot is midway in the vehicle, so both parts of the vehicle share equally in the pivoting. This action produces the effect of four-wheel coordinated steering, that is, the front-and-rear wheels run in each others paths, backward and forward.

Articulated steering includes a shipping lock pin. The pin is made of heavy duty steel and is located under the operator's seat. When installed in mating holes in the front and rear chassis, the pin prevents articulation when transporting the equipment. Before operating, the shipping lock pin must be removed to allow normal steering.

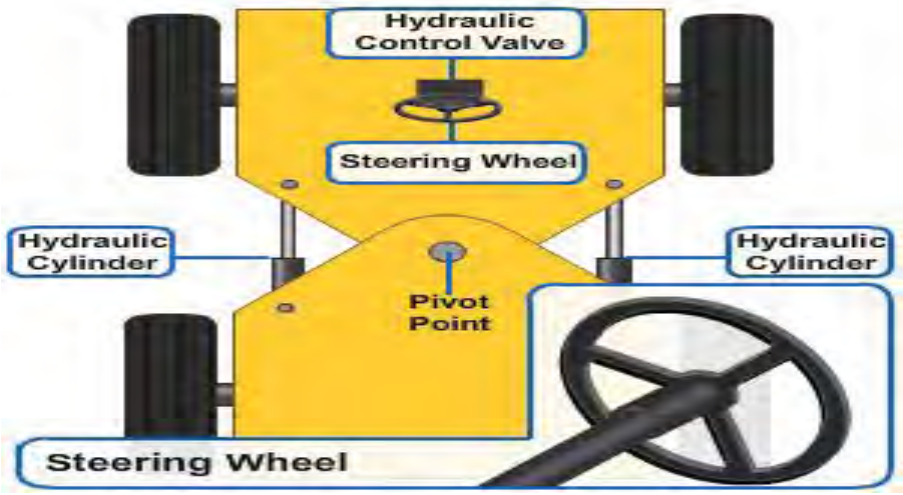


Figure 4-3 – Articulated steering in operation.

1.5.0 Front-and-Rear Steering

Some wheeled equipment have been designed to be steered by angling the front wheels, the rear wheels, and or both the front-and-rear wheels.

Front-wheel steering is the standard method. The vehicle follows the angling of the front wheels. The rear wheels do not go outside the path of the front wheels, but instead trail inside.

In rear-wheel steering, the rear wheels swing outside the path of the front wheels. The advantages are greater effectiveness in handling off-center loads at either the front or rear and maintaining stability on side slopes. This type of steering is used with forklifts, and front-end loaders, as it keeps the weight of the front-end loader squarely behind the bucket on turns and keeps the front wheels trailing the rear wheels while backing away from banks and dump trucks. In new equipment, articulated steering has replaced rear-wheel steering. *Figure 4-4* allows you to operate rear-wheel steering on a 12K forklift.

In four-wheel steering, the front wheels turn one way and the rear wheels turn to the same angle but in the opposite direction. Whether the equipment is moving forward or backward, the trailing wheels always move in the same path as the leading wheels. This design lessens rolling resistance in soft ground, because one set of wheels prepares a path for the other set. Additionally, this design provides maximum control of the direction of the load. It also enables the equipment to be held on a straight course and permits short turns in proportion to the maximum angle of the wheels. *Figure 4-4* allows you to operate four-wheel steering on a 12K forklift.

In crab steering, both sets of wheels turned in the same direction. If both sets of wheels turn at the same angle, the equipment moves in a straight line at an angle to its centerline. Both four-wheel and crab steering achieve a desired direction by using different turning angles on independently controlled front and rear wheels. *Figure 4-4* allows you to operate crab steering on a 12K forklift.

Figure 4-4 – Steering a 12K forklift.

The following are symptoms of steering troubles and must be documented and reported to the maintenance shop for repair.

- Excessive steering wheel play (the need to excessively rotate the steering wheel in order to turn the direction of the front wheels)
- Hard steering
- Vehicle wanders
- Vehicle pulls to one side when braking
- Front-wheel shimmy (side-to-side vibration)
- Front-wheel tramps (high-speed shimmy)
- Steering kickback (a strong and sudden movement of the steering wheel in the opposite direction from that to which the steering wheel is turned)
- Improper tire wear
- Unusual noises such as rattles, squeaks, and squeals

Test your Knowledge (Select the Correct Response)

1. What is the major function of the tie rod assembly?

   A. Keep the front and rear wheels in proper alignment
   B. Connect both right and left wheels
   C. Keep the front wheels in proper alignment
   D. Adjust all wheels for alignment

2. Which of the following components is NOT a part of a power steering?

   A. Hoses
   B. A fluid reservoir
   C. A hydraulic pump
   D. A leaf clip

3. What type of steering design reduces rolling resistance in soft ground because one set of wheels prepares a path for the other set?

   A. Front and rear
   B. Articulated
   C. Rear
   D. Four wheel

2.0.0 SUSPENSION SYSTEMS

The suspension system uses springs to anchor the vehicle wheels or tracks to, and suspend them from, the frame (*Figure 4-5*). It also supports the weight of the vehicle and allows the vehicle to be driven under varying speeds, loads, and conditions, including rough terrain, without great risk of damage.

Suspension systems are grouped into two categories: nondependent and independent.

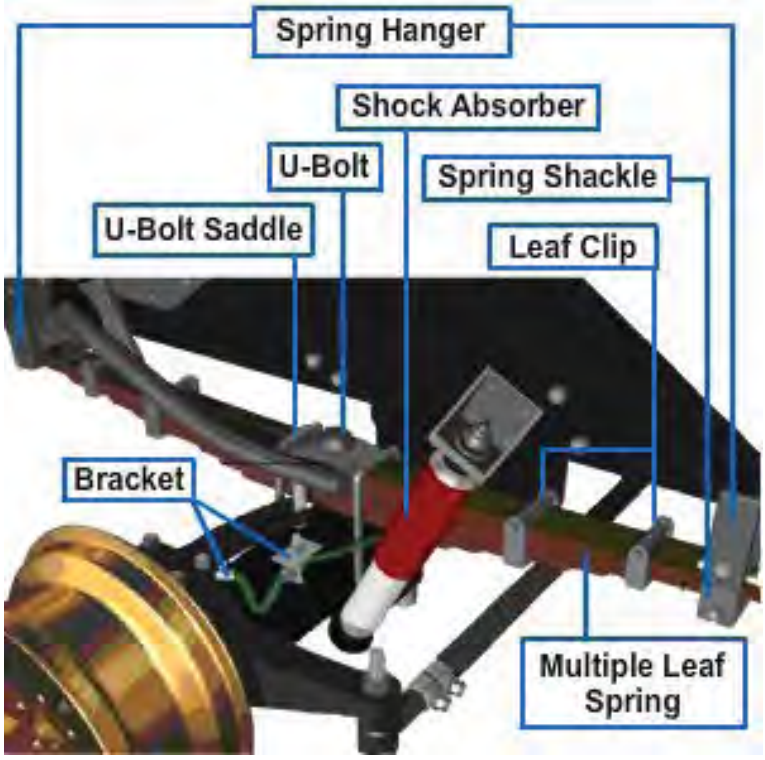


Figure 4-5 – Front axle suspension system.

2.1.0 Non-Independent Suspension

Non-independent suspension has both left and right wheels attached to the same solid axle. When one tire hits a bump in the road, its upward movement causes a slight tilt in the other wheel. With a solid axle, the steering knuckle and wheel spindle assemblies are connected to the axle beam by bronze-bushed kingpins, or spindle bolts, which provide pivot points for each wheel.

2.2.0 Independent Suspension

Independent suspension allows one wheel to move up and down with a minimum effect on the other wheels. Since each wheel is attached to its own suspension unit, movement of one wheel does not cause direct movement of the wheel on the opposite side of the vehicle. With the independent front suspension the use of ball joints provides pivot points for each wheel. In operation, the swiveling action of the ball joints allows the wheel and spindle assemblies to be turned left and right and to move up and down with changes in road surfaces. This type of suspension is most widely used on modern vehicles.

2.3.0 Suspension Components

The basic components of non-independent and independent suspension systems are springs, a torsion bar, and shock absorbers.

2.3.1 Springs

Springs support the frame and body of the vehicle as well as the load it carries. They allow the wheels to withstand the shocks of uneven road surfaces and provide a flexible connection between the wheels and the body. The best spring absorbs road shock rapidly and returns to its normal position slowly. An extremely flexible or soft spring allows too much movement of the vehicle superstructure, while a stiff or hard spring does not allow enough movement.

The springs do not support the weight of the wheels, rims, tires, and axles. Such parts make up the “unsprung weight” of the vehicle.

Multiple Leaf Spring – The multiple leaf spring, shown in *Figure 4-5*, is part of the front axle suspension system. It consists of steel strips, known as leaves, of different lengths fastened together by a U-bolt through the center. The longest leaf is called the master leaf. Each end of the master leaf is rolled into an eye which serves as a means of attaching the spring to the hanger and shackle beneath the vehicle. Leaf clips surround the leaves at two or more intervals along the spring. They are used to keep the leaves from separating on the rebound after the spring has been depressed. The clips allow the spring leaves to slide but prevent them from separating and throwing the entire rebound stress on the master leaf. The spring thus acts as a flexible beam. Leaf springs may be suspended lengthwise (parallel to the frame) or crosswise.

When the multiple leaf spring is compressed, it must straighten out; therefore, spring shackles are required at one or both ends of the spring. Spring shackles provide a swinging support and allow the spring to straighten out after compression. One shackle is used in either the front or rear to support springs installed lengthwise. Two shackles are used to support springs installed crosswise. *Figure 4-6* shows how a leaf spring is attached to a frame by a spring shackle.

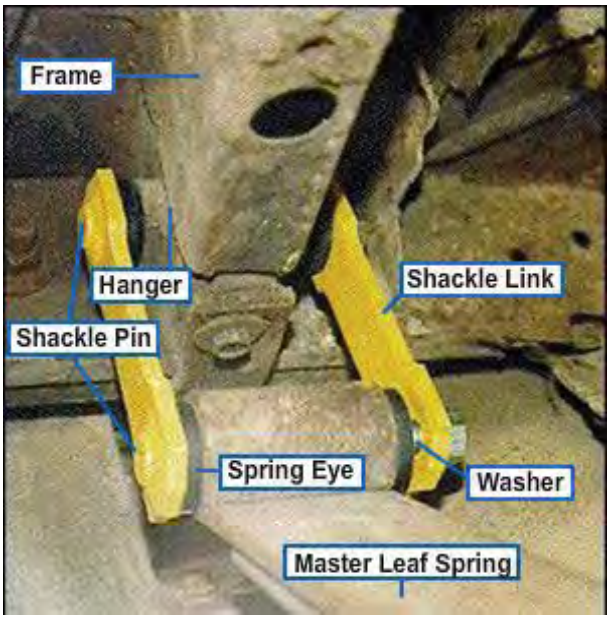


Figure 4-6 – Spring shackle.

The most common types of spring shackles are the link shackle and the U-shackle. Link shackles are commonly used on heavy equipment; whereas, U-shackles are commonly used on passenger cars and light trucks.

During a pre-start check, ensure that these shackles are tight and that bushings within the shackles are not worn out or frozen tight. Occasionally spraying lubricant on the spring leaves helps to prevent squeaking at the ends. Follow the lubrication chart provided in the operator's manual.

On some wheeled tractors, link shackles support a transverse spring on the ***dead axle***. Most wheeled tractors do not have springs, and all load cushioning is done by large, low-pressure tires.

Track tractors have one large leaf spring (*Figure 4-7*) supported without spring shackles. Fastened to the engine support, the leaf spring rests on the frame supporting the tracks and rollers. Brackets on the track frames keep the spring from shifting.

Some vehicles are equipped with leaf springs at the rear wheels only; others are equipped with leaf springs at both front and rear wheels.

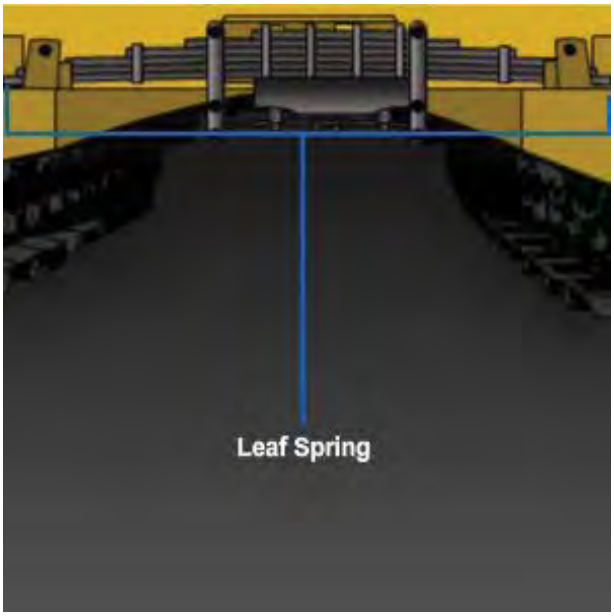


Figure 4-7 – Partially removed tracklayer spring.

Coil Springs – Independent suspension systems generally use coil springs because coil springs provide a smooth ride. They are located between the upper and lower control arms as shown in *Figure 4-8*.

Normally, the use of coil springs has been limited to passenger vehicles. Recently, however, they have been used on trucks.

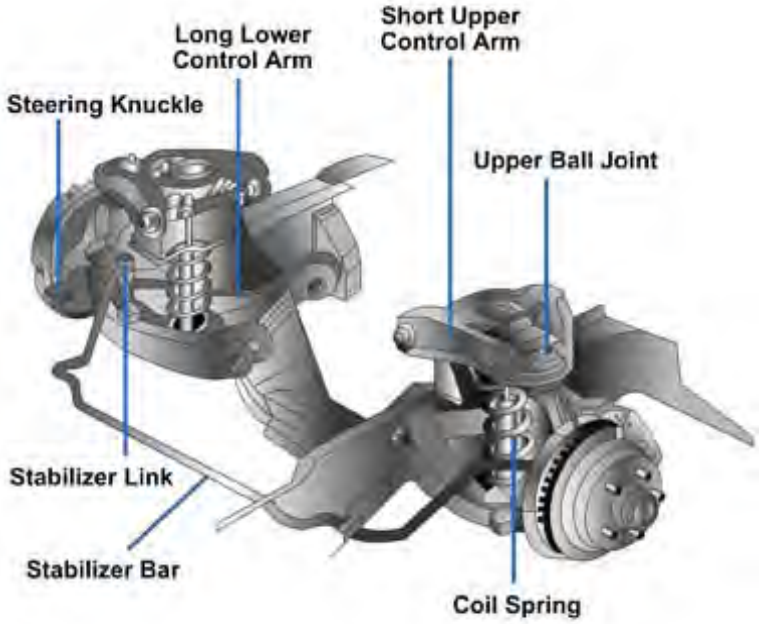


Figure 4-8 – Coil spring suspension.

Figure 4-9, shows how a coil spring is mounted. The spring seat and hanger are shaped to fit the coil ends and hold the spring in place. Spacers of rubberized material are placed at each end of the coil to prevent squeaking. The rubber bumper, mounted in the spring supporting member, prevents metal-to-metal contact when the spring is compressed. Most vehicles are equipped with coil springs at the two front wheels, while some others have them at both front and rear wheels.

When performing a pre-start check, inspect the coil springs as well as the upper and lower control arms. Rubber bushings are commonly used in the inner ends of the arms. These bushings are prone to wear and should also be inspected.

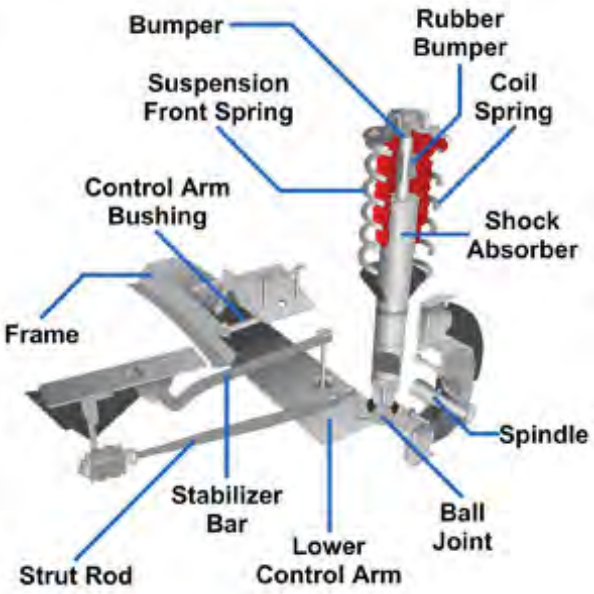


Figure 4-9 – Coil spring mounting.

2.3.2 Torsion Bar

The torsion bar is a rod made of spring steel and treated with heat or pressure to make it elastic so it will regain its original shape after being twisted.

Torsion bars, like coil springs, are frictionless and require the use of shock absorbers. The torsion bar is serrated at each end and attached to the torsion bar anchor at one end and the suspension system at the other end (*Figure 4-10*).

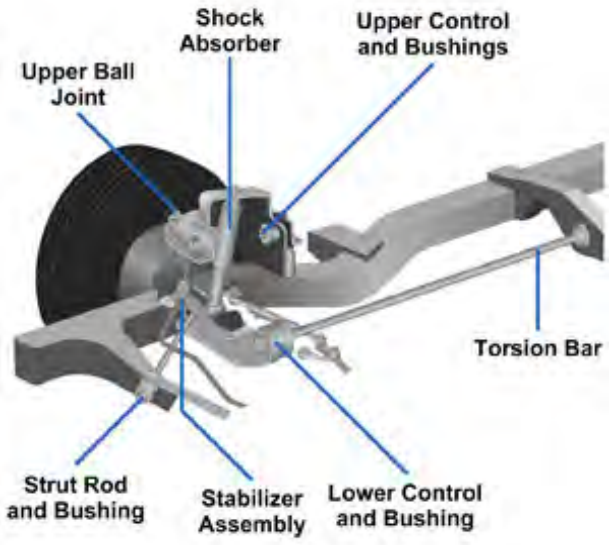


Figure 4-10 – Torsion bar location.

2.3.3 Shock Absorbers

The springs alone cannot meet the requirements for a light vehicle suspension system. A stiff spring can cause a rough ride, because it does not flex and rebound when the vehicle passes over a bump. At the same time, an extremely flexible spring can also cause a rough ride because it rebounds too much. For these reasons, shock absorbers, also shown in *Figure 4-10*, are needed to smooth the ride of the vehicle. By using air or hydraulic pressure to balance spring stiffness and flexibility, they keep the vehicle from jolting too much. Although single-acting shock absorbers control only spring rebound, double-acting shock absorbers control spring compression and spring rebound and permit the use of the more flexible springs.

During a pre-start check, visually inspect the shock absorbers for any signs of leakage (oil wetness) and damage. Also, inspect the bushing on each end of the shock absorber to ensure it is not smashed or split. In addition, make sure that the shock absorber's fasteners are tight.

The following are symptoms of suspension troubles and must be documented and reported to the maintenance shop for repair.

- Hard steering
- Vehicle wanders
- Vehicle pulls to one side during normal driving
- Front-wheel shimmy or tramps (high-speed shimmy)
- Steering kickback
- Hard or rough ride
- Sway on turns
- Spring breakage
- Sagging springs
- Noises

Test your Knowledge (Select the Correct Response)

4. What component supports the frame and the body of the vehicle?

   A. Tie rods
   B. Springs
   C. Torque rods
   D. Shock absorber

3.0.0 TIRES

Because tires are expensive, they require proper care and maintenance. While natural wear and tear affects tire life, abuse and neglect can cause premature tire failure. Proper maintenance of tires results in better performance and longer service and prevents a hazardous tire failure that can cause loss of life and equipment.

3.1.0 Types of Tires

The vehicles and equipment you will be operating are commonly equipped with either radial-ply or bias-ply tires.

3.1.1 Radial-Ply Tires

Radial-ply tires (*Figure 4-11*) are constructed with casing plies perpendicular to the tread direction, with several layers of tread-reinforcing plies (steel or fabric) just under the tread area. This construction permits flexing of the tire with minimal tread distortion, good traction, and a soft ride.

3.1.2 Bias-Ply Tires

Bias-ply tires (*Figure 4-12*) are constructed of rayon, nylon, or polyester casing plies in a crisscross pattern wrapped around steel bead wires. These bead wires prevent the tire from opening up and separating from the rim at high speeds. The casing plies give the tire its shape.

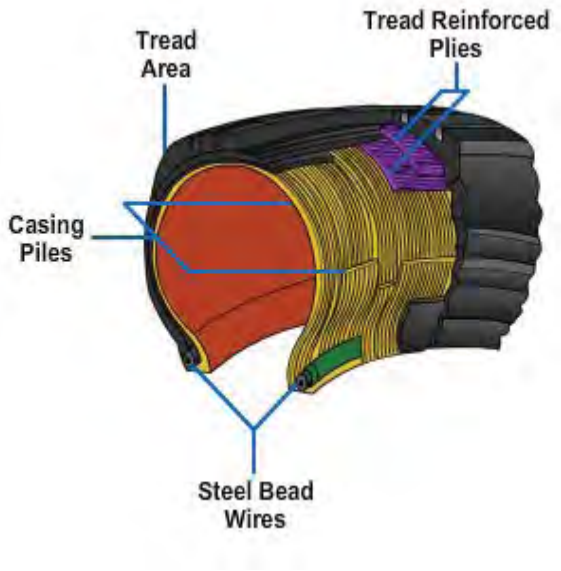


Figure 4-11 – Radial-ply tire construction.

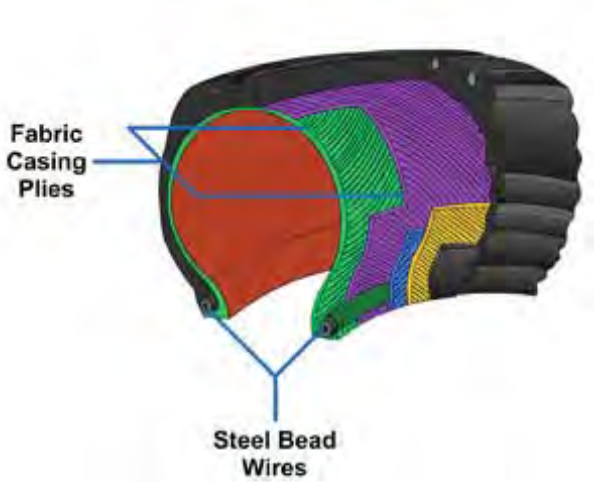


Figure 4-12 – Bias-ply tire construction.

Matching – For longer tire life and more efficient performance, tires on all-wheel drive vehicles and dual wheels must be the same size and tread design and have the same tread wear. Improperly matched tires cause rapid, uneven wear and can also cause transfer case and differential failures.

Accurate matching of tires is necessary, because tires on all-wheel drive vehicles rotate at the same speed when all axles are engaged. Because they are locked together, dual wheels turn at the same speed. Dual wheels as well as driving wheels must have the same circumference and diameter. When one tire of the dual wheels is worn considerably more than the other, the worn out tire cannot carry its proper share of the load and will scrub the road. The result is uneven and rapid wear on both tires and/or tire failure.

Tires should be used in sets. Mixing different types (bias ply, fiber glass belted, radial ply) must be avoided. Snow tires should be of the same size and type of construction as the front tires. Radial-ply tires should always be used in sets.

NOTE

Do not under any circumstances use radial-ply tires with bias-ply tires, on dual wheels or on the same axle.

Mixing tires on a vehicle can cause loss of steering control, inadequate vehicle handling, and potential mechanical damage. These problems vary depending on the stability of the tires used, differences in dimensions, differences in air pressure, and other operating conditions.

3.1.3 Tube and Tubeless

Older tire designs required a separate inner tube made of rubber and a liner known as a boot; however, newer tires designs do not require an inner tube. Instead these tires are tubeless. In tubeless tires, the air is sealed in a space between the outer casing and the rim. This space and the point of contact of the tire against the rim must be airtight. The rim, on which the valve for inflating the tire is mounted, becomes a part of the air-retaining chamber. It is important not to tear or otherwise damage the sealing ribs.

3.2.0 Types of Tire Treads

The outer surface of the tire, which contacts the road, is called the tread. Tire treads are made for specific purposes. The type of equipment you are operating and the type of job you are performing dictate what type of tire and tread you should use. Common types of tires treads are directional, non-directional, cross-country, regular, rock service, and earthmovers.

3.2.1 Directional Tread

The directional mud and snow tread (*Figure 4-13*) is of a V-design with large spaces between the lugs, the projecting parts of the tire. Because of tire rotation and flexing, the spaces between the lugs are kept free from mud and snow, improving traction.

On ***live axles***, directional tread tires are mounted so that the point of the V-design makes contact with the ground first. In this manner, traction is delivered in only one direction.

Figure 4-13 – Directional mud and snow tread.

On dead axles and on ***graders***, directional tread tires are mounted so that the open V-design makes contact with the ground first (*Figure 4-14*). Tires operating in this manner, do not produce traction.

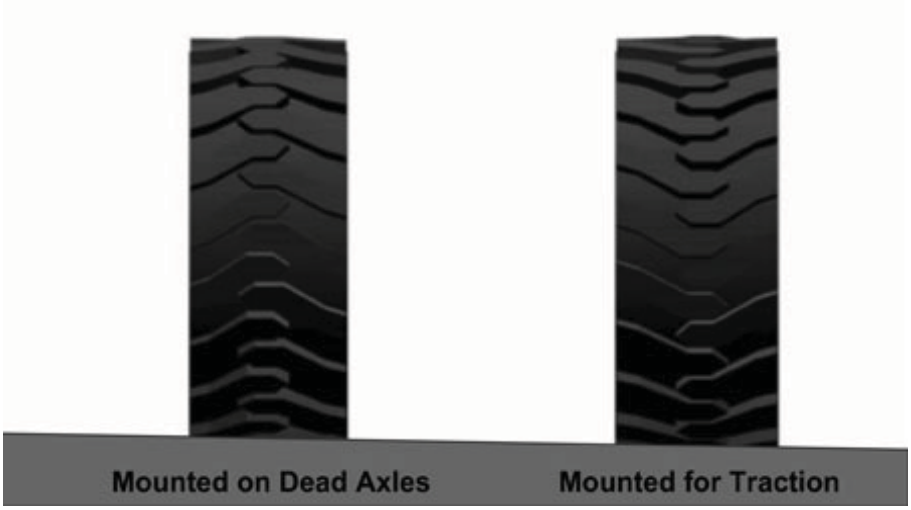


Figure 4-14 – Mounting and rotation of directional tread tires.

3.2.2 Non-Directional Tread

The non-directional mud and snow tread (*Figure 4-15*) also has large spaces between the lugs. The lugs are placed perpendicular to the center line of the tire. This design provides good traction in both forward and backward directions.

Figure 4-15 – Non-directional mud or snow tread.

3.2.3 Cross-Country Tread

The cross-country tread (*Figure 4-16*) is the same as the mud and snow tread, except that the cross-country tread has rounded shoulders.

Figure 4-16 – Cross-country tread.

3.2.4 Regular Tread

Regular tread (*Figure 4-17*) has small spaces between the tread patterns. This allows for a quiet ride and safe driving on wet and dry roads. This type of tread is often used on modern highway tires.

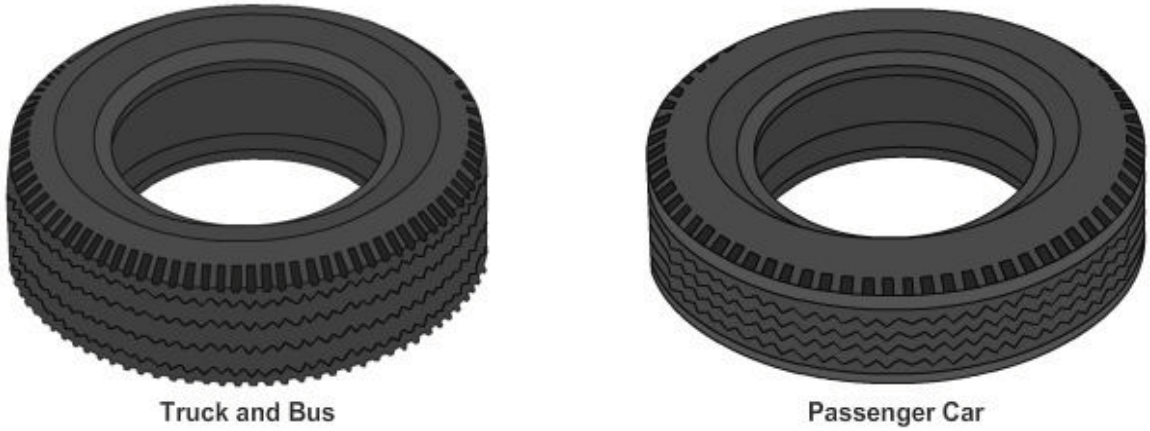


Figure 4-17 – Regular tread.

3.2.5 Rock Service Tread

The rock service tread (*Figure 4-18*) is characterized by narrow voids between lugs. The voids prevent loose rock from getting caught and tearing the tread lugs loose from the tire body. This non-directional tread design is used on rough terrain tires.

Figure 4-18 – Rock service tread.

3.2.6 Earthmover Tread

The earthmover tread (*Figure 4-19*) is used on tires that operate in heavy equipment work areas, such as borrow pits or off-road service.

Figure 4-19 – Earthmover tread.

3.3.0 Valves

Virtually all tires have valves (*Figure 4-20*). Tire valves consist of a stem, a core, and a cap.

3.3.1 Valve Stem

For speed and convenience during tire inflation, the valve stem should be readily accessible. To prevent scraping against the brake drum, it should be properly centered in the valve hole in the tire, and it should be placed so the valve extends through the rim (wheel) as shown in *Figure 4-20.*

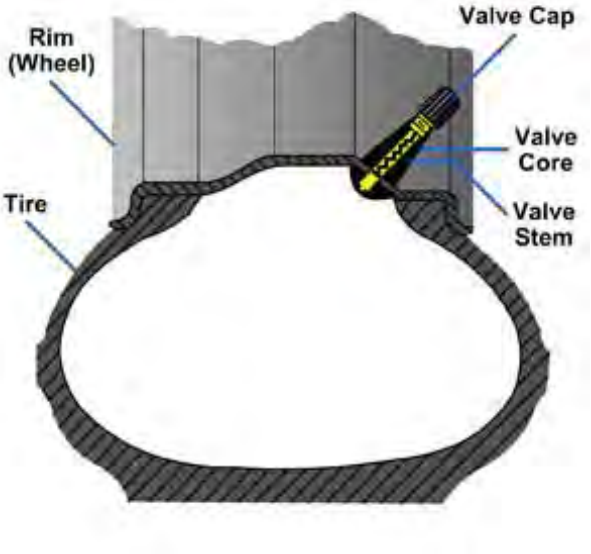


Figure 4-20 – Tire valve.

On dual wheels, the valve on the inner tire should point away from the vehicle. The valve on the outer tire should point towards the vehicle. In this arrangement the valves are between the dual wheels. For convenience in inspecting pressure and inflation, the valves should be 180 degrees from each other (*Figure 4-21)*. In addition, spare tires should be mounted so that the valve is accessible for inspecting and inflating.

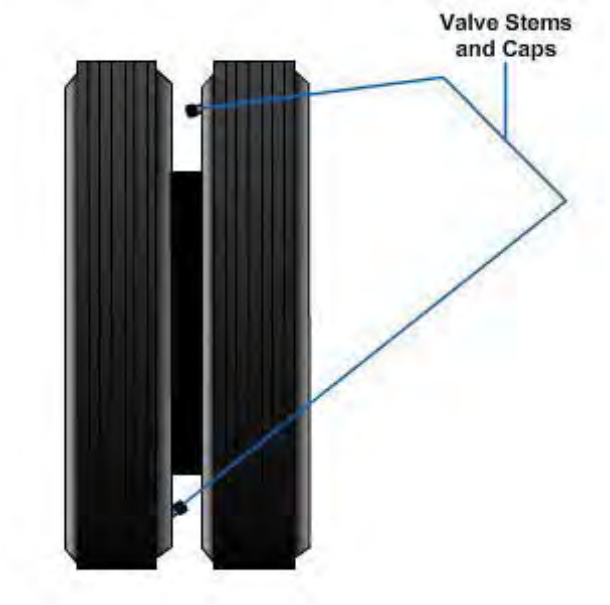


Figure 4-21 – Location of valves on dual wheels.

3.3.2 Valve Cores

The valve core, shown in *Figure 4-20*, is the part of the valve that is screwed into the valve stem and permits air under pressure to enter but prevents it from escaping.

Two types of valve cores and sizes are in use today. The two types are the visible spring type and the concealed spring type (*Figure 4-22*). The two are interchangeable. Valve cores come in two sizes, one for the standard bore valve stem and one for the large bore valve stem.

The core shell has a rubber washer that provides an airtight seal against the tapered seat inside the stem. Directly below the shell is a cup that contains a rubber seat, which, in the closed position, is forced against the bottom of the shell, forming an airtight seal. The pin on top of the valve core, when pushed down, forces the cup away from the shell, permitting air to flow.

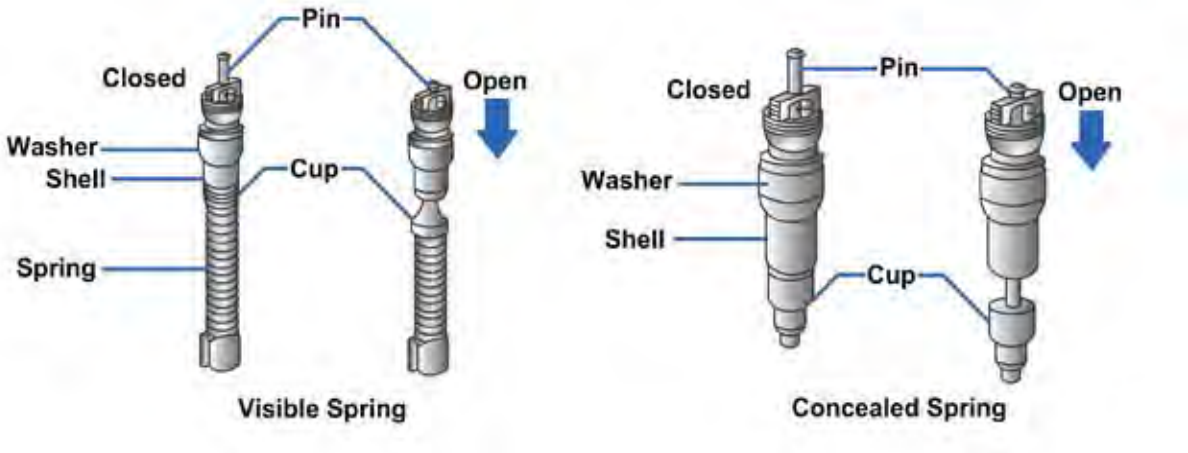


Figure 4-22 – Types of valve cores.

3.3.3 Valve Cap

The valve cap is another component of the valve. Screwed on the end of the stem, the valve protects the stem threads and provides a second airtight seal. In addition, the valve cap keeps dirt and moisture out of the valve body.

There are two types of valve caps: the screwdriver and the plain (*Figure 4-23*). The screwdriver cap has a forked tip that may be used to install or remove the valve core. The plain cap generally is used on rubber-covered valves and has a skirt that contacts the rubber covering on the valve stem. Both caps are interchangeable.

Preventive maintenance includes ensuring that all valve stems have valve caps.

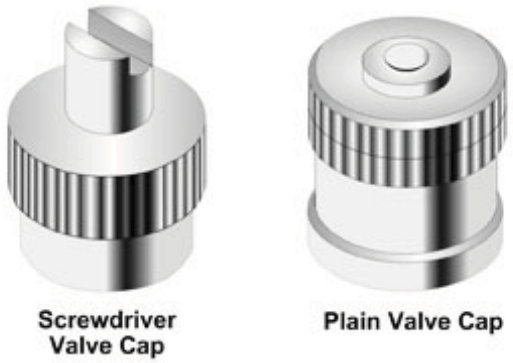


Figure 4-23 – Valve caps.

3.4.0 Types of Rims

The rim is an important part of the tire assembly. The rim is a circular metal structure around which tire is fitted. Rims provide the means of attaching the tires to the vehicle axles. There are single-piece and multi-piece rims.

3.4.1 Single-Piece Rim

The single-piece rim (*Figure 4-24*) has a continuous one piece assembly. Such a rim is normally used with tubeless tires.

Preventive maintenance of single-piece rims includes inspecting for cracks, dents, and out of round stud holes. If such conditions are discovered, the rim must be replaced.

Figure 4-24 – Single-piece rim.

3.4.2 Multi-Piece Rim

The multi-piece rim consists of two or more components, one of which is a side or locking ring that holds the tire and other components on the rim by interlocking the components when the tire is inflated.

Multi-piece rims are normally used with an inner tube and liner. They are common on fuel carts and forklifts. *Figure 4-25* shows the different configuration of multi-piece rims.

Preventive maintenance of multi-piece rims includes inspecting for proper rim components including the side and/or lock ring. In addition, you should inspect for sprung or bent side and/or lock rings. If such conditions are discovered, the rim must be replaced.

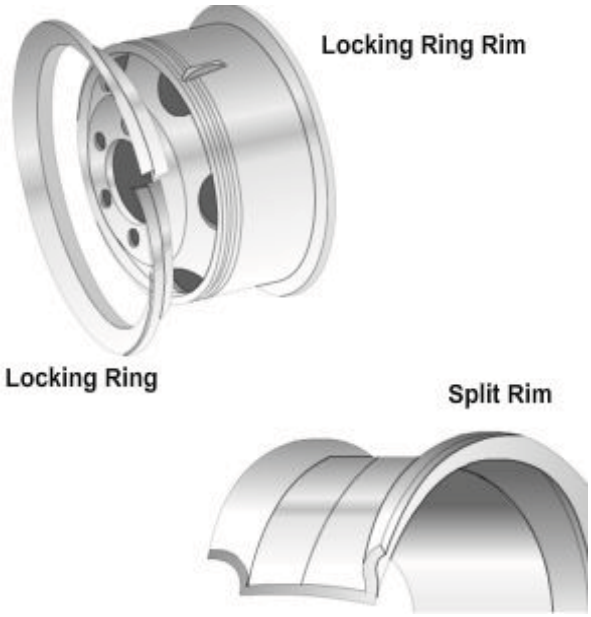


Figure 4-25 – Multi-piece rims.

3.5.0 Tire Inspections

Tires are punctured by sharp objects, bruised by rough roads, and injured by road shocks. Driving with a seriously damaged tire is dangerous. The damaged tire may blow out and cause the operator to lose control of the vehicle.

Before and after operating a vehicle, carefully inspect its tires. Remove glass, nails, rocks, and other foreign materials embedded in tires. Tires give longer mileage, better fuel efficiency, and a more comfortable drive when damage is repaired immediately.

3 5.1 Inflation

Correct air pressure is the basis for reliable tire performance. Tires are designed to operate at specified air pressures for given loads and inflated to the prescribed air pressure for the driving condition.

Properly Inflated – A properly inflated tire, as shown in *Figure 4-26 A*, shows proper contact with the road.

Under Inflated – An underinflated tire is shown in *Figure 4-26 B*. This tire does not contain enough air for its size and the load it must carry. It flexes excessively in all directions and gets hot during operation. The heat can weaken the tire cord, causing the tire to blow out. Under inflation also causes tread edges to scuff the road, putting uneven wear on the tread and shortening tire life. Never run a tire flat, or nearly flat, unless the tactical situation in combat requires it. If a tire runs flat for even a short distance or almost flat for a long distance, it may be ruined beyond repair.

Over Inflated – An over inflated tire is shown in *Figure 4-26 C.* Too much air pressure can also cause tire failure. Excessive pressure prevents the tire from flexing enough, causing hard jolts. When an overinflated tire hits a stone or rut, the cords may snap and cause a break in the cord body. The center of the tread wears more rapidly and does not permit equal wear across the entire tread. Hard riding from too much air pressure also increases wear and tear on the vehicle.

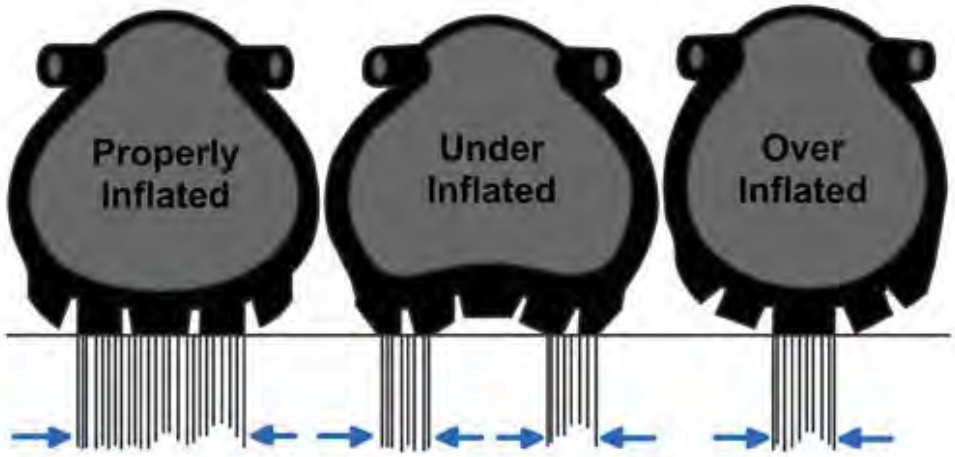


Figure 4-26 – Proper and improper tire inflation.

3.5.2 Air Pressure

Gauges, like the one shown in *Figure 4-27*, measure air pressure in pounds per square inch (psi). Medium Tactical Vehicle Replacements (MTVRs) are issued with a type of gauge that not only measures air pressure but also is used with a hose and air compressor for quick tire inflation.

To measure air pressure using a gauge like the one shown in *Figure 4-27*, simply remove the tire valve cap. Using the chuck, the round end of the gauge, directly and firmly press down onto the valve stem. If you hear a hissing sound, you are releasing air out of the tire, press down harder. The indictor bar, on the opposite end of the gauge, will slide out at a distance corresponding to the pressure in the tire.

Figure 4-27 – Air pressure gauge.

Conveniently, the tire air pressure gauge can be used to adjust an over inflated tire. You can manually release a small amount of air from a tire by lightly applying the chuck to the valve stem. It can also be used to reduce tire pressure before operating in soft sand and over dunes. Doing so, increases the amount of tire surface in contact with the sand, providing better flotation (support). However, never manually reduce the tire pressure so much that the tire slips on its rim. The tire pressure for normal and off-road conditions are usually listed on a data plate on the vehicle's dashboard or in the operator's manual.

MTVRs are equipped with Central Tire Inflation Systems (CTIS). During operation, the CTIS maximizes traction and mobility by checking and adjusting the air pressure in all tires to correspond to the type of terrain. The CTIS also features a light that alerts the operator when substantial damage has occurred to one or more tires.

Whether you manually release air or use the CTIS, when operating with reduced tire pressure, drive at low speed. Additionally, when the situation permits, inflate the tires to normal pressure.

3.5.3 Mechanical Irregularities

Tire wear is often caused by mechanical irregularities, such as imbalanced tires, crocket front-end alignment, and operating an all-wheel drive vehicle with the front-wheel drive engaged on hard-surfaced roads.

When inspecting tires, look for visual signs of wear similar to those shown in *Figure 4-28*. Tire wear must be documented and reported to the maintenance shop.

Figure 4-28 – Visual inspection of tire wear.

3.6.0 Tire Removal

Before removing a tire from a vehicle, ensure the emergency brake is locked and the transmission lever, depending on the type of transmission, is in park, first, or reverse. In addition, locate something suitable with which to block the wheels, such as a wheel chock, a basic issued item on MTVRs. Blocking the wheels prevents the vehicle from rolling as you raise it with the jack. Remember to never block the wheels on the axle you are raising with the jack.

The following are steps for removing a tire from a vehicle or light truck:

Step 1. If the vehicle is equipped with a hubcap, remove the hubcap by using the lug wrench or a suitable substitute.

Step 2. Slightly loosen the bolts or nuts that hold the wheel to the hub.

Step 3. Raise the wheel with the jack and observe the vehicle to ensure that it does not roll while being raised. If the vehicle starts to roll, lower the jack and add additional blocking to the wheels. Also, observe the jack and ensure that it does not sink into the ground from the weight of the vehicle. If the jack shows signs of sinking, move the vehicle to a more stable surface or place a plank of solid wood or steel matting under the jack to spread out the ground-bearing pressure.

Step 4. When the wheel is approximately 1 inch off the ground, finish removing the lug nuts or bolts and remove the tire from the vehicle.

WARNING

Do not leave the vehicle suspended on the jack. If repairs are needed on the vehicle while the tire is removed, place an approved safety stand or suitable blocks under the axle to support the vehicle. If no repairs are needed on the vehicle, install the spare tire as soon as possible. Failing to do so may result in serious injury to personnel or damage to the vehicle.

On split rims, also called dual-disc wheels (*Figure 4-29*), the inner and outer discs are fastened together by two nuts on each hub bolt, one nut for each wheel. With this arrangement, either single or dual wheels can be securely mounted on the same hub. The outer nut must be loosened first to free the outer wheel disc from the hub. Loosening the outer nut, which threads over the inner nut, unfastens the outer wheel disc. In removing split rims, you will find left-hand threads on both inner and outer nuts on the outer wheels and right-hand threads on those on the inner wheels.

To mount and tighten the wheels, simply reverse the procedure described above.

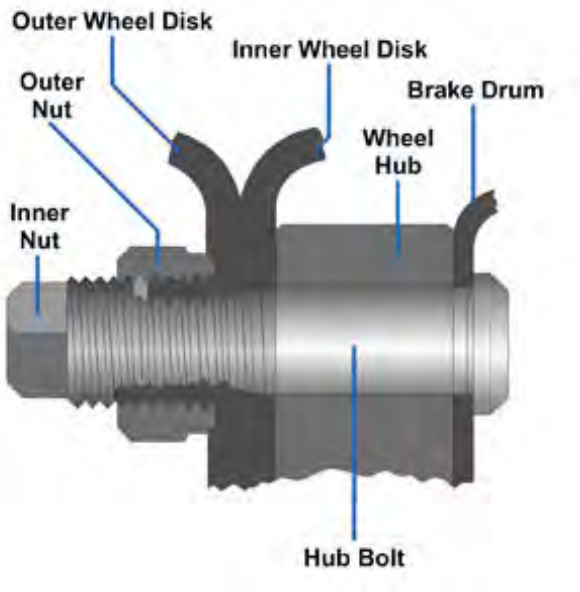


Figure 4-29 – Split rim.

On trucks equipped with spoke wheels, remove the clamps which secure the rim on the spoke wheel (*Figure 4-30*), and lift off the rim with the tire and tube. If the spoke has two tires, you can lift off the second rim after removing the spacer separating the rims. When installing the wheels, remember to install the outer wheel in a position that places the valve stem 180 degrees from the stem on the inner wheel, as shown in *Figure 4-21*.

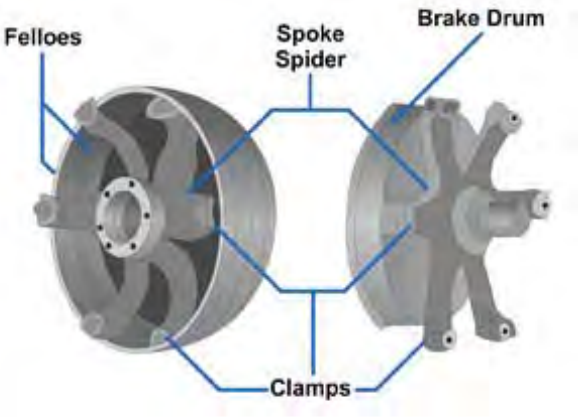


Figure 4-30 – Truck spoke wheels.

WARNING

Possible hazard to personnel if lug nut is removed before clamp is loosened. In addition, some tire and wheel assemblies weigh as much as 500 pounds. Do not attempt to lift or catch tire/wheel assembly without the aid of an assistant and a suitable lifting device. Failure to comply may result in injury or death to personnel.

3.7.0 Tire Repair

Tires are often repaired by using pneumatic tire demounters and spreaders, safety cages, cold patches, and hot patches.

3.7.1 Pneumatic Tire Demounter

The pneumatic tire demounter (*Figure 4-31*) holds the wheel and tire still while it breaks the tire bead loose from the wheel. It has an adapter, for removing the tire from or replacing it on the rim. Pneumatic tire demounters can be manual, hydraulic, or air-operated. The one shown in *Figure 4-31* is a powered-operated demounter for automotive and light truck tires.

Figure 4-31 – Pneumatic tire demounter.

3.7.2 Pneumatic Tire Spreader

The pneumatic tire spreader (*Figure 4-32*) separates the tire beads enough to allow close inspection and maintenance on the inside of the tire.

Remember, when using any tire repair equipment, such as the pneumatic tire demounter and spreader, closely follow the instructions in the operator's manual as well as the instructions posted in tire shop.

Figure 4-32 – Pneumatic tire spreader.

3.7.3 Inflation Safety Cage

The inflation safety cage (*Figure 4-33*) holds the tire in proper position and allows the operator to inflate the tire at a safe distance.

Figure 4-33 – Inflation safety cage.

3.7.4 Cold Patches

Cold patches are used to repair punctures and small breaks or holes in inner tubes and tires. The procedure for applying a cold patch is as follows:

Step 1. Buff or roughen the surface at least 1 inch around the hole. Then clean it with solvent. When a buffer is not available, use the perforated cover of the kit as a scraper.

Step 2. Apply a thin coat of rubber patching cement evenly over the roughened surface and allow it to dry.

Step 3. From the kit, choose a patch of the proper size, about 3/4 inch larger than the hole in the inner tube. Remove the protective covering from the sticky side of the patch; place the patch over the hole, and rub it down firmly.

Step 4. Inflate the inner tube enough air to check for leaks. If you cannot hear or feel air escaping from the patch, you can make another check by inserting the patched area in water. If there are no escaping air bubbles, the inner tube may be dried and replaced.

3.7.5 Hot Patches

Hot patches consist of a slow burning block of fuel held in a notched metal pan on the bottom of which is a patch of uncured rubber. To apply a hot patch, follow the manufacturer's instructions on the kit.

Although methods of applying hot patches vary with the clamping devices provided and the shape of the patch, you will still clean and roughen the tube just as you did in applying the cold patch. Place the patching unit in the notches of the patch and clamp it to the tube, ignite the burning material and allow it to burn, then remove it after it has cooled for at least 5 minutes. After this, examine the completed patch to see if the edges of the patching material are attached securely to the tube. Then install the valve core and test the tube. Hot patches of assorted sizes are supplied in kits similar to cold patch kits. You will also find pressure clamps and roughening tools in the hot patch kits.

3.7.6 Tire Equipped with Locking Ring

Unless your tire shop is well equipped, it may not have the machinery required for repairing some truck tires, such as those with split rims or those equipped with side or locking rings, or the machinery it has may not work on those types of tires.

When repairing tires equipped with locking rings, first remove the valve core and deflate the tire. Force the tire bead away from the removable side ring with a slide hammer device intended for this purpose. Next, remove the side ring. Turn the wheel and tire over and loosen the other bead. Once the beads are broken, the tire can be removed from the rim by standing the tire on the thread and prying the wheel out of the tire. Ensure the valve stem is not bent or damaged as the wheel is removed.

To replace the tire, position the wheel. Lower the tire over the rim, and at the same time, make sure the valve stem is passed through the valve hole and points upward.

NOTE

The valve stem should always point towards the locking ring. If there is no locking, or side ring, the valve stem should point towards the disc portion of the wheel.

The next step is to center the side ring and force one end into position with your foot. You can merely walk around the top of the ring and force it to slide into the locking groove. Inflating a tire mounted on a locking ring rim is dangerous. An improperly seated lock ring may blow off, causing serious injury to any person in its path. If a locking ring is difficult to install, it may be sprung and using it is a safety hazard. Before applying air pressure to this tire, be sure that the locking ring is seated against the rim of the wheel through its entire circumference. If the lock ring does not seat properly, inflate it to 5 to 10 pounds, then tap the locking ring carefully with a mallet.

When you must inflate a tire that is already mounted, use a snap-on chuck, which is an air hose that snaps onto the valve stem. This allows you to stand to one side of the tire. Make it a professional practice always to stand away from a tire while it is being inflated.

Figure 4-34 shows how to repair a tire equipped with a locking ring.

Figure 4-34 – Repairing a tire equipped with a locking ring.

3.7.7 Tubeless Tire Repair

Before replacing a tubeless tire, examine the rim carefully for dents, roughness, and rust; any defects may impair or break the air seal. Straighten out any dent with a hammer, and use steel wool or a wire brush to clean out any rust or grit in the bead seat area. After cleaning, paint any bare metal spots where the tire bead seats so that the tire is easier to remove later. If the rim is badly damaged, replace it with a new one.

The procedure for repairing a tubeless tire is as follows:

Step 1. Inspect the inside of the tire and remove nails or other damaging items. Then scrape the damaged area with a sharp-edged tool and buff. Be careful not to damage the liner or expose any cords.

WARNING

Serious injury can result using your bare hand to feel for obstructions, use a rag to feel inside the tire.

Step 2. Lubricate the hole by pushing bonding compound into it from both sides of the tire. Also, pour bonding compound on the insertion tool and push it through the hole with a twisting motion until it can be inserted and withdrawn easily.

Step 3. Place a plug slightly larger than the hole in the tire in the eye of the insertion tool hole. Wet the plug with bonding compound. Always pour it directly from the can so the compound in the can does not become contaminated.

Step 4. While stretching and holding the plug with your hand, insert the plug into the hole from the inside of the tire. Stretch and hold the plug until it is forced into the hole and one end extends through it.

Step 5. After the plug extends through the tire, remove the insertion tool and cut off the plug approximately 1/16 inch above the surface.

Step 6. When using a cold patch, carefully remove the backing from the patch and center the base of the patch on the damaged area. Stitch the patch down firmly with the stitching tool working from the center out.

Step 7. When using a vulcanizing hot patch, cover the area with a light coat of glue and allow it to dry. This glue normally comes with the hot patch kit. Remove the backing from the patch and center it on the damaged area. Clamp it finger tight, apply heat, allow it to cure and then cool.

NOTE

Each patch or plug kit should contain specific instructions.

Figure 4-35 shows how to repair a tire puncture.

Figure 4-35 – Repairing a tire puncture.

You can repair a punctured tire without removing it from the rim. In this case, insert the plug from the outside in.

NOTE

On radial-ply tires, repairs can only be made in the central tread area between the major grooves.

The procedures for removing and remounting a tubeless tire are similar to those for tube tires. If the seal is broken or defective, use a tube inside the tire; otherwise, the tire will lose air, and you will have to inflate it frequently. Some tubeless passenger car tires must be removed from the backside of the rim to prevent stretching the bead wires too far, causing them to break. If in doubt about any detail of the procedure for changing tubeless tires, follow the tire manufacturer's instruction or consult the maintenance supervisor.

3.7.8 Earthmover Tire Repair

When a tire sustains major damage or blowout or reaches its normal wear limits, it must be removed. Size alone makes removal and replacement of earthmover tires difficult. Additionally, the rough terrain on which the Operator must repair the tire is far from ideal. Certain tools are necessary to change these large tires. The hydraulic bead

breaker is a clamping device specifically designed to break the giant beads for easier tire removal.

For maximum safety, before attempting to remove the tire, make sure that the wheel has been jacked up and the equipment is properly blocked from rolling. After the equipment has been safely cribbed, deflate the tire completely by removing the valve core.

Clamping Device –
The clamping device (*Figure 4-36*) is used to aid in breaking the tire beads. Attached to the rim flange, it holds the hydraulic ram and shoe assembly. When securing the clamping device to the rim, release the primary clamping device to permit a vertical position, as shown in *Figure 4-36*. Then hold the clamping device in place with one hand and with the other hand, tighten the larger clamping screw lightly. Swing the reaction screw, until it is approximately perpendicular to the side of the rim flange. Turn the reaction screw to a vertical position, as shown. Tighten the primary clamping screw firmly by hand.

Figure 4-36 – Clamping Device.

When the clamping device is secured in place, turn the handle on the bottom of the reaction screw. This handle swivels up and down to permit maximum movement of the clamping device side arms to ease hooking the ram cylinder into place.

The hydraulic cylinder and shoe assembly (*Figure 4-37*) are actuated by a pump. The pump applies hydraulic pressure to force the ram with the attached shoe down between the rim flange and tire bead. This action separates the tire bead from the rim.

When securing the ram to the clamping device, place the ram and shoe assembly between the arms of the clamping device where the bracket of the cylinder is secured into the notches of the clamping device side arms, as shown in *Figure 4-37*.

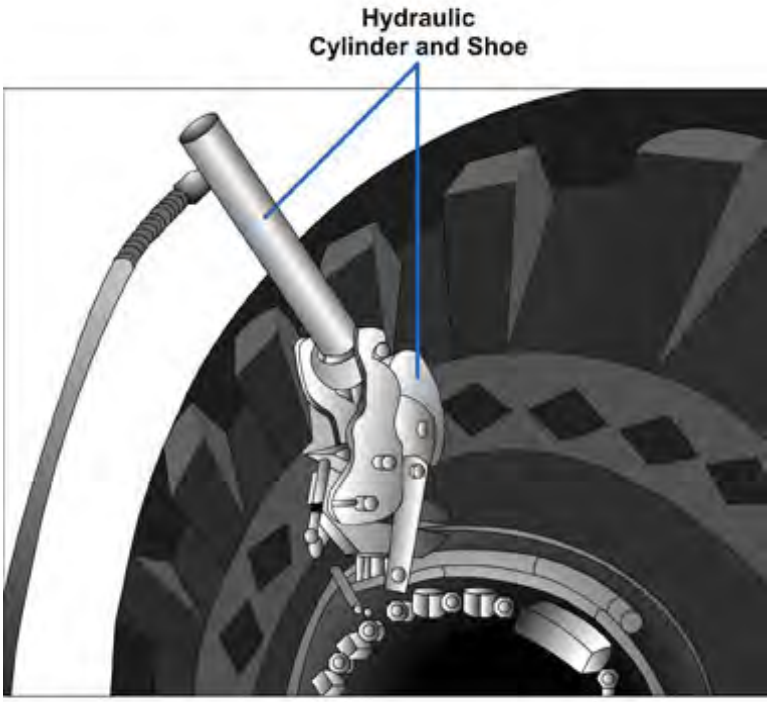


Figure 4-37 – Hydraulic cylinder and shoe.

Applying pressure to the hydraulic cylinder forces the shoe down over the clamping device, as shown in *Figure 4-37.* The jaw of the clamping device acts as a guide for the shoe. The convex side of the shoe bears against the sidewall of the tire, forcing it inward between the tire bead and rim flange, thus breaking loose the bead from the rim.

Figure 4-38 shows how the wedges are placed on each side of the shoe assembly to hold the bead of the tire away from the rim flange for easy removal of the shoe assembly. After forcing the shoe between the tire bead and rim flange and freeing it from that portion of the tire bead, insert the wedges to keep the tire bead separated from the rim. Then remove pressure slowly from the hydraulic cylinder. Then remove the hydraulic cylinder and clamping device from the rim and place the clamping device approximately 90 degrees from the wedge. Continue this process until the tire bead is completely free from the rim flange.

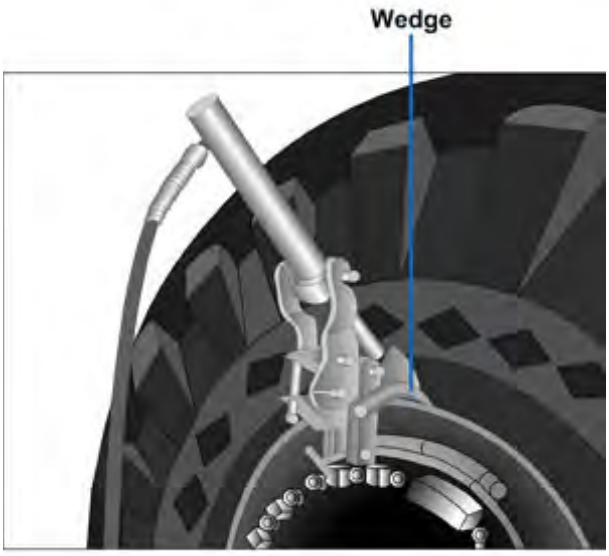


Figure 4-38 – Operation of hydraulic cylinder and shoe.

3.8.0 Tire Rotation

Tire manufacturers recommend rotating tires, or changing them from one wheel to another, so that they wear evenly. Tire rotation is performed to the manufacturer's specification for each vehicle. *Figure 4-39* shows three examples of tire rotations.

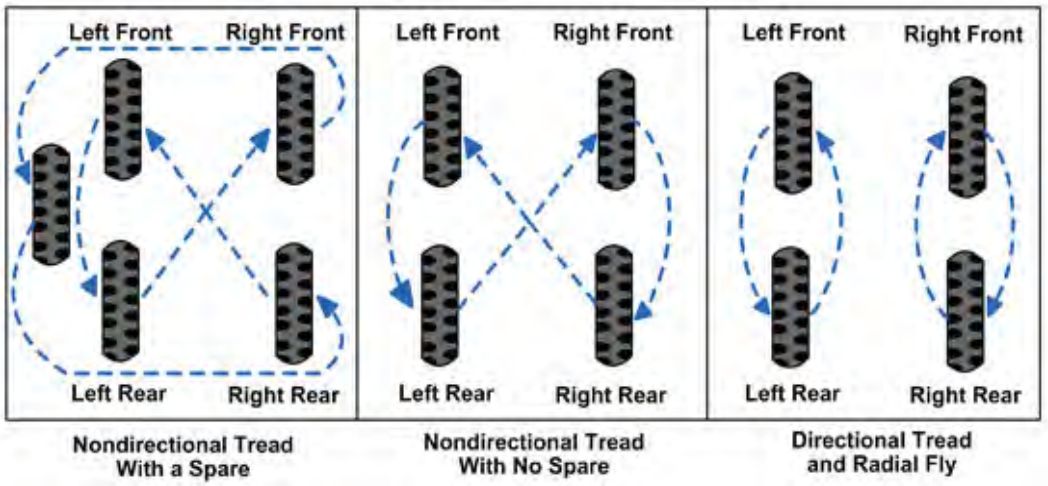


Figure 4-39 – Tire rotations.

3.8.1 Tire Safety

In most commands, the maintenance supervisor supervises the tire shop. When you are assigned to the tire shop, the maintenance supervisor should ensure that you are briefed on tire safety. The shop supervisor, the tire shop foreman, or the crew leader may conduct this brief.

People inexperienced in tire repair should only repair tires under the direct supervision of an experienced person. Additionally, always refer to the appropriate manufacturer's manuals for directions and instructions and remember: SAFETY COMES FIRST.

Test your Knowledge (Select the Correct Response)

5. **(True or False)** Improperly matched tires can cause transfer case and differential failure.

   A. True
   B. False

6. On duals wheels, the valve of the outside dual is placed at what degrees from the valve on the inside dual?

   A. 30
   B. 90
   C. 120
   D. 180

7. What condition prevents a tire from flexing and causing hard jolts?

   A. Over inflated tires
   B. Under inflation tires
   C. Traveling on a gravel road
   D. Traveling in a quarry

8. **(True or False)** When you raise a vehicle with a jack, always block the wheels on the axle that is being raised with the jack.

   A. True
   B. False

9. On an inner tube to be patched, you should buff or roughen the surface at least how many inches around the hole to be patched?

   A. 1/2 inch
   B. 1 inch
   C. 1 1/2 inch
   D. 2 inches

10. When assembling a tire equipped with a lock ring that does NOT seat properly, you should inflate the tire with how many pounds of air pressure before tapping the lock ring with a mallet?

    A. 5 to 10 pounds
    B. 15 to 20 pounds
    C. 25 to 30 pounds
    D. 35 to 40 pounds

11. When plugging a tire, you should cut the plug at approximately what distance from the surface?

    A. 3/4 inch
    B. 1/2 inch
    C. 1/4 inch
    D. 1/16 inch

4.0.0 BRAKE SYSTEMS

Good brakes are critical for ensuring the safe operation of vehicles and equipment. The brake system must not only stop the vehicle or equipment, it must do so in a smooth and uniform manner. In order to accomplish this, the brake system relies on friction.

Friction is the resistance in relative motion between two surfaces in contact with each other. When a stationary surface is forced into contact with a moving surface, the rubbing action between the two surfaces slows down the moving surface. In nearly all brake systems, the brake drums provide the moving surface, and the brake shoes provide the stationary surface. The friction between the brake drum and the brake shoes slows the drum and wheel, and the friction between the tire and the road surface slows and stops the vehicle or equipment.

4.1.0 Individual Service Brakes

On modern equipment, individual service brakes are provided for each wheel and are operated by a foot pedal. Modern equipment also has emergency and/or parking brakes operated by a separate pedal or hand lever.

Individual service brakes are classified as external contracting brake, internal expanding brake, disc brake, and mechanical parking brake.

4.1.1 External Contracting Brakes

External contracting brakes (*Figure 4-40*) are sometimes used for parking brakes on motor vehicles and cranes and for controlling the speed of auxiliary equipment drive shafts. In operation, moving the brake lever tightens the brake band (or shoe) of an external contracting brake around the rotating drum. The brake band is made of comparatively thin, flexible steel, shaped to fit the drum, with a frictional lining riveted to the inner surface. This flexible band cannot withstand the high pressure required to produce the friction needed to stop a heavily loaded or fast-moving vehicle, but it works well as a parking brake or hold brake. *Figure 4-41* shows an external contraction brake in operation.

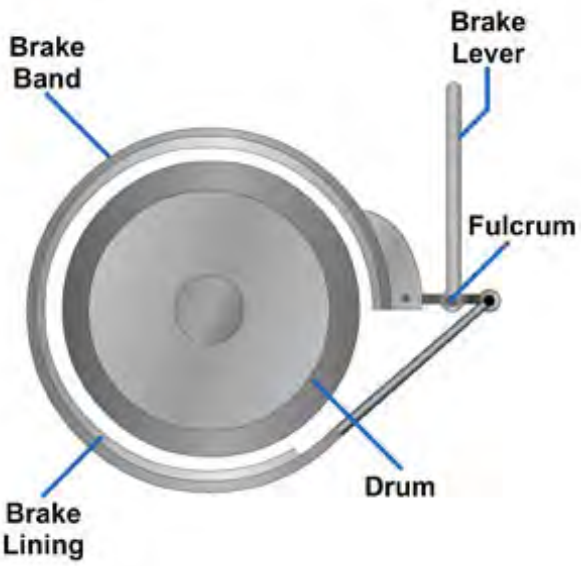


Figure 4-40 – External contracting brake.

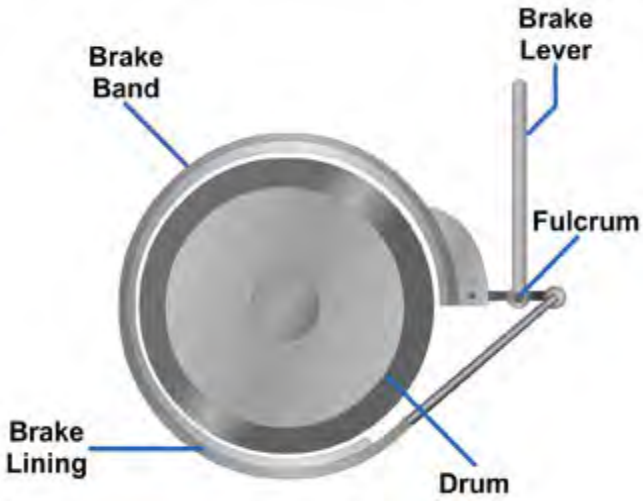


Figure 4-41 – External contracting brake in operation.

Figure 4-42 shows an external contracting transmission parking brake. The brake band is anchored opposite the point where pressure is applied. In addition to supporting the band, the anchor allows adjustment of the brake lining clearance. Other adjusting screws and bolts are provided at the ends of the band.

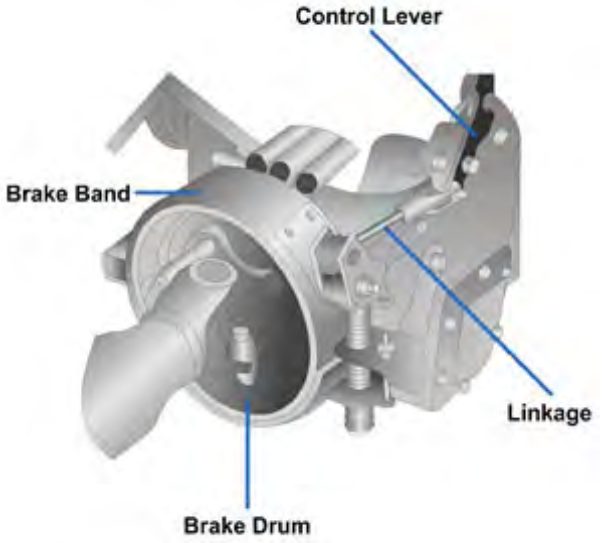


Figure 4-42 – External contracting transmission parking brake.

4.1.2 Internal Expanding Brakes

Internal expanding brakes are used almost exclusively as wheel brakes, but can be found on some cranes. This type of brake permits a compact and economical construction. The brake shoe and brake-operating mechanism are supported on a backing plate or brake shield attached to the vehicle axle, as shown in *Figure 4-43*. The brake drum is attached to the rotating wheel. It acts as a cover for the shoe and operating mechanism and furnishes a frictional surface for the brake shoes.

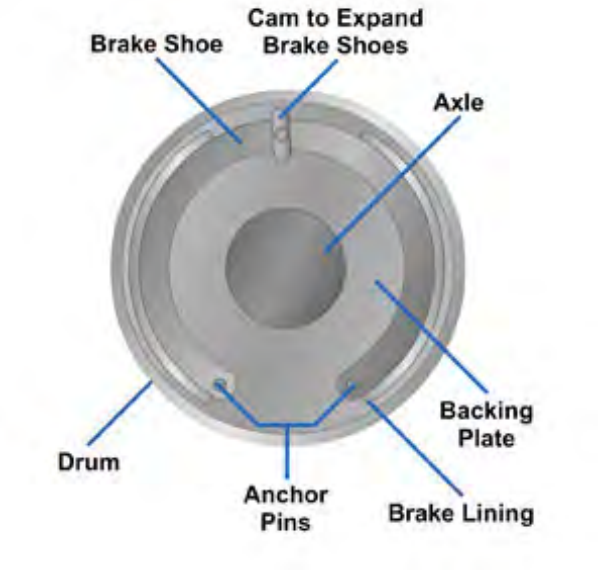


Figure 4-43 – Internal expanding brake.

The brake shoe of an internal expanding brake is forced outward against the drum to produce the braking action. One end of the shoe is hinged to the backing plate by an anchor pin, while the other end is unattached and can be moved in its support by the operating mechanism. When force from the operating mechanism is applied to the unattached end of the show, the shoe expands and slows down the motion of the wheel. A retracting spring returns the shoe to the original position when braking action is no longer required. *Figure 4- 44* shows the operation of an internal expanding contracting brake.

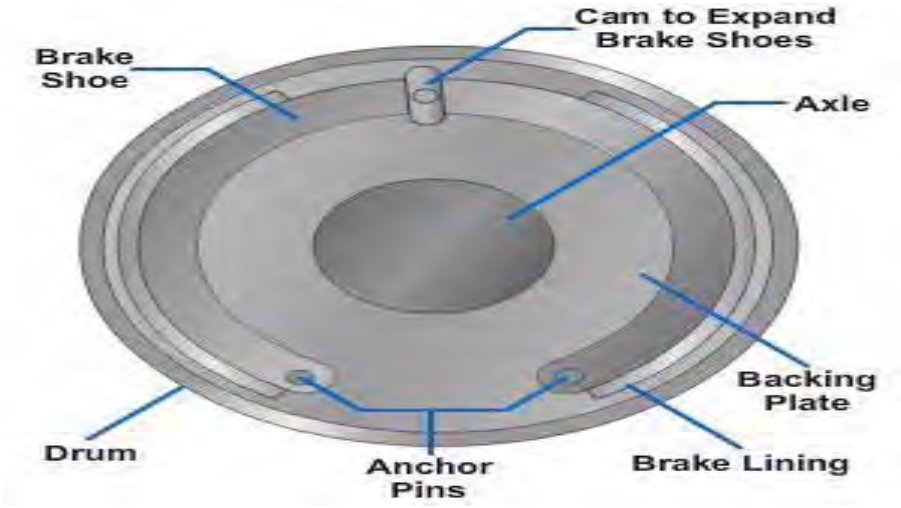


Figure 4-44 – Internal expanding brake in operation.

4.1.3 Disc Brakes

The disc brake has a metal disc (rotor) and a pair of flat brake pads instead of a drum and curved brake shoes. *Figure 4-45* shows a sectional view of a disc brake assembly. The two flat pads are on the two sides of the disc. The assembly which holds the flat pads is called the caliper assembly. In operation, the movement of the piston in the caliper assembly forces the pads against the two sides of the disc. The piston is actuated by hydraulic pressure from the master cylinder. The effect is to clamp the rotating disc between the stationary pads, as shown in *Figure 4-46.*

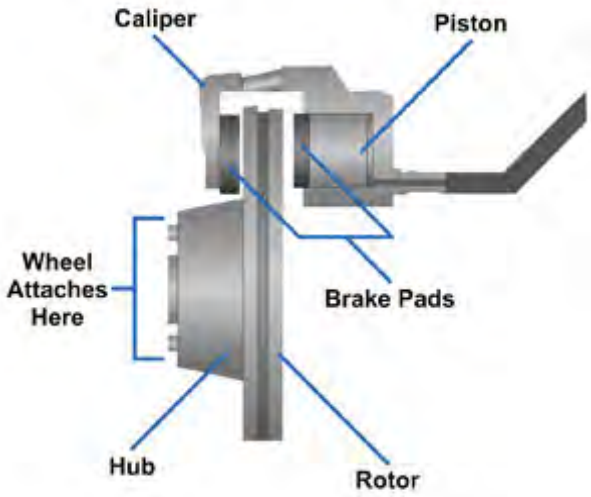


Figure 4-45 – Sectional view of a disc brake.

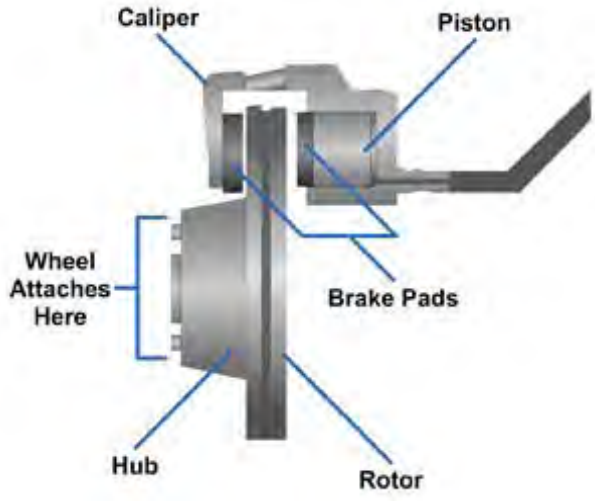


Figure 4-46 – Disc brake in operation.

4.1.4 Mechanical Parking Brake

In most vehicles, a hand lever or foot pedal engages the parking brake. The parking brake has its own system and can be either an external contracting brake on the drive shaft (*Figure 4-47 A*) or a mechanical linkage that works the rear wheel brakes (*Figure 4-47 B*).

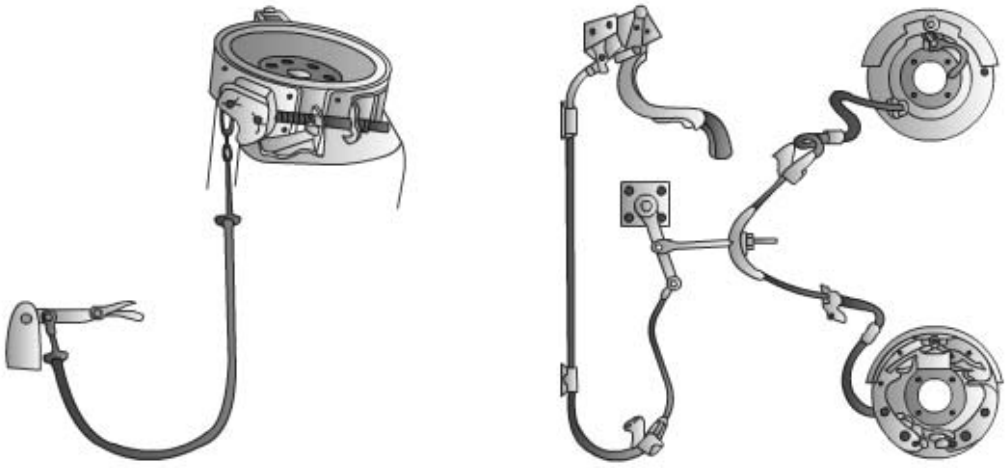


Figure 4-47 – Parking break configuration.

4.2.0 Hydraulic Brake System

The hydraulic brake system is primarily a liquid connection or coupling between the brake pedal and the individual brake shoes and drums.

Figure 4-48 shows a hydraulic brake system consisting of one master cylinder. The master cylinder serves as a reservoir for the brake fluid. It contains pistons and valves which change mechanical force to hydraulic pressure when the operator depresses the brake pedal.

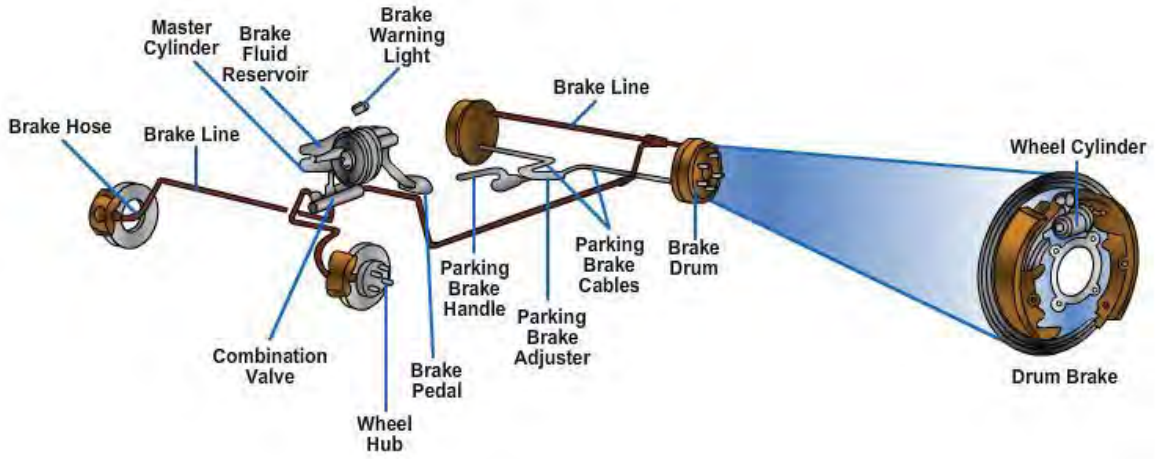


Figure 4-48 – Typical hydraulic brake system.

The pressure on the brake pedal moves the piston within the master cylinder. The piston forces the brake fluid from the master cylinder through tubing and flexible hoses to the wheel cylinders. The wheel cylinders control the movement of the break shoes at each wheel.

As pressure on the pedal increases, greater hydraulic pressure builds up within the brake cylinders and exerts greater force against the brake drum or brake discs, stopping the wheels.

When the operator releases pressure on the pedal, the retracting springs on the brake shoes return the wheel cylinder pistons to their released positions. This action forces the brake fluid back through the flexible hose and tubing to the master cylinder.

Hydraulic brakes are self-equalizing brakes. If the actuating pistons were all the same size, each brake in the hydraulic system would receive an identical hydraulic force when the brakes were applied, because a force exerted at any point upon a closed liquid is distributed equally through the liquid in all directions at the same time. All brake systems have larger wheel cylinders in the front than in the rear because when a vehicle stops, weight automatically shifts forward due to inertia, requiring more front-wheel braking.

The operation of a dual system master cylinder is basically the same as a single master cylinder. However, the dual system master cylinder has two separate hydraulic pressure systems. One is normally connected to the front brakes, the other to the rear brakes. If either the system fails, the other remains operational.

The master cylinder, like other parts in the brake system, is subject to wear, leaks, and deposits or corrosion on the cylinder wall and piston. Part of your pre-start operation is to check the cylinder reservoir fluid level and add clean brake fluid to maintain the manufacturer’s specifications.

The brake lines transmit fluid and pressure from the master cylinder to the wheel cylinders, which are mounted on the brake-backing plate, and change the hydraulic pressure into mechanical force. Inside each cylinder two pistons move in opposite directions by hydraulic pressure. This movement pushes the brake shoes against the brake drum or disc. The brake shoes are made of steel that transmits force to the lining attached to the face of the shoe, which makes contact with the brake drums or discs. During contact with one another, the lining and the drum or disc create the frictional surface that gives the braking effect.

4.3.0 Air Brake System

The air brake system uses compressed air to apply the brakes. Air under pressure can be conveniently stored and carried through lines or tubes. Considerable force is available for braking since operating air pressure may be as high as 100 psi.

Figure 4-49 shows the location of basic air brake system components. These include a brake pedal, a hand brake valve, an air pressure gauge, an air compressor, a safety valve, a governor, and air tanks.

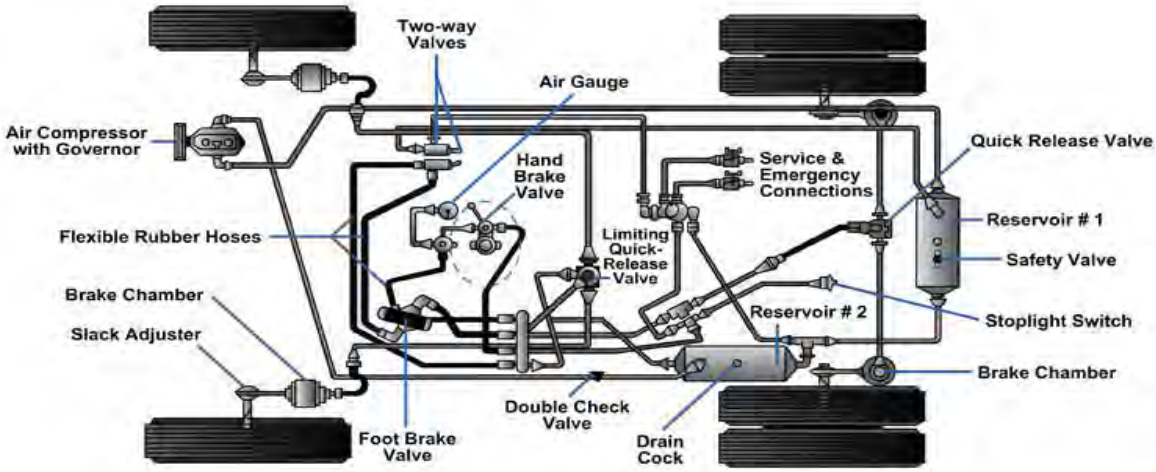


Figure 4-49 – Typical air brake system.

4.3.1 Brake Pedal

The operator applies brakes by depressing the brake pedal, also called the foot valve or treadle valve. It gives the operator control of the air brake system. When the brake pedal is engaged, air from the air tanks flows through the brake pedal valve through the brake lines to the brake chambers close to the wheel brakes. These chambers contain flexible diaphragms. The force of the air admitted into the chambers causes the diaphragms to operate the brake shoes through a mechanical linkage.

Pushing the pedal down harder applies more air pressure. Letting up on the brake pedal reduces the air pressure and releases the brakes. Releasing the brakes allows some compressed air out of the system; therefore, the air pressure in the tanks is reduced and the tank must be recharged by the air compressor. Pressing and releasing the pedal unnecessarily may release air faster than the compressor can replace it, and should the pressure become too low, the brakes cannot work properly and brake failure will occur.

4.3.2 Hand Brake Valve

All brakes on a vehicle and on a trailer (when one is used) are operated together by a brake valve. Independent control of brakes is necessary under bad conditions, especially if you have to put on the trailer brakes without applying the truck or tractor brakes. The hand brake valve or independent trailer control valve, shown in *Figure 4-50*, provides the operator control of the trailing load at all times.

Figure 4-50 – Hand brake valve on a MTVR, truck-tractor.

4.3.3 Air Pressure Gauge

The air pressure gauge lets you know if you have proper air pressure within the reservoir. A low air warning device should turn on before the pressure drops below 60 psi in the air tank. This gauge is usually on the vehicle's instrument panel. If the pressure fails to build up or exceeds the maximum limit, secure the truck until the fault is corrected.

4.3.4 Air Compressor

The air compressor pumps air into the air storage tanks (reservoirs). The air compressor is driven by the engine through gears or a V-belt. The compressor may be air-cooled or may be cooled by the engine lubrication system. It may have its own oil supply or be lubricated by engine oil. If the compressor has its own oil supply, be sure to check the oil during your pre-start check.

4.3.5 Safety Valve

The safety relief valve is installed in the first tank into which the air compressor pumps air. The safety valve protects the tank and the rest of the system from excessive pressure. The valve is usually set to open at 150 psi. If the safety valve has to release air pressure, something is wrong in the air brake system. This problem should be documented and reported to the mechanic inspectors.

4.3.6 Governor

The governor controls the air compressor output. When air tank pressure rises to the cutout level, about 125 psi, the governor stops the compressor from pumping air. When the tank pressure falls to the cut-in pressure, about 100 psi, the governor allows the compressor to start pumping again.

4.3.7 Air Storage Tanks

The air storage tanks (reservoirs) are used to hold compressed air. The number and size of air tanks varies among vehicles. The tanks hold enough air to allow use of the brakes several times, even if the compressor stops working.

NOTE

Compressed air usually has some water and some compressor oil in it, which is bad for the air brake system. The water can freeze in cold weather and cause brake failure. The water and oil tend to collect in the bottom of the air tank; therefore, each air tank is equipped with a drain valve in the bottom.

There are two types of drain valves: automatic and manual. Automatic drain valves automatically expel the water and oil. An automatic valve system may also be equipped with a manual drain valve.

Manual drain valves similar to those shown in *Figure 4-51*, are operated by pulling a cable. Other types of manual valves are operated by turning the valve a quarter turn. Part of your post-operational procedures is to drain all air tanks at the end of each day.

Figure 4-51 – Manual drain valves on trailer.

4.3.8 Alcohol Evaporator

Some air brake systems have an alcohol evaporator to put alcohol into the air system. This helps reduce the risk of ice in air brake valves and other parts during cold weather. Ice inside a brake system can make the brakes non-operational.

If your vehicle has an alcohol system, inspect the container during each pre-start check and fill it up as necessary. Daily draining of the air tanks is still required to get rid of the water and oil.

4.4.0 Air-Over Hydraulic Brake System

*Figure 4-*52 shows an air-over hydraulic brake system. This system combines the use of compressed air and hydraulic pressure for brake operation.

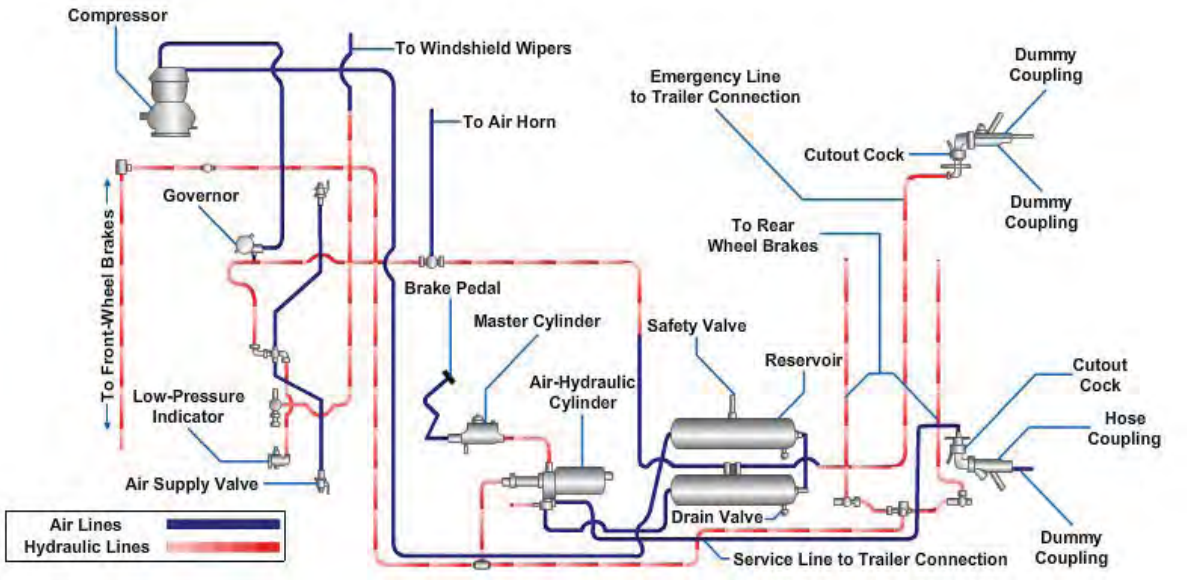


Figure 4-52 – Typical air-over hydraulic brake system.

The air-over hydraulic break system has an air-over hydraulic power cylinder (*Figure 4-53*) that contains an air cylinder and a hydraulic cylinder in tandem. Each cylinder is fitted with a piston and a common rod. The air piston is of greater diameter than the hydraulic piston. This difference in the two pistons results in much greater hydraulic pressure than air pressure admitted to the air cylinder. Valve action varies with the amount of pressure applied to the brake pedal. When the operator applies heavy brake pedal pressure for hard braking, the hydraulic pressure in the master cylinder (which operates the valves) causes greater valve movement. As a result, the valve admits more air pressure into the air-over-hydraulic power cylinder and this higher air pressure causes a stronger braking action.

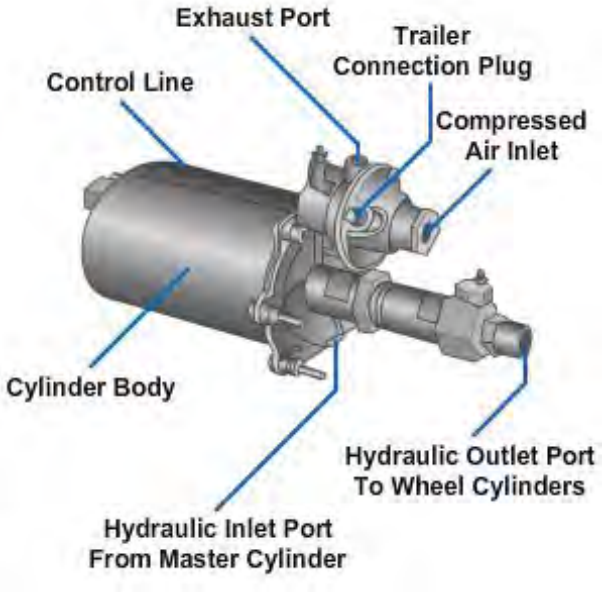


Figure 4-53 – Air-over hydraulic power cylinder.

4.5.0 Vacuum Brakes

In the vacuum brake system, depressing the brake pedal opens a valve between the power cylinder, which contains a piston, and the intake manifold to which the power cylinder is connected. When you apply the brakes, air is exhausted from the cylinder head of the piston. At the same time, atmospheric pressure acts on the rear side of the piston to exert a powerful pull on the rod attached to the piston.

When the brake valve is closed, the chamber ahead of the piston is shut off from the intake manifold and is opened to the atmosphere. The pressure is then the same on both sides of the piston; therefore, no pull is exerted upon the pull rod. The brakes are released and the piston returned to its original position in the power cylinder by the brake shoe return springs. *Figure 4-54* shows a vacuum brake in operation.

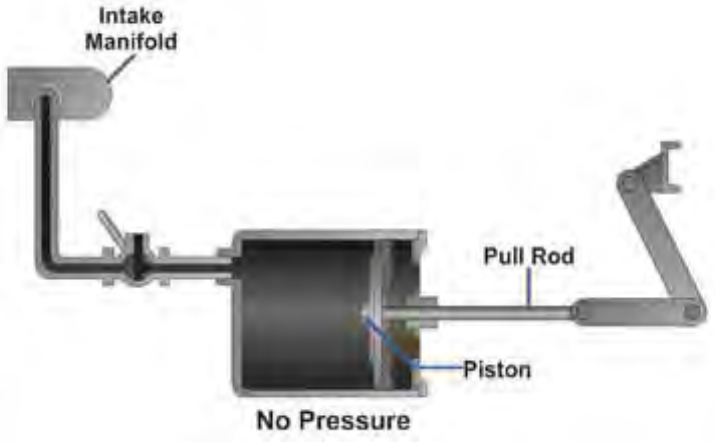


Figure 4-54 – Vacuum brake in operation.

HydrovacTM (*Figure 4-55*) is a trade name for a one-unit vacuum power-braking system. It combines a hydraulic control valve, a vacuum power cylinder, and a hydraulic slave cylinder into one assembly. This assembly is connected to both the master cylinder and the wheel brakes and eliminates the need for mechanical connections with the brake pedal.

Pressure on the brake pedal forces fluid from the master cylinder through the check valve to the slave cylinder and to the wheel cylinders. Also, the foot pedal pressure, acting through the master cylinder, acts against the slave cylinder piston to help the vacuum pistons and pushrods press against the brake shoes.

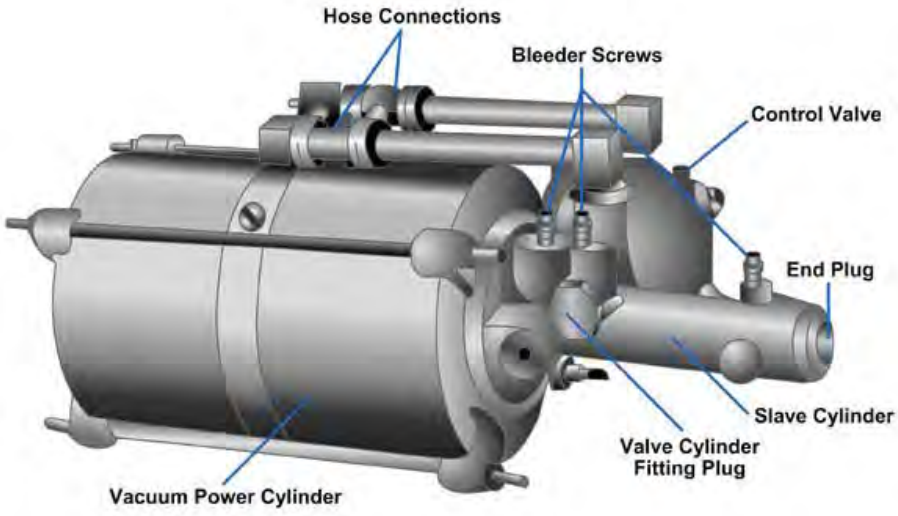


Figure 4-55 – HydrovacTM power cylinder.

4.6.0 Anti-Lock Brake System

The anti-lock brake system (ABS) provides control during braking. Skidding causes a high percentage of vehicle accidents on the highway and the ABS (*Figure 4-56*), also known as a skid control brake system, uses wheel speed sensors, hydraulic valves, and an on-board computer to prevent or limit tire lockup.

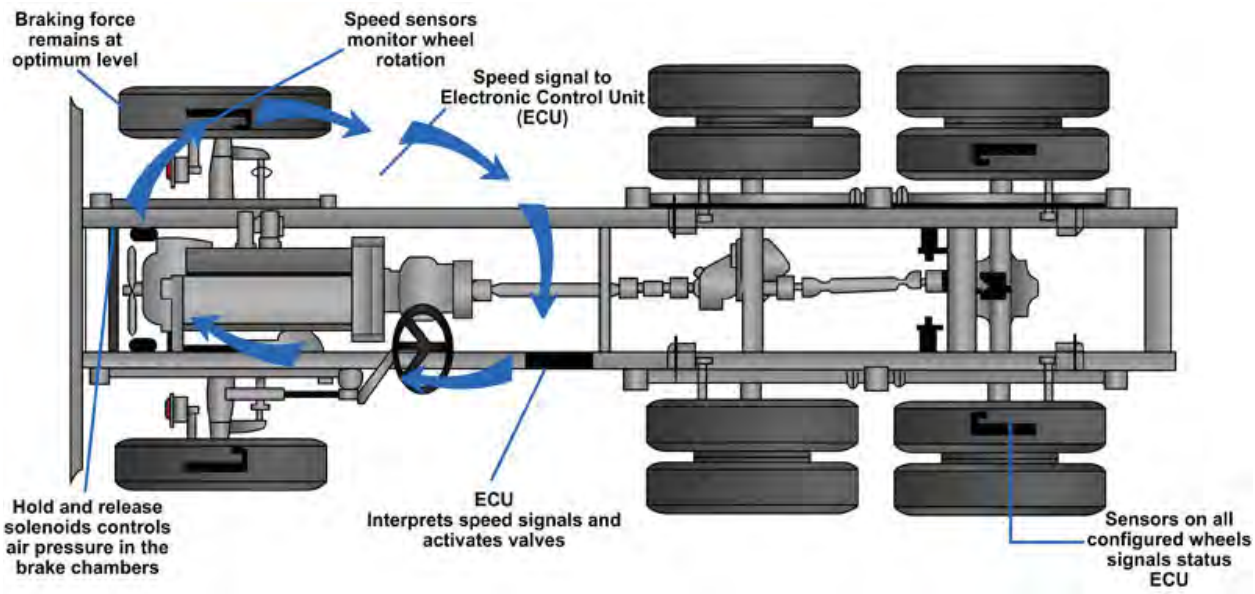


Figure 4-56 – Anti-lock brake system.

Tips on using the anti-lock braking system are as follows:

- With anti-lock brakes, all an operator needs to do is "brake and steer." With four-wheel anti-lock brakes, push the brake pedal hard while steering normally and keep your foot firmly on the brake pedal until the vehicle comes to a complete stop. Operators with rear-wheel anti-lock brakes should step firmly with care and if they feel the wheel locking, should release some pressure.
- Expect noise and vibration in the brake pedal when using anti-lock brakes. The mechanical noise or pulsation of anti-lock brakes when in use might catch an operator by surprise; however, these sensations tell you that the system is working.
- Remember that you can steer while braking with a four-wheel anti-lock brake system. Steering is not always instinctive in an emergency. But steer out of danger while braking with anti-lock brakes. And remember that while you have steering capability, your vehicle may not turn as quickly while braking on a slippery road as it would on dry pavement. The rear-wheel anti-lock brakes typically found on light-duty trucks provide vehicle stability but do not provide the steering capability of four-wheel anti-lock brakes.
- Anti-lock brakes can often stop more quickly than conventional brakes, but they cannot overcome the laws of physics. Anti-lock brakes function well on wet-paved surfaces and icy or packed snow-covered roads. Stopping times will be longer on gravel or fresh snow, although operators will not experience the dangerous lockup of wheels usually associated with conventional brakes.

- Drive safely because anti-lock brakes are only as good as the operators using them. Anti-lock brakes cannot compensate for driving too fast or too aggressively or failing to maintain a safe distance between vehicles. They cannot guarantee recovery from a spin or skid before braking. Also avoid extreme steering maneuvers while anti-lock brakes are engaged.
- Your anti-lock braking system instrument panel light will go on for a few seconds after starting the ignition. The light goes on so the system can conduct the normal system test. If the light does not go on during ignition or goes on during normal driving, this means that the anti-lock braking system has a problem and has been shut off. Conventional braking will continue. Consult the manufacturer's service manual if this problem occurs.
- Since anti-lock brake systems vary, consult the vehicle's operator's manual for more information.

Remember, to do the following when performing a pre-start check on the brake systems:

- Inspect the self-contained lubricating oil system on the air compressor
- Inspect the brake fluid level
- Inspect for leaks in the system
- Inspect for loose connections or parts
- Drain air reservoirs
- Use the proper brake fluid, refer to operator's manual
- Inflate tires properly

Failure to perform such inspections can lead to brake troubles during operation, such as:

- The brake pedal going to the floorboard with no resistance
- One brake dragging
- All brakes dragging
- The vehicle pulling to one side during braking
- Soft or spongy pedal
- Excessive pedal effort required
- Noisy brakes
- Air in the system
- Loss of brake fluid
- The brakes heating up during driving and failing to release
- Leaky brake cylinders
- Grabbing braking action
- Depressing the brake pedal not slowing the vehicle

These break troubles must be documented and reported to the maintenance shop for repair.

Test your Knowledge (Select the Correct Response)

12. Which of the following is NOT a classification of brakes?

    A. External contracting
    B. Internal expanding
    C. Disc
    D. Internal disc

13. In a hydraulic brake system, what component controls the movement of the brake shoes at each wheel?

    A. The wheel cam
    B. The wheel cylinder
    C. The wheel crank
    D. The wheel gear

14. Which of the following components of an air brake system helps reduce the risk of ice in air brake valves?

    A. Safety valve
    B. Treadle valve
    C. Alcohol evaporator
    D. Limiting quick–release valve

Summary

The knowledge you gained from this chapter is necessary for performing pre-start checks. Pre-start checks involve inspecting the chassis systems, which includes the steering system, suspension system, tires, and brakes.

In this chapter, you learned how the steering linkage assembly functions in varies types steering systems. In addition, you learned the purpose of the suspension system and its components, including springs and shock absorbers.

You learned how to recognize proper tire inflation and tire wear. You learned how to properly remove and repair tires. Additionally, you learned about the different types of brake systems featured in vehicles and construction equipment.

Review Questions (Select the Correct Response)

1. What part of the steering system connects the front wheels of the vehicle?

   A. Steering linkage
   B. Steering gear
   C. Steering column
   D. Steering pitman arm

2. Which of the following is NOT a type of steering trouble?

   A. Hard steering
   B. Vehicle wander
   C. Steering kickback
   D. Hard or rough ride

3. What type of steering is used to turn a whole section of a machine from a vertical hinge?

   A. Front and rear
   B. Articulated
   C. Rear
   D. Crab

4. What type of steering swings the rear wheels outside the path of the front wheels?

   A. Front and rear
   B. Articulated
   C. Rear
   D. Four wheel

5. **(True or False)** Crab steering moves a machine in a straight line at an angle to its center line.

   A. True
   B. False

6. Which of the following components of a multiple leaf spring keeps the springs from separating on the rebound after the spring has been depressed?

   A. Spring hanger
   B. Leaf clip
   C. Spring seat
   D. Spring shackle

7. Which of the following components of a multiple leaf spring provides a swinging support and allows the spring to straighten out when compressed?

   A. Spring hanger
   B. Leaf clip
   C. Spring seat
   D. Spring shackle

8. What parts are used to prevent the spring from shifting on track type of tractor?

   A. Brackets
   B. Shackles
   C. Hangers
   D. U-Bolts

9. Coil springs are generally used on which of the following suspension systems?

   A. 4 x 4 suspension systems
   B. 4 x 6 suspension systems
   C. Independent suspension systems
   D. All suspension systems

10. Rubberized fabric spacers placed at each end of spring coils serve what function?

    A. They prevent oil leakage.
    B. They prevent squeaking.
    C. They prevent grease leakage.
    D. They provide a tighter seal between the coil spring and the steering bushing.

11. Double-acting shock absorbers perform which of the following function?

    A. Prevent metal-to-metal contact when the springs are compressed and absorb torsion from the springs
    B. Control spring rebound only
    C. Control spring compression and spring rebound
    D. Prevent metal-to-metal contact when the springs are compressed and check spring rebound

12. Which of the following is NOT a symptom of suspension trouble during vehicle operation?

    A. Vehicle wanders
    B. Vehicle pulls to one side during normal driving
    C. Stiff spring
    D. Sway on turns

13. **(True or False)** Abuse and neglect are primary causes of the premature failure of tires.

    A. True
    B. False

14. When operating a vehicle in soft sand, you should take what action?

    A. Increase the air pressure in the tires
    B. Reduce the air pressure in the tires
    C. Install tire chains
    D. Change tires

15. What component of a tire assembly permits air to enter the tire under pressure, but prevents it from escaping?

    A. Tire ply
    B. Tire bead
    C. Valve core
    D. Valve cap

16. What component of a tire assembly prevents dirt and moisture from entering the valve body?

    A. The valve cap
    B. The valve cup
    C. The valve jacket
    D. The valve spring washer

17. **(True or False)** Preventive maintenance includes ensuring that all valve stems have valve caps.

    A. True
    B. False

18. **(True or False)** Radial-ply tire can be used with bias-ply tires on the same axle.

    A. True
    B. False

19. Which of the following types of tire treads is of a V-design with large spaces between the lugs?

    A. Cross-country tread
    B. Regular tread
    C. Non-directional tread
    D. Directional tread

20. How are tires mounted on dead axles?

    A. The point of the V-design makes contact with the ground first.
    B. The open V-design makes contract with the ground first.
    C. The perpendicular position of the lugs meets the ground first.
    D. The rounded shoulders of the lugs meet the ground first.

21. Which of the following types of tires treads have rounded shoulders and lugs that are placed perpendicular to the center line of the tire?

    A. Cross-country tread
    B. Regular tread
    C. Non-directional tread
    D. Directional tread

22. What tread is characterized by narrow voids between the lugs.

    A. Earthmover
    B. Cross-country
    C. Rock service
    D. Regular

23. When repairing tires equipped with locking rings, you should perform which of the following steps first?

    A. Force the tire bead away from the removable side ring.
    B. Inflate the tire to find the hole.
    C. Plug the hole in the tire.
    D. Remove the valve core and deflate the tire completely.

24. **(True or False)** When assembling tires equipped with a locking ring, you should install the valve stem so that it points towards the locking ring.

    A. True
    B. False

25. **(True or False)** When physically inspecting the inside of a tubeless tire, you should use a rag to protect your hand from injury.

    A. True
    B. False

26. **(True or False)** Tire rotation is performed according to the manufacturer's specifications.

    A. True
    B. False

27. Which of the following personnel supervise the tire shop?

    A. Transportation supervisor
    B. Maintenance supervisor
    C. Projects supervisor
    D. Heavy shop supervisor

28. **(True or False)** Personnel inexperienced in tire repair should repair tires only under direct supervision of an experienced person.

    A. True
    B. False

29. **(True or False)** A brake system must not only stop a unit of CESE but also must stop it in a smooth, uniform manner.

    A. True
    B. False

30. Which of the following types of brakes cannot withstand the high pressure required to produce the friction needed to stop a heavily loaded vehicle?

    A. Disc
    B. Drum
    C. External contracting
    D. Internal expanding

31. Internal expanding brakes are used almost exclusively on _____.

    A. track loaders
    B. wheel brakes
    C. brakes for controlling speeds of auxiliary drive shafts
    D. winch brakes

32. When the braking action is no longer required of an internal expanding brake system, the brake shoes are returned to their original position by what power source?

    A. Vacuum pull
    B. Brake fluid pressure
    C. Retracting springs
    D. Gravity

33. Which type of braking system has a pair of flat pads instead of curved brake shoes?

    A. Disc
    B. Mechanical
    C. Air
    D. Electrical

34. **(True or False)** A mechanical parking brake may be linked mechanically to either the rear wheel brakes or the external contracting brake bands located on the drive shaft.

A. True
B. False

35. On a hydraulic brake system, what component serves as a reservoir for the brake fluid?

A. Brake fluid storage tank
B. Brake reservoir
C. Master cylinder
D. Slave cylinder

36. On a vehicle brake system, where are the larger wheel cylinders mounted?

A. The rear wheels
B. The front wheels
C. The front and rear left wheels
D. The front and rear right wheels

37. What action forces the brake fluid back through the flexible hose and tubing to the master cylinder?

A. Retracting springs on the brake shoes
B. Retracting springs on the brake pedal
C. Suction from the master cylinder pump
D. All of the above

38. **(True or False)** Part of your pre-start responsibility is to check the cylinder reservoir fluid level and add clean fluid to maintain the manufacturer's specifications.

A. True
B. False

39. Which of the following braking components does NOT create the frictional surface that gives the braking effect?

A. Lining
B. Drum
C. Disc
D. Shoe

40. **(True or False)** An air brake system uses compressed air to apply the brakes.

A. True
B. False

41. When the brake pedal is engaged, air from the air tank flows through what component before flowing through the brake lines connected to the brake chambers?

A. Double–check valve
B. Brake pedal valve
C. Limiting quick-release valve
D. Hand brake valve

42. **(True or False)** Pressing and releasing the brake pedal unnecessarily may release air out from the air tank faster than the compressor can replace it.

A. True
B. False

43. In an air brake system, what component pumps air into the storage tanks?

A. The governor
B. The evaporator
C. The air compressor
D. The master cylinder pump

44. Which of the following components of an air brake system protects the tank and the rest of the system from too much air pressure?

A. The safety valve
B. The alcohol evaporator
C. The drain cock
D. The slack adjuster

45. At what pounds per square inch (psi) of air pressure does a governor stop the compressor from pumping air?

A. 30
B. 60
C. 90
D. 125

46. **(True or False)** Compressed air usually contains water and compressor oil.

A. True
B. False

47. A low air warning device should turn on before the pressure in the air tank(s) drops lower than what pressure?

A. 120 psi
B. 90 psi
C. 60 psi
D. 30 psi

48. On a tractor-trailer equipped with air brakes, which of the following components provides the operator control of the trailing load at all times?

A. Master cylinder valve
B. Hand brake valve
C. Trailer protection valve
D. Double-check valve

49. **(True or False)** Because of the size of the air piston in an air-over hydraulic brake system, the air pressure is a much greater pressure than the hydraulic pressure that is admitted to the air cylinder.

A. True
B. False

50. In a vacuum brake system, what force acts on the rear side of the piston to exert a powerful pull on the rod attached to the piston?

A. Compressed air
B. Mechanical pressure
C. Vacuum
D. Atmospheric pressure

51. What type of vacuum braking system contains within one unit, a hydraulically actuated control valve, a vacuum power cylinder, and a hydraulic slave cylinder?

A. Hydrovac
B. Air-hydraulic unit
C. Electric vacuum unit
D. Air pack

52. Which of the following items of a brake system is the operator's responsibility to inspect during pre-start check?

A. Brake fluid level
B. Loose connections or parts
C. Leaks
D. All of the above

53. **(True or False)** Noises and vibration while using the anti-lock brakes are symptoms of major brake problems.

A. True
B. False

Trade Terms Introduced in this Chapter

Dead axle	Also called steering axle, the dead axle supports part of the vehicle's weight and provides a mounting for the wheel assembly. On rear-wheel drive vehicles, the front axle is a dead axle.
Graders	Machines used for leveling roads by moving laterally and side casting.
Live axles	Also called driving axles, live axles transmit power. On rear-wheel drive vehicles, the rear axle is a live axle.

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.

Construction Mechanic Basic, Volume 2, NAVEDTRA 14273, NAVEDTRA 14081, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1999.

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Fundamentals of Service, Tires and Tracks, 5th ed., Deere & Company, Moline, IL, 1986.

Manual for Truck and Bus Drivers, Commercial Drivers License, Florida Department of Highway Safety and Motor Vehicles, Tallahassee, FL, 1989.

Nichols, Herbert L., Jr., *Moving the Earth,* 3rd ed., North Castle Books, Inc., Greenwich, CT, 1985.

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Chapter 5

Electrical and Hydraulic Systems

Topics

1.0.0 Electrical Systems

2.0.0 Hydraulic Systems

To hear audio, click on the box. 

Overview

The electrical and hydraulic systems are major components designed to perform a variety of functions that support the operation of vehicles and equipment. These systems are responsible for control starting, charging, braking, steering, lifting, and the movement of all attachments. This chapter covers the basic components of the electrical and hydraulic systems used in vehicles, construction equipment, and material handling equipment and weight handling equipment.

Objectives

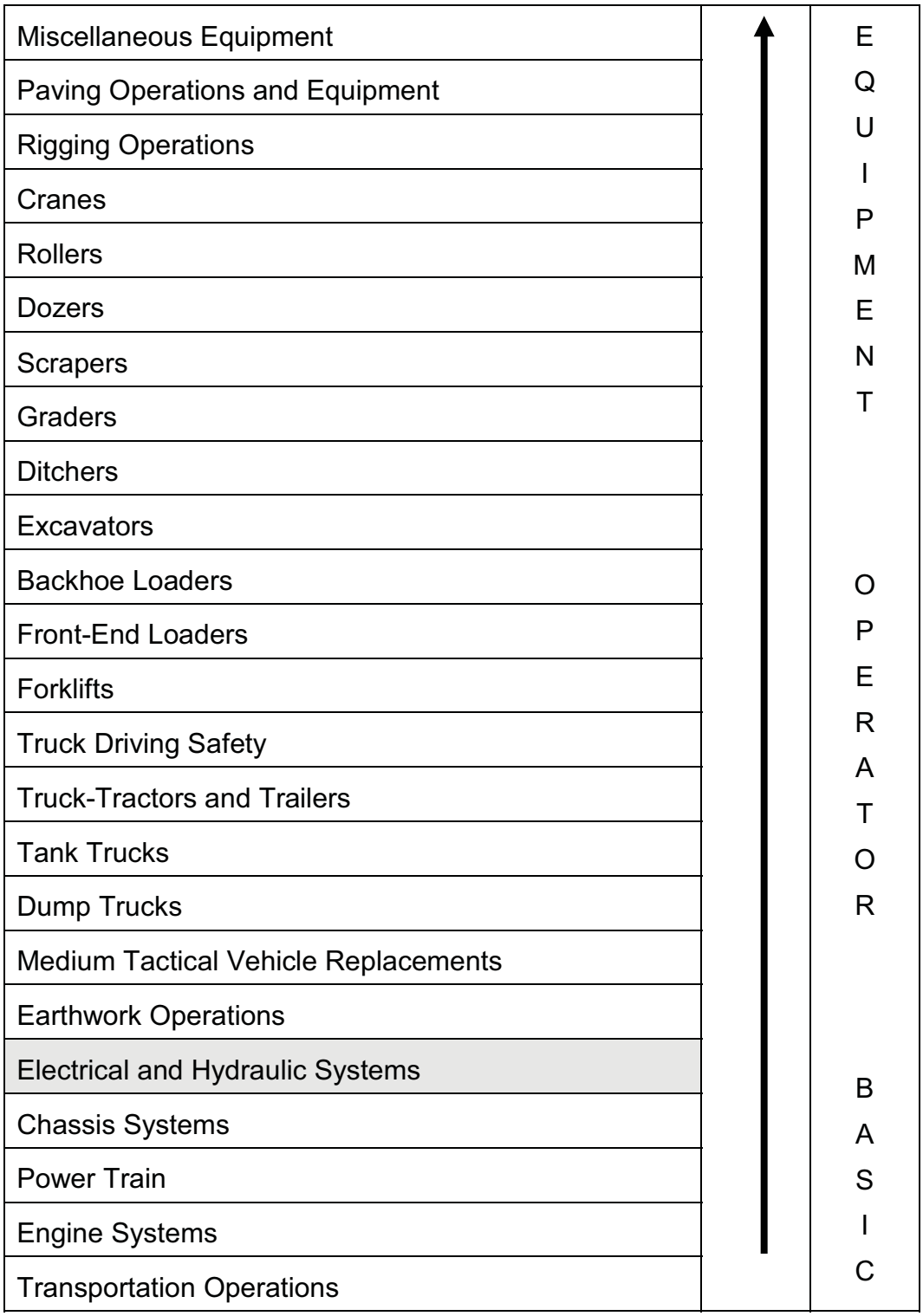
When you have completed this chapter, you will be able to do the following:

1. Identify the basic components of electrical systems.
2. Identify the basic components of hydraulic systems.

Prerequisites

None

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



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 ELECTRICAL SYSTEMS

Proper performance of pre- and post-operational checks and operator maintenance requires a basic understanding of the electrical systems used on vehicle and construction equipment. The basic components of the electrical system are the following: a storage battery, a charging system, starting circuits, a lighting system, and gauges.

1.1.0 Storage Battery

The storage battery is the heart of the charging circuit. It is an electrochemical device for producing and storing electricity. A vehicle battery has several important functions, which are as follows:

- Operates the starting motor, ignition system, electronic fuel injection system, and other electrical devices for the engine during engine cranking and starting.
- Supplies all of the electrical power for the vehicle when the engine is not running.
- Assist the charging system by providing electricity when the demand for current, the movement of electrons, is above the output limit of the charging system.
- Acts as a capacitor (voltage stabilizer) that smoothes current flow through the electrical system.
- Stores energy (electricity) for extended periods.

Lead-acid cell-type batteries are used in vehicle, construction, and materials-handling equipment. This type of battery produces direct current (DC), electricity that flows in only one direction. When the battery is discharging (current flowing out of the battery), it changes chemical energy into electrical energy, thereby releasing stored energy. During charging (current flowing into the battery from the charging system), electrical energy is converted into chemical energy. The battery can then store the energy until the vehicle requires it.

1.1.1 Battery Construction

A typical lead-acid storage battery is shown in *Figure 5-1*. Like most batteries, it consists of a molded container with individual cell compartments, cell elements, cell connectors, cell covers, terminals, and vented filler caps.

The container is made of molded hard rubber, plastic, or bituminous material. It must withstand shock and vibration, cold weather, and engine heat.

The battery element is made up of negative and positive plates, separators, and straps. The element fits into a cell compartment in a battery case. Most vehicles batteries have six elements.

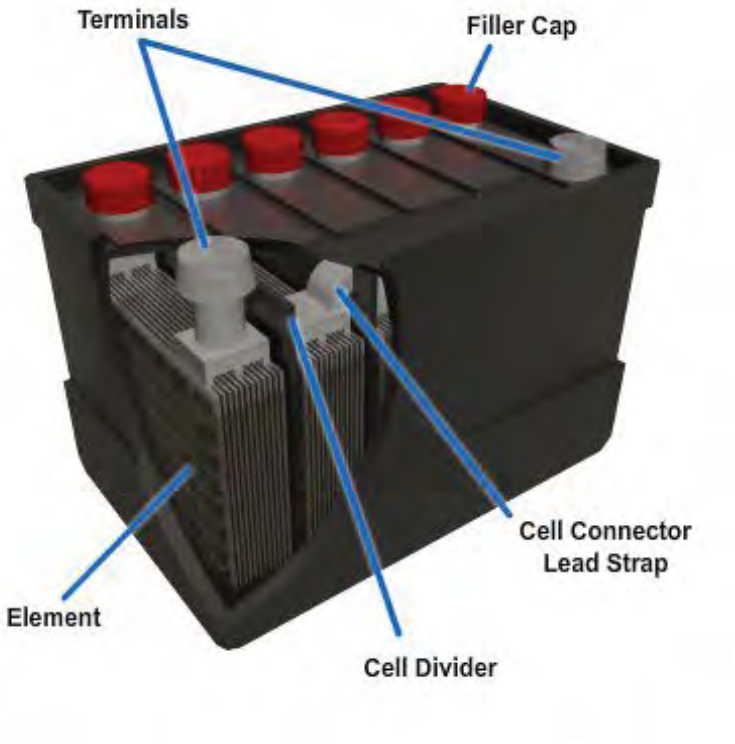


Figure 5-1 – Typical storage battery.

Each cell compartment contains two kinds of chemically active lead plates, known as positive and negative. The battery plates are made of grid (stiff mesh framework) coated with porous lead. Charged negative plates contain spongy (porous) lead (Pb), which is gray in color. Charged positive plates contain lead peroxide (PbO2), which is chocolate brown in color. The lead is the active material of the plate.

The plates are submerged in a sulfuric acid solution, known as electrolyte, made of 60 percent water and 40 percent sulfuric acid. Since the lead on the plates is porous like a sponge, the acid easily penetrates into the active material. This aids the chemical reaction and the production of electricity.

To prevent the plates from touching each other, sheets of thin and porous insulating materials, called separators, are inserted between the plates, allowing electrolyte, to easily flow between the plates.

The battery cover is made of the same material as the container and is bonded to and seals the container. The cover provides openings for a positive and a negative terminal, and a filler cap for each cell. The positive terminal is larger than the negative terminal and has a red painted (+) symbol; the negative terminal is smaller and may have a black or green painted (-) symbol. The terminals serve as connections for the cable ends connecting the battery plates to the vehicle electrical system.

Part of a pre-start check includes inspecting the battery. Look for signs of corrosion on or around the battery, signs of leakage, a cracked case or top, missing filler caps, and loose or missing hold-down clamps.

In addition, on vent batteries, remove the filler caps and inspect the electrolyte level. Some batteries have a fill ring which indicates the electrolyte level. The electrolyte should be even with the fill ring. If there is no fill ring, the electrolyte should be high enough to cover the tops of the plates. Some batteries have an electrolyte-level indictor

(Delco Eye). This gives a color coded visual indication of the electrolyte level; black indicates that the level is okay, and white indicates that the level is low.

If the electrolyte level in the battery is low, fill the cells to the correct level with distilled water (purified water). Use only distilled water because it does not contain the impurities found in tap water. Tap water contains many chemicals that reduce battery life. These chemicals contaminate the electrolyte and collect in the bottom of the battery case. If enough contaminates collect in the bottom of the case, the cell plates short out, ruining the battery.

WARNING

Electrolytes can burn through clothing and cause severe burn to eyes and skin. When servicing a battery, wear safety goggles, acid-proof gloves, and a rubber apron.

NOTE

Unlike vent batteries, maintenance-free batteries do not require periodic electrolyte inspections. They are designed to operate for a long period of time without loss of electrolyte.

During the pre-start check, if you discover that the top of the battery is dirty, use a stiff bristle brush and a mixture of water and baking soda to wash it; however, be careful not to allow the cleaning solution to enter the battery.

To clean the terminals, remove cables and inspect the terminals to see if they are deformed or broken. Clean the terminal and the inside surfaces of the cable clamps with a cleaning tool before replacing them on the terminal posts.

CAUTION

Do not use a scraper or knife to clean battery terminals. This action removes too much metal and can ruin the terminal connection.

When reinstalling the cables, coat the terminals with petroleum or white grease. This will keep acid fumes off the connections and keep them from corroding again. Tighten the terminals just enough to secure connection. Over-tightening will destroy the treads on the cable bolt.

1.1.2 Battery Capacity

The capacity of a battery is measured in ampere-hours (Ah). The ampere-hour capacity is equal to the product of the current in amperes and the time in hours during which the battery is supplying this current. The ampere-hour capacity varies inversely with the discharge current. The size of a cell is determined by its ampere-hour capacity. The capacity of a cell depends upon many factors, the most important of which are the following:

- The area of the plates in contact with the electrolyte
- The quantity and specific gravity of the electrolyte
- The type of separators
- The general condition of the battery (degree of sulfating, plates buckled, separators warped, sediment in bottom of cells, etc.)
- The final limiting voltage, the pushing force behind electricity

1.2.0 Charging Systems

The charging system performs two jobs: it recharges the battery and during operation, generates current.

The two types of charging systems used on vehicle and construction equipment are direct current (DC) and alternating current (AC). Both systems generate AC (electricity that changes direction); however, the difference is the way they convert AC to DC (electricity that flows in only one direction).

1.2.1 DC Charging System

A DC charging system has a generator and a regulator (*Figure 5-2*). The generator produces AC, which is mechanically converted to DC by a rectifier assembly consisting of commutator bars and brushes.

The regulator in the DC charging system opens and closes the charging circuit, prevents overcharging of the battery, and limits the output of the generator to safe rates.

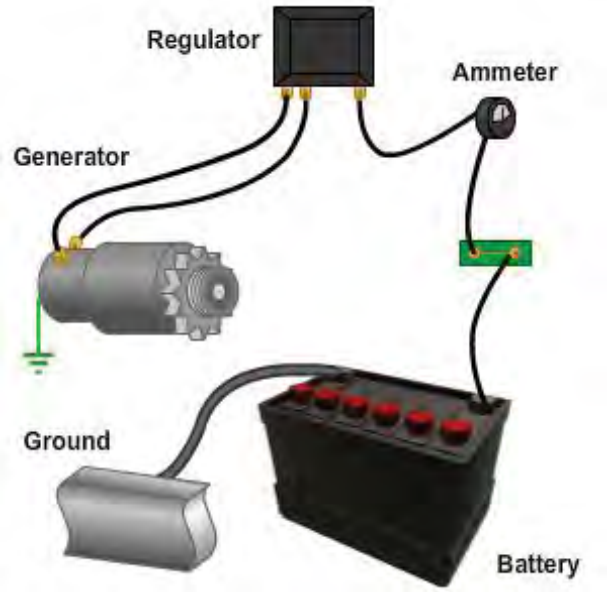


Figure 5-2 – DC charging system.

1.2.2 AC Charging System

An AC charging system has an alternator and a regulator (*Figure 5-3*). The alternator is really an AC generator. Like the generator, the alternator produces AC; however, the AC is converted electronically by a rectifier assembly consisting of diodes. Most alternators are more compact than generators of equal output and supply a higher current output at low-engine speeds.

The regulator in the charging system limits the alternator voltage to a safe, preset value.

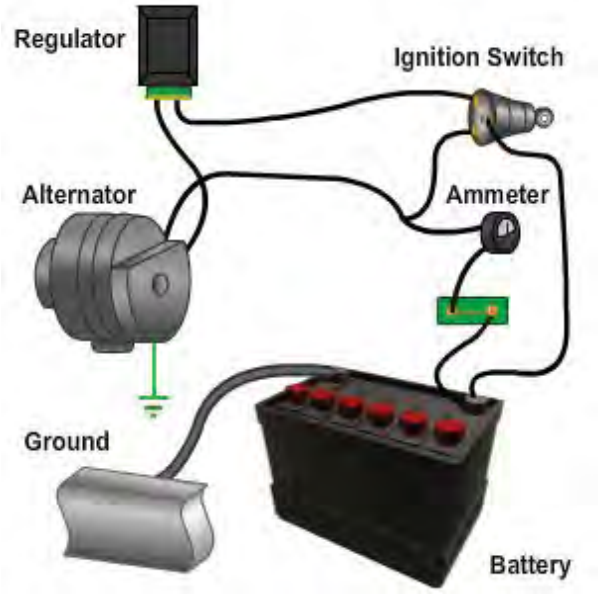


Figure 5-3 – AC charging system.

1.2.3 Charging System

All charging systems operate in three stages: during starting, the battery supplies all load current; during peak operation, the battery helps the generator supply current; and during normal operation, the generator supplies all current and recharges the battery.

In both electrical systems, the battery starts the electrical circuit that supplies the spark to start the engine. The engine then drives the generator or alternator that produces current to take over the operation of the ignition, lights, and accessory loads. The battery also supports the generator or alternator during peak operation when the electrical loads are excessive. But once the engine is started the generator or alternator is the “work horse”, providing current to the ignition and accessory circuits. The generator supplies current as long as the engine is at speed and running. When the engine slows down or stops, the battery takes over part of, or the entire, load.

1.3.0 Starting Circuits

High voltage is often necessary to ensure sufficient starting power due to the high compression ratios of some diesel engines. To accomplish this task, parallel, series, and series-parallel systems are used to increase either the voltage or amperage.

1.3.1 Parallel System

An example of a parallel system, as shown in *Figure 5-4*, is two 12-volt, 200-amp batteries connected from the starter to the positive terminal of one battery to the positive terminal of the second battery.

The negative side of the batteries are connected from the ground to the negative terminal from one battery to the negative terminal of second battery. This system provides 12 volts and 400 amps, providing more amperage for starting.

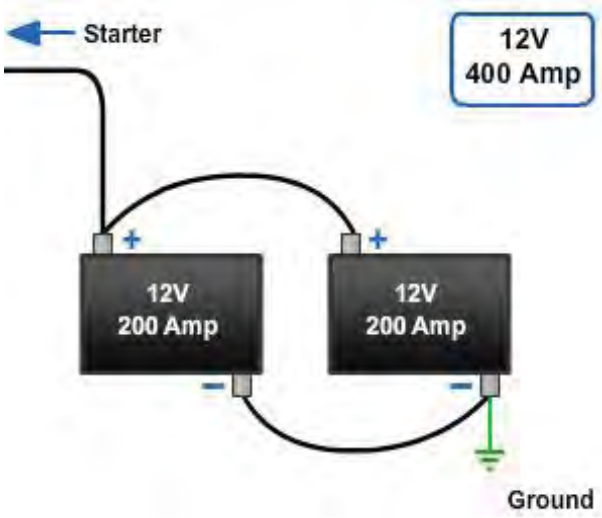


Figure 5-4 – Parallel system.

1.3.2 Series System

An example of a series system, as shown in *Figure 5-5*, has two 12-volt, 200-amp batteries that are connected from the positive terminal of one battery to the negative terminal of the second battery.

The remaining positive terminal is connected to the starter and the remaining negative terminal is connected to the ground. This system provides 24 volts and 200 amps, providing more volts for starting.

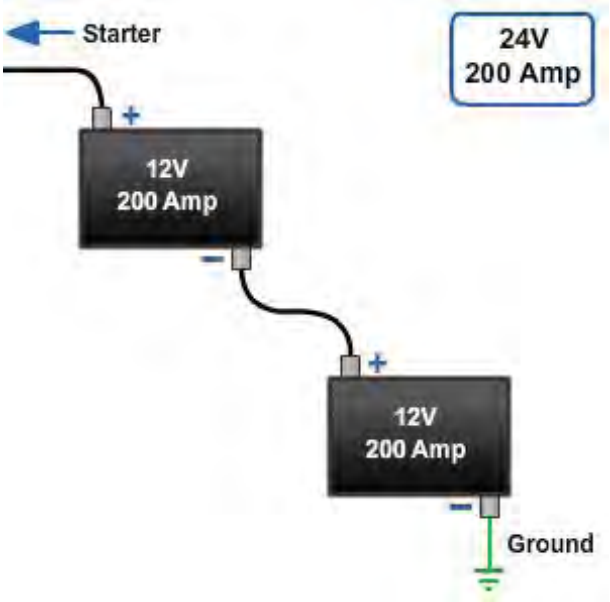


Figure 5-5 – Series system.

1.3.3 Series-Parallel System

A series-parallel system provides a series connection of the batteries for starting and a parallel connection for normal operation.

An example of a series-parallel system is when two sets of parallel batteries, as shown in *Figure 5-6,* are connected in series and the negative terminal from one set of the batteries is connected to the positive terminal of the other set. This system provides 24 volts and 400 amps. This combination is used for cranking large construction equipment.

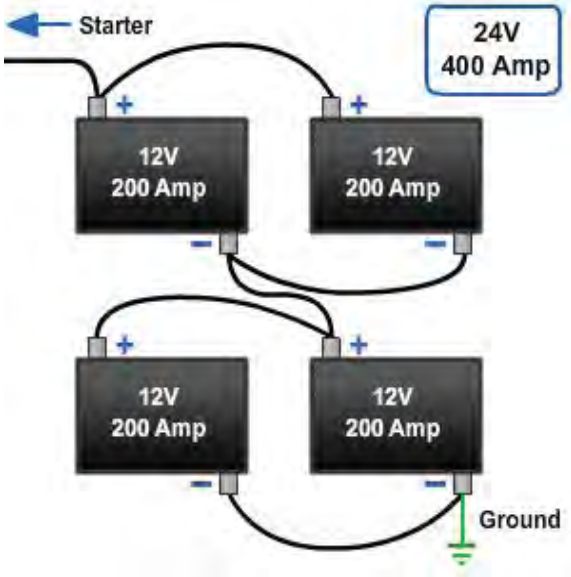


Figure 5-6 – Series-parallel system.

⚠ CAUTION ⚠

Use extreme care when jump starting is required. Hooking up jumper cables from a 24-volt system to a heavy-duty 12-volt system can cause severe battery damage, starter destruction, or even an explosion. If you are unsure of the starting circuit, get assistance from the mechanic field crew.

1.4.0 Lighting System

The lighting system on vehicles, construction, and materials-handling equipment includes the lamps and bulbs, clearance lights, side marker lights, reflectors, taillights and brake lights, auxiliary lights, and fuses. *Federal Motor Carrier Safety Regulations Pocketbook* outlines standards for lights on vehicles.

Every vehicle and piece of construction and material handling equipment has an electrical system that provides power to bulbs for clearance, side marker, tail, brake, and auxiliary lights.

1.4.1 Lamps and Light Bulbs

Naval Construction Force equipment uses light bulbs that operate on a low-voltage current of 12 or 24 volts, depending upon the voltage of electrical system.

Bulbs are rated by units of luminous intensity known as candlepower (cp). Light bulbs can range from one-half cp to 50 cp. The greater the cp of the bulb, the more current it requires when lighted. Bulbs are identified by a number on the base shell.

Operators are responsible for replacing burned-out light bulbs on equipment. When replacing a bulb in a vehicle, be sure that the new bulb is of the proper rating.

Manufacturers have designed bulbs with such a wide variety of designs (*Figure 5-7*) that it is impossible to identify all the bulbs here.

Figure 5-7 – Bulb configurations.

However, a common bulb design has either one or two electrical contacts at the bottom of the base shell. On each side of the base shell there is a metal nib. The nibs are fitted to interlock with the J-shaped slots on bayonet sockets (*Figure 5-8*). This design prevents the bulb from unscrewing itself when subject to vibration.

Because of some unique designs, certain bulbs must be handled with care; for example, quartz bulbs, made of pure, fused quartz crystals, should not be handled by unprotected hands. The oil in skin can cause the bulb to fail instantly; therefore, check the operator's manual before replacing any bulb.

Figure 5-8 – Double-contact bulb and bayonet socket.

Each group of lights in a branch circuit has a switch and is protected by a fuse or circuit breaker. Each light in the group is provided with one or more light bulbs that are rated for the particular circuit.

1.4.2 Fuses

Fuses are safety devices placed in electrical circuits to protect wires and electrical units from a heavy flow of current. Each circuit, or at least each individual electrical system, is provided with a fuse that has an ampere rating for the maximum current required to operate the unit.

The fuse element is made from a metal that has a low-melting point and is the weakest point in the electrical circuit. In case of a short circuit or other trouble, the fuse burns out first and this opens the circuit just as a switch would do. Visual examination of a burned-out fuse usually provides a quick indication of the problem. A discolored sight glass indicates the circuit has a short either in the wiring or one of its components. If the glass is clear, the problem may be an overload in the circuit.

When replacing a fuse, ensure that it has a rating equal to the one burned out. Also, ensure that the malfunction that caused the failure has been determined and repaired.

1.4.3 Headlights

Headlights are large sealed beams (*Figure 5-9*). The bulb consists of a lens, glass reflector and filaments, made of tungsten wire responsible for converting electrical energy into light output. Some filaments are designed to provide brighter, long and wide range of illumination. These types of filaments are used for high beams. Other filaments are designed to provide dimmer, short and narrow range of illumination. These types of filaments are used for low beams.

Figure 5-9 – Typical headlight assembly.

The headlight switch is an ON/OFF switch and rheostat (variable resistor) in the instrument panel or on the steering column. It controls the current flow to the beam. The rheostat is for adjusting the brightness of the instrument panel lights.

1.4.4 Taillights and Brake Lights

Taillights (*Figure 5-10*) are red and must be visible from a minimum distance of 500 feet from the rear of the vehicle. Replace taillight lens, if they are faded red, cracked, broken, or do not fit tightly.

Figure 5-10 – Trailer taillights.

Brake lights (*Figure 5-10*) are usually combined with the taillights by using a double-contact, double-filament bulb; however, they may be separate lights. Brake lights must light up immediately when the brake pedal is depressed; that is, at the beginning of the downward action of the brake pedal.

Brake lights are safety-required items, therefore, must be operational at all times. Burnt-out or weak brake lights should be documented and repaired before anyone operates the vehicle or equipment.

1.4.5 Turn-Signal Lights

Turn-signal lights indicate a left or right turn by providing a flashing light signal at the rear and front of the vehicle. By using the turn-signal, an operator minimizes hazardous surprises.

The turn-signal light switch is located on the steering column. It is designed to automatically shut off after the turn is completed by the action of the canceling cam.

In addition to headlights, taillights, and turn signal lights, all vehicles that operate at night must have clearance and side marker lights. These lights outline the length, height, and width of the vehicle. Part of your pre-start responsibility is to ensure that these lights work and are clean.

1.4.6 Clearance Lights

Clearance lights outline the maximum width of the vehicle (*Figure 5-11*). These lights highlight the protruding front and rear corners of the vehicle, which are subject to collision with other vehicles or persons.

Figure 5-11 – Location of lights and reflectors on truck tractor.

Clearance lights should be mounted at a height best suited for visibility from a minimum distance of 500 feet from the vehicle. Clearance lights on the front corners of a vehicle should be amber in color. Clearance lights on the rear corners should be red in color.

Some states require that larger vehicles have identification lights to outline the maximum height of the vehicle. Some vehicles have a separate switch for the clearance lights that outline the width of the vehicle and those that outline the length of the vehicle. When operating a vehicle at night, do not forget to turn the clearance lights on.

1.4.7 Side Marker Lights

Side marker lights (*Figure 5-11*) are similar to clearance lights; however, they indicate the maximum length of the vehicle as viewed from the side. They must be visible from a minimum distance of 500 feet from the vehicle.

Side marker lights mounted near the front of the vehicle are amber in color; those mounted near the rear of the vehicle are red in color.

1.4.8 Reflectors

Reflectors, like those shown in (*Figure 5-11*), are an additional safety precaution in case lights burn out or break. When mounting reflectors, ensure they are between 24 to 42 inches above the ground.

1.4.9 Auxiliary Lights

Auxiliary lights are lights that can be turned on or off for the convenience or safety of the driver or passengers. These lights are wired independently from the headlights. Examples of auxiliary lights include spotlights, backup lights, parking lights and blackout lights. Remember, when performing pre-start checks, you should ensure that all auxiliary lights work.

Spotlights – Spotlights are often mounted on construction equipment and materials-handling equipment. When conducting pre-start checks, always make sure the spot-lights work because you never know when you will encounter conditions or situations requiring their use.

Backup Lights – Backup lights are accessories for many vehicles. They may be mounted singly or as a pair, one on each side of the vehicle. Backup light lenses must be colorless and must turnoff automatically when the vehicle is moving forward. Backup lights may also be connected to an audible signal. A backup light must be aimed to strike the road at a distance that does not exceed 25 feet from the rear of the vehicle.

Parking Lights – Parking lights are white or amber in color. They are located on the front of the vehicle. They turn on and off with the same switch as the taillights.

Blackout Lights – Military vehicles, like the Medium Tactical Vehicle Replacement (MTVR) are equipped with blackout lights (*Figure 5-11*). Black out lights provides the operator with enough light to operate in total darkness; however, the lighting is minimal. It is only visible to a leading or trailing vehicle and not to a distant enemy.

1.5.0 Gauges and Warning Indicators

Besides gauges that indicate traveling speed and miles traveled, vehicles have gauges which allow you to monitor the condition of the vehicle. In addition, these vehicles have warning indicators that light up and audible alarms to alert you of potential problems.

On the instrument panel of these vehicles, you may see analog type gauges and color-coded warning indicators, as shown in *Figure 5-12.*

Figure 5-12 – Analog gauges and color-coded warning indicators on MTVR.

1.5.1 Water Temperature Gauge

When operating a vehicle or equipment, you must monitor the water or coolant temperature gauge. If your machine has an analog type of gauge (*Figure 5-12*), you must know the normal operating temperature; always refer to the operator's manual. If the water temperature gauge reads above the normal range and the warning indicator lights up, the engine may be overheating. Shut down the engine at once and determine the reason.

WARNING

Use extreme caution when removing a hot radiator cap. Steam coming from the radiator will cause severe burns.

CAUTION

Do not add cold water to a hot engine when it is not running. Rapid cooling of an overheated engine will cause severe damage to the cylinder head and block. To cool an overheated engine down, leave the engine running and add water slowly. Watch for the steam that may be produced when adding water. Should a radiator hose burst, shut down the engine before the temperature gets too high.

1.5.2 Oil Pressure Gauge

The oil pressure indicator is one of, if not the, most important gauges to monitor. Every vehicle and equipment has an oil pressure warning indicator and/or gauge (*Figure 5-12*).

During a pre-start check, always inspect the oil level in the engine. If the oil level is low, add oil until it is at the proper level. Start the engine; if oil pressure does not register on the gauge or the warning indicator stays on for 30 seconds, shut down the engine.

During operation, should the vehicle start to lose oil pressure and the warning indicator come on, shut down the engine immediately. Operating without proper oil pressure causes severe damage to the engine.

NOTE

A rule of thumb, after starting an engine, the oil pressure gauge should show 30 pounds of oil pressure after the engine runs for 30 seconds. Should the oil level be correct but no pressure registers on the gauge, shut down the engine. Then document and report the problem.

1.5.3 Air Pressure Gauge

Vehicles with air brake systems are equipped with air pressure gauges and/or warning indicators (*Figure 5-12*). These instruments indicate the amount of pressure in the tanks.

Air pressure should start building as soon as the engine starts. During operation, it must be maintained within a range of 100 pounds per square inch (psi) to 120 psi. If the air pressure drops below 60 psi, the warning indicator and an audible alarm will come on.

WARNING

Do not operate any vehicle that has a leak its air brake system. With the engine at operating rpm, the air pressure system should build from 85 to 100 psi within 45 seconds in dual-air systems. In single-air systems (pre-1975), the pressure should build up from 50 to 90 psi within 3 minutes.

1.5.4 Fuel Level Gauge

When performing a pre-start check, visually check the fuel. During the day, watch the fuel gauge (*Figure 5-12*) to ensure it shows a slow depletion of fuel. Should the fuel gauge not move in a reasonable amount of time, assume the fuel gauge is broken. In this case, visually check the fuel from time to time to ensure that you do not run out of fuel during operation.

1.5.5 Volt Gauge

Some vehicles have volt gauges (*Figure 5-12*). These gauges indicate the voltage output of the battery. Higher-than-normal voltage may cause damage to the battery.

1.5.6 Hydraulic Pressure Gauge

Most types of construction equipment are equipped with hydraulic pressure gauges. When operating such equipment, you must watch for leaks. Consult the operator's manual for the pressure at which the equipment should be operated. Should the pressure not reach the normal operating range or should you detect a leak, be sure to document and report the problem.

1.5.7 Hydraulic Temperature Gauge

Most types of construction equipment are also equipped with hydraulic temperature gauges. In most cases, if the hydraulic temperature exceeds the recommended temperature, it is because the fluid level is too low.

Should the fluid level be correct and the equipment overheats, you are overworking the hydraulic system. Stop your machine and check the hydraulic fluid level. Be careful because the hydraulic fluid is hot and the hydraulic system may be pressurized. If the fluid level is normal, let the machine sit at idle to cool the hydraulics.

Test your Knowledge (Select the Correct Response)

1. Which of the following is NOT a function of the storage battery?

   A. Supplies all of the electrical power for the vehicle when the engine is not running
   B. Assist the charging system by providing electricity when the demand for current, the movement of electrons, is above the output limit of the charging system
   C. Generates energy (electricity) for extended periods
   D. Acts as a capacitor (voltage stabilizer) that smoothes current flow through the electrical system

2. The charging system recharges the battery and performs what other function?

   A. Stores charged amps
   B. Generates current during operation
   C. Stores charged voltage
   D. Generates current before operation

3. Which of the following starting circuits is NOT used to increase either the voltage or amperage from a set of batteries?

   A. Parallel system
   B. Series system
   C. Series-parallel system
   D. Double-series system

4. Clearance lights outline which of the following areas of a vehicle?

   A. The maximum width only
   B. The maximum height only
   C. The maximum length only
   D. The maximum height and length

5. A brake light is usually combined with the taillight using what type of bulb?

   A. Single-contact, double–filament
   B. Double-contact, double–filament
   C. Double-contact, florence filled
   D. Single-contact, single–filament

6. **(True or False)** When the temperature reading on a water temperature gauge starts to rise above normal range, you should stop and determine the reason.

   A. True
   B. False

7. After an engine is started, what is the rule of thumb for the oil pressure gauge?

A. It should indicate 10 pounds pressure in 30 seconds
B. It should indicate 30 pounds pressure in 30 seconds
C. It should indicate 60 pounds pressure in 30 seconds
D. It should indicate 90 pounds pressure in 90 seconds

2.0.0 HYDRAULIC SYSTEMS

Hydraulic systems, like the one shown in *Figure 5-13*, are found on construction and materials-handling equipment such as forklifts, excavators and front-end loaders. The hydraulic system produces a great amount of power by transmitting high pressurized fluid throughout various components, including a reservoir, strainer and filters, pump, control valves, cylinders, hoses, couplers and accumulator. Some hydraulic systems also transmit fluid to a motor.

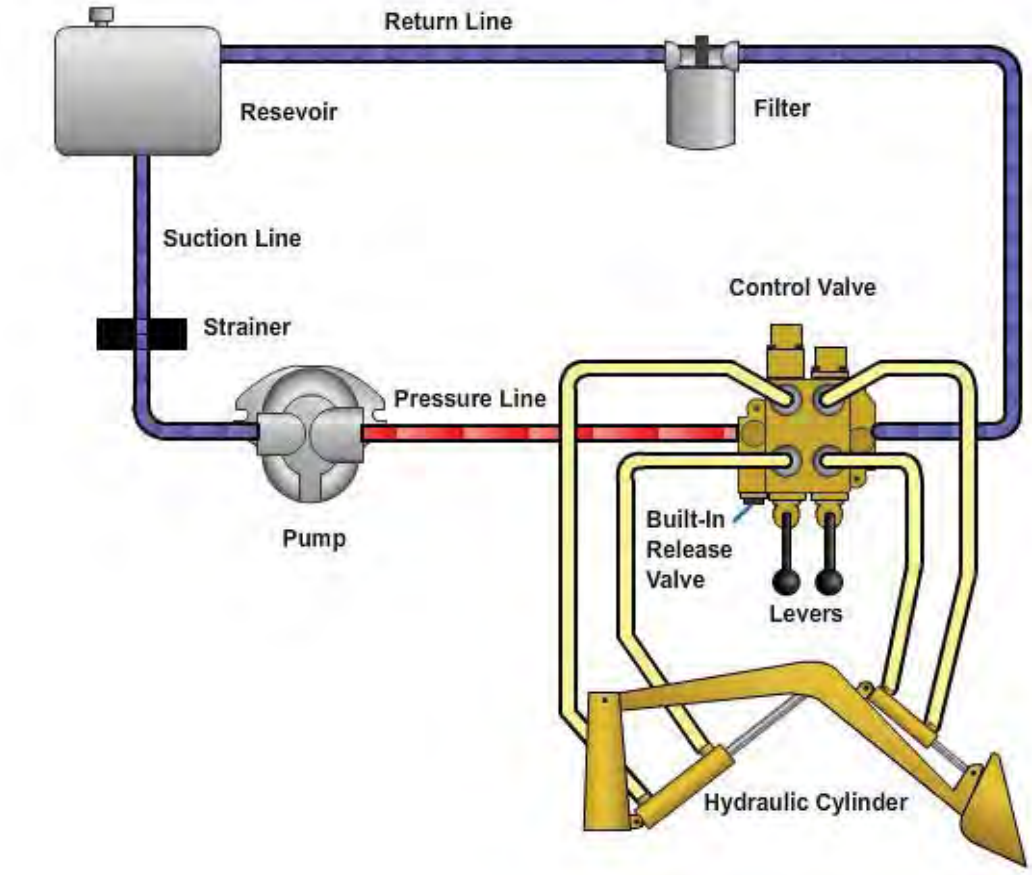


Figure 5-13 – Hydraulic system on a front-end loader.

2.1.0 Hydraulic Reservoir

The hydraulic reservoir stores fluid. Beyond having enough fluid to supply the hydraulic system for normal operation, the reservoir has an addition supply to replace fluid lost because of minor leaks in cylinders, hoses, couplers, and accumulators. Before the fluid is reused in the system, the reservoir allows the settling of any impurities and the separation of air from the fluid.

The basic hydraulic reservoir, as shown in *Figure 5-14*, has enough space to hold all the fluid when the cylinders retract and some space to spare for expansion of hot fluid. This space allows the fluid to foam, thus purging itself of air bubbles that normally occur as the fluid flows from the reservoir, through the system, and back to the reservoir.

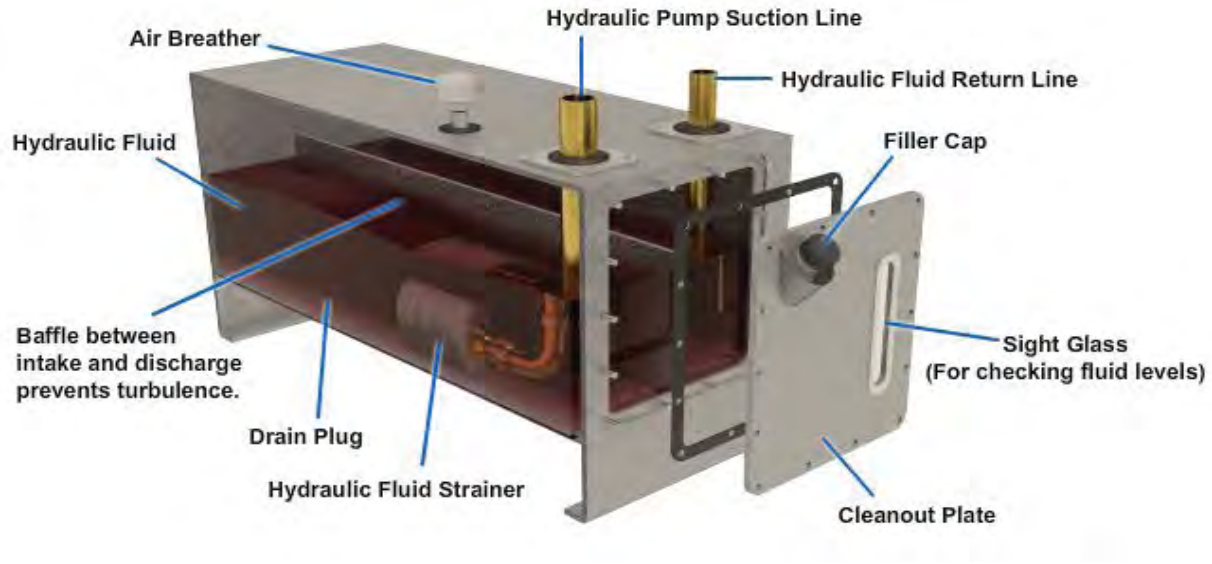


Figure 5-14 – Basic hydraulic reservoir.

The air vent allows the air to be drawn in and pushed out of the reservoir by the ever-changing fluid level. An air filter is attached to the air vent to prevent drawing atmospheric dust into the system. Because it is essential that the fluid is always kept at the correct level, equipment often has sight gauges that allow the operator to visually see the level in the reservoir. The baffle plate segregates the outlet fluid from the inlet fluid. This allows the fluid time to dissipate air bubbles, contaminants to settle, and the return fluid to cool before it is picked up by the pump to be reused.

You must maintain the proper hydraulic fluid level. In some systems, low fluid level causes overheating because the fluid does not have enough time to cool in the reservoir before it is picked up by the pump. In other systems, low fluid level causes air to get into the pump. In this event, the system will not work at all.

Before adding hydraulic fluid to a reservoir, refer to the operator's manual to learn what type to use. Additionally, clean around the filler cap or tube to prevent dirt from getting into the system.

2.2.0 Strainer and Filters

Foreign particles in the fluid can damage the hydraulic system; therefore, hydraulic systems have a strainer and one or more filters to remove such particles.

The strainer, made of fine mesh wire screens, may be located in the reservoir or in the pump suction line. Its purpose is to remove large particles.

Filters, made of paper elements, may be located in the reservoir, return line, or in the pressure line. Their purpose is to remove fine particles.

2.3.0 Hydraulic Pumps

The hydraulic pump does not create pressure in the system, instead; it supplies a continuous flow of fluid to the system. As the fluid leaves the pump, it soon encounters flow restriction. The restriction creates pressure by causing the flow to build up.

When there is enough pressure, a relief valve opens and the pressurized fluid is directed to the reservoir or to the control valve, depending on the position of the control lever in the cab.

2.4.0 Control Valves

By the skillful use of levers, an operator can manipulate the control valves responsible for the volume and pressure of the fluid as well as the direction of its flow. By doing so, the operator can regulate the speed and operation of the hydraulic cylinders.

CAUTION

Operate hydraulic control levers should be operated smoothly to eliminate the jerking motion, which can cause rapid wear and failure of the mechanical parts. Additionally, never hold the control levers in the power position too long, this will cause overheating.

2.5.0 Hydraulic Cylinders

Hydraulic cylinders convert fluid power into linear motion. The force created by the linear motion is determined by the amount of fluid pressure and the area of the piston contacted by the fluid. Thus the larger the piston, the more force generated.

Hydraulic cylinders used on heavy equipment are either single- or double-acting cylinders.

2.5.1 Single-Acting Cylinders

Single-acting cylinders similar to the one shown in *Figure 5-15* are used to exert force in only one direction. This means the weight or resistance moved must be located so it causes the cylinder to return to its original position when pressure is relieved from the piston. A common use of this type of cylinder is in a hydraulic jack.

Figure 5-15 – Single-acting hydraulic cylinder in operation.

2.5.2 Double-Acting Cylinders

Double-acting cylinders are used on equipment which needs force in two directions. Unlike the single-acting cylinder, the double-acting cylinder contains seals at both ends of the piston where the piston rod passes through the end of the cylinder. This cylinder, can direct fluid to either side of the piston and cause the piston rod to extend or retract under pressure.

The double-acting cylinder shown in *Figure 5-16* is called an unbalanced cylinder. This means that the cylinder can exert more force in one direction than in the other. This is due to the piston rod preventing fluid from acting on the full area of the piston on one side.

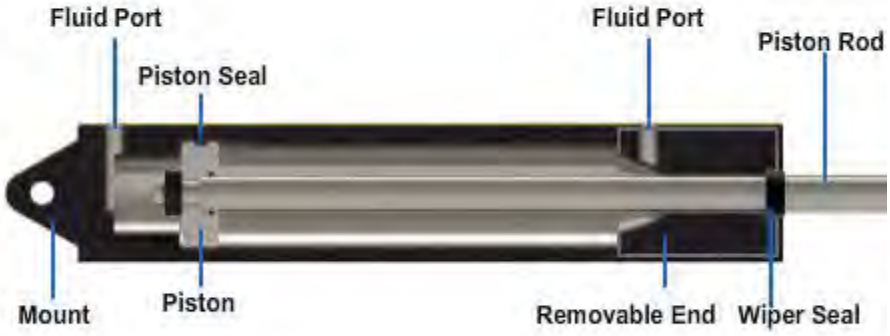


Figure 5-16 – Double-acting hydraulic cylinder in operation.

NOTE

Before and after operating a hydraulic system, use a clean rag to wipe off all foreign material collected by the wiper seals (*Figure 5-16*). This practice prevents such material from entering and damaging the cylinder.

Before storing equipment, coat the exposed hydraulic cylinders and attachments with grease recommended by manufacturer. This practice will protect the equipment against harsh elements, such as salty air, strong winds, and blowing sand. Remember to wipe off the grease before using the equipment.

2.6.0 Hydraulic Hoses

Hydraulic hoses are designed for specific fluid, temperature, and pressure ranges and are provided in various specifications.

Hydraulic hoses consist of at least three parts: an inner tube, a reinforcement layer, and an outer cover (*Figure 5-17*).

The inner tube carries the hydraulic fluid. It is made of a synthetic material resistant to deterioration from the fluid. The reinforcement layer or layers are made of either fabric or rubber for low-pressure systems, or wire braid for high pressure applications. These layers give the hose its strength. The outer cover is weather-, oil-, and abrasion-resistant.

Figure 5-17 – Hydraulic hose construction.

Part of your pre- and post-operational check is to inspect the hydraulic hoses for cracking or splitting, pinhole leaks, improper hose length, rubbing, heat, twisting, and so forth. Any problems with the hydraulic hoses should be repaired before equipment use.

In addition, here are some hints that will help reduce hose leakage and maintenance:

- Leave a little slack in the hose between connections to allow for swelling when pressure is applied. A taut hose is likely to pull out of its fittings.
- Do not loop a hose unless the manufacturer requires it. This causes unnecessary flexing of the hose as pressure changes. Angled fittings should be used instead of loops.
- Do not twist a hose; twisting causes the hoses to weaken.
- Use clamps or brackets to keep a hose away from moving parts or to prevent chafing when the hose flexes.
- Keep hoses away from hot surfaces, such as manifold and exhaust systems. If you are unable to do so, install a heat shield to protect the hose.
- Route hoses so there are no sharp bends. This is critical with high-pressure hoses.

2.7.0 Quick-Disconnect Couplers

Quick-disconnect couplers (*Figure 5-18*) are used where hydraulic hoses must be connected and disconnected frequently without fluid loss. Quick-disconnect couplers allow an operator to quickly couple or uncouple an attachment, like a bucket to a front-end loader.

A quick-disconnect coupler is a self-sealing device and does the work of two shutoff valves and a tube coupler. More importantly, there is no need to drain or bleed the system each time an operator makes a hookup.

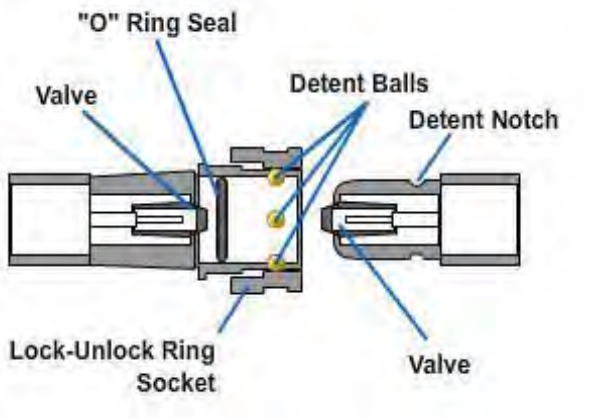


Figure 5-18 – Quick-disconnect coupler.

A quick-disconnect coupler consists of two halves held and sealed together by a locking device. Each half has a spring-loaded valve. When the coupler is connected, the valves open, allowing fluid to flow through in either direction. When the coupler is disconnected the springs close the valves, preventing the loss of fluid and the entrance of air.

When quick-disconnect couplers are disconnected on attachments, you must insert dust plugs into the coupler ports. This prevents foreign matter from entering the hydraulic system. A common practice when dust plugs are unavailable is to use a plastic bag to wrap the couplers.

WARNING

Hydraulic systems can create up to 3,000 pounds of pressure per square inch and hydraulic fluid may reach temperatures above 200°F. Remember to wear protective gloves and use extreme care when disconnecting and reconnecting quick-disconnect couplers.

2.8.0 Accumulators

Accumulators are sometimes placed in a hydraulic system to absorb shock. These are frequently used on tracked front-end loaders and other equipment containing hydraulic systems subjected to severe shock when dumping loads.

The accumulator is a large cylinder that contains gas or a coil spring. When heavy shock is felt in the hydraulic system, fluid enters this cylinder and compresses the gas or spring. A piston, bladder or a diaphragm separates the fluid from the gas or spring. Once the shock stabilizes, the fluid is forced back to the operating portion of the system.

2.9.0 Hydraulic Motors

Some hydraulic systems have motors that provide power to winches, drive conveyors on ditching machines which are used in other applications where mechanical drives are impractical.

The hydraulic motor converts fluid power energy to rotary force called torque. The fluid enters the housing and drives the rotating members of the winch as shown in *Figure 5-19*. The fluid is then discharged and returns to the reservoir or pump.

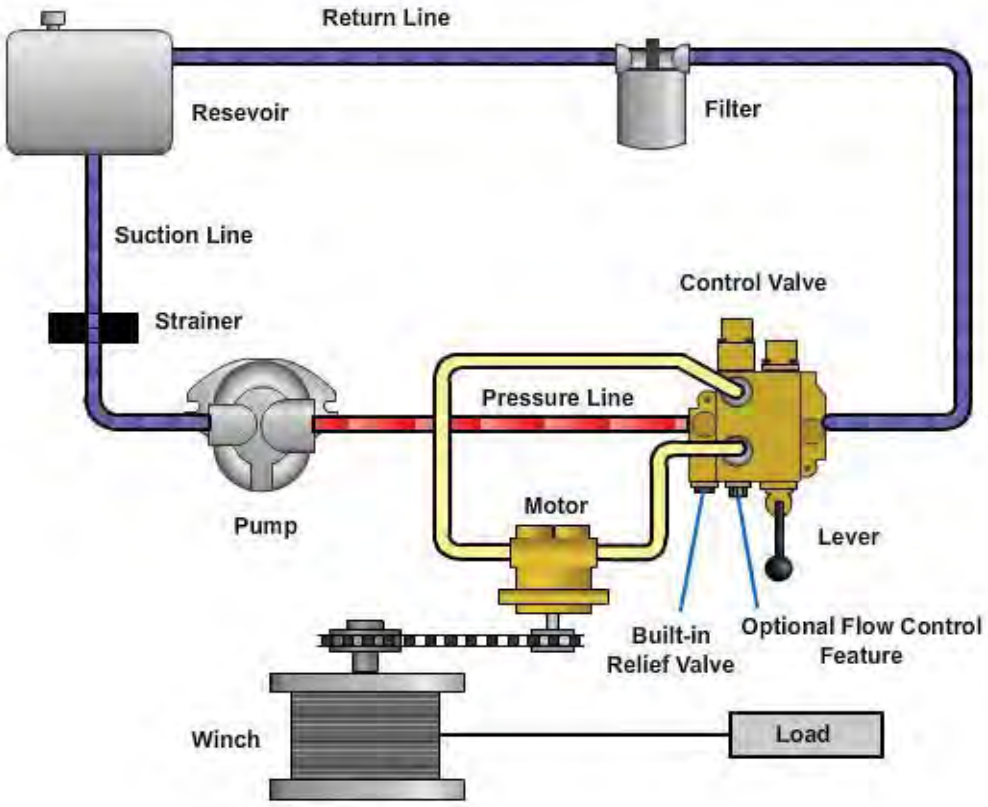


Figure 5-19 – Hydraulic system with motor.

Test your Knowledge (Select the Correct Response)

8. The baffle plate in the hydraulic fluid reservoir does NOT allow which of the following conditions to occur?

    A. The dissipation of air bubbles
    B. The settling of contaminants
    C. The cooling of the return fluid
    D. An excessive formation of air bubbles

9. The force created by a hydraulic cylinder is determined by the pressure of the fluid and what other system?

    A. The size of the hydraulic hoses
    B. The speed of the engine
    C. The area of the piston contacted by the fluid
    D. The skillful use of control valves

10. **(True or False)** The hydraulic motor converts fluid power energy to rotary force.

    A. True
    B. False

Summary

In this chapter, you were introduced to electrical and hydraulic systems. You learned how the vehicle electrical system supports the battery, lights and gauges and warning indicators on the instrument panels.

In addition, you learned how the hydraulic system and all its components including a reservoir, pump, control valves, and cylinders generate great power to perform material-handling operations.

Review Questions (Select the Correct Response)

1. Which of the following components is NOT a basic component of an automotive and construction equipment electrical system?

   A. A storage battery
   B. A charging system
   C. A starting circuit
   D. An electrostat

2. Which of the following components is the heart of the charging circuit?

   A. The storage battery
   B. The starting circuit
   C. The lighting system
   D. The gauges

3. You can thoroughly clean a battery by using a stiff brush and what kind of solution?

   A. Water and baking soda
   B. Water and soap
   C. Water and detergent
   D. Water and vinegar

4. **(True or False)** The cell elements of a battery contain two types of lead plates, known as positive and negative.

   A. True
   B. False

5. In what units is the capacity of a battery measured?

   A. Series
   B. Ampere-minutes
   C. Ampere-hours
   D. Candle power

6. **(True or False)** DC and AC are the two types of charging systems used on automotive and construction equipment.

   A. True
   B. False

7. What component of the charging system supplies the electrical power and rectifies its current mechanically by using commutator bars and brushes?

   A. The generator
   B. The alternator
   C. The regulator
   D. The coil

8. **(True or False)** Compared to generators, most alternators supply a lower current output at low-engine speeds.

   A. True
   B. False

9. Which of the following stages is NOT an operating stage of a charging system?

   A. The battery supplies all load current during starting
   B. The battery supports the generator supply current during peak operations
   C. The generator supplies all current and recharges the battery
   D. The battery supplies all current for peak operations

10. **(True or False)** In both electrical systems, the battery starts the electrical circuit that supplies the spark to start the engine.

    A. True
    B. False

11. **(True or False)** Hooking up jumper cables from a 24-volt system to a heavy-duty 12–volt system can cause severe battery damage, starter destruction, or even an explosion.

    A. True
    B. False

12. Which of the following is NOT a component of the lighting system?

    A. Lamps and bulbs
    B. Clearance lights
    C. Fuses
    D. Stators

13. Which of the following personnel is responsible for replacing bad bulbs on equipment?

    A. The Dispatcher
    B. The Yard Boss
    C. The Operator
    D. The Company Clerk

14. Which classification of lights outlines the height of a vehicle?

    A. Clearance
    B. Side marker
    C. Identification
    D. Taillight

15. As viewed from the side, what classification of lights indicates the full-over-all length of a vehicle?

    A. Clearance
    B. Side marker
    C. Identification
    D. Taillight

16. Which of the following items is used as an additional safety precaution in case lights burn out or break?

    A. Auxiliary light
    B. Spotlight
    C. Backup light
    D. Reflectors

17. **(True or False)** Brakes lights are a safety-required item and must be operational at all times.

    A. True
    B. False

18. Which of the following lights must turnoff automatically when a vehicle is moving forward?

    A. Brake
    B. Parking
    C. Backup
    D. Side marker

19. Which of the following components is the weakest point in an automotive electrical circuit?

    A. The bulb
    B. The fuse
    C. The wiring
    D. The electrical connections

20. **(True or False)** Cold water should NOT be added to an overheated engine when it is running.

    A. True
    B. False

21. A low air pressure warning light or buzzer should come on when the air pressure drops below which of the following pressures?

    A. 60 psi
    B. 90 psi
    C. 120 psi
    D. 150 psi

22. What action should you take if the hydraulic fluid level is normal, but the hydraulic fluid temperature gauge indicates the fluid has exceeded the recommended operating temperature range?

    A. Continue to operate at a slow speed
    B. Shut down the engine to allow the hydraulic fluid to cool
    C. Idle the engine to allow the hydraulic fluid to cool
    D. Continue to operate running the engine at full speed

23. When operating a piece of equipment, what action should you take if the fuel gauge does NOT indicate any depletion of fuel?

    A. Visually check the fuel level from time to time
    B. Assume the fuel tank is full
    C. Ignore the gauge
    D. Park the equipment and notify the mechanic field crew

24. Which of the following is NOT a component of a hydraulic system?

    A. A reservoir
    B. A pump
    C. Control valves
    D. A thermostat

25. Which of the following components stores fluid for the hydraulic system?

    A. Hydraulic cylinder
    B. Accumulator
    C. Reservoir
    D. Fluid box

26. Which of the following components creates the flow of fluid within the hydraulic system?

    A. The hydraulic cylinder
    B. The control valve
    C. The hydraulic pump
    D. The strainer

27. **(True or False)** Hydraulic control levers should be operated smoothly to eliminate any jerking motion that causes rapid wear of mechanical parts?

    A. True
    B. False

28. What type of hydraulic cylinder exerts force in only one direction?

    A. Single-acting
    B. Double-acting
    C. Single-contacting
    D. Double-contacting

29. **(True or False)** A pre-start check on a hydraulic cylinder includes using a clean rag to remove the foreign material collected by the wiper seal.

    A. True
    B. False

30. When performing pre- and post operational inspections, you should inspect hydraulic hoses for which of the following conditions?

    A. Cracking only
    B. Rubbing and cracking only
    C. Twisting and rubbing only
    D. Twisting, rubbing, and cracking

31. Which of the following components performs the work of two shutoff valves and a tube coupler?

    A. Pressure relief line
    B. Relief valve
    C. Quick-disconnect coupler
    D. Oil strainer

32. What component installed in a hydraulic system is used to absorb shock?

    A. Shock absorber
    B. Accumulator
    C. Piston seal
    D. Control valve

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.

Construction Mechanic Basic, NAVEDTRA 14264A, NAVEDTRA 14081, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1999.

Equipment Operator, Basic, NAVEDTRA 14081, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1994.

Fundamentals of Service, Power Trains, Deere & Company, Moline, IL, 2005.

Principles of Automotive Vehicles, TM 9-8000, Headquarters, Department of the Army, Washington, DC, 1988.

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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 6

Earthwork Operations

Topics

1.0.0 Project Planning

2.0.0 Earthwork Computations

3.0.0 Construction (Grade) Stakes

4.0.0 Leveling Equipment

5.0.0 Soils

6.0.0 Techniques of Earthwork Operations

To hear audio, click on the box. 

Overview

Roads, runways, buildings, and other temporary or permanent structures require a solid foundation. To build this foundation, the Naval Construction Force (NCF) must perform earthwork operations, often referred to as horizontal construction.

Earthwork operations include much more than just moving earth. An Equipment Operator must also plan and develop the steps to complete the project, study and understand project drawings, compute earthwork volumes, read and use construction grade stakes, transfer elevations with leveling equipment, and understand the characteristics of soils and the procedures used in earthwork operations.

Objectives

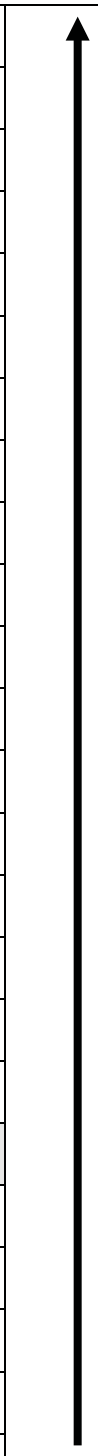
When you have completed this chapter, you will be able to do the following:

1. Understand the sequence of project planning.
2. Identify how to perform earthwork computations.
3. Identify types and use of construction (grade) stakes.
4. Identify types and use of leveling equipment.
5. Understand formation and stabilization of soils.
6. Identify techniques of earthwork operations.

Prerequisites

None

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

Miscellaneous Equipment		EQUIPMENT
Paving Operations and Equipment		
Rigging Operations		
Cranes		
Rollers		
Dozers		
Scrapers		
Graders		
Ditchers		
Excavators		
Backhoe Loaders		OPERATOR
Front-End Loaders		
Forklifts		
Truck Driving Safety		
Truck-Tractors and Trailers		
Tank Trucks		
Dump Trucks		
Medium Tactical Vehicle Replacements		
Earthwork Operations		
Electrical and Hydraulic Systems		BASIC
Chassis Systems		
Power Train		
Engine Systems		
Transportation Operations		

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 PROJECT PLANNING

In the NCF, the entire history of each construction project, from the initial planning phase, through the execution phase, to the closeout phase, is documented in a Seabee Project Package (*Figure 6-1*). This package, consisting of five sections, is used for all tasked projects.

SEABEE PROJECT PACKAGE

(*Required On All Projects)
(**Requirement may be waived in a contingency operation)

SECTION #1 GENERAL INFORMATION AND CORRESPONDENCE

1A
- *Tasking Letter/Correspondence
- *Outgoing Messages and Correspondence
- *Incoming Messages and Correspondence

1B
- Project Scope Sheet
- Project Organization
- Project Planning Milestones
- Project Package Sign-Off Sheet
- Deployment Calendar
- Pre-construction Conference Summary
- Pre-deployment Site Visit Summary
- Joint Turnover Memorandum
- Pre- Beneficial Occupancy Date (BOD) Inspection Request

SECTION #2 ACTIVITIES AND NETWORK

2A
- *Level II Bar Chart
- *Two week Schedules
- *Master Activity Listing
- *Master Activity Summary Sheets
- **Level III Precedence Diagram

2B
- Level III Bar Chart
- Construction Activity Summary Sheets (CAS Sheets, recommend including filled out 1250-1s)
- CAS Sheets of Completed Activities
- Two Week Labor Summaries
- Situation Report (SITREP) Feeders
- Other Computer Printouts/Reports

SECTION # 3 RESOURCES

3A
- *30/60/90-Day Material List
- *30/60/90-Day Material List Letter
- *Bill of Materials
- *Tool Requirement Summary
- *Equipment Requirement Summary

3B
- List of Long Lead Items
- Material Take Off Worksheets
- Bill of Materials/Material Take Off Comparison Worksheets
- Material Transfer Requests
- Add On/Reorder Justification Forms
- Add-On/Reorder BMs
- Borrow Log

Figure 6-1 – Seabee project package.

SECTION #4 PLANS

4A
*Quality Control Plan Cover Sheet
*Quality Control Plan
*Safety Plan Cover Sheet
*General Safety Plan
*Safety Plan
**Environmental Plan

4B
Daily Quality Control Inspection Reports
Field Adjustment Request (FAR) Submittal Log
FARs
Request For Information (RFI) Submittal Log
RFIs
Design Change Directives (DCD)
Concrete Placement Clearance Forms
Pre-placement Photos for Concrete Placements.
Asphalt Placement Clearance Forms
Utility Interruption Request
Excavation Request
Road Closure Request
Engineering Service Request
Mineral Products Request
Other Quality Control Forms
Daily Safety Inspection Reports
Emergency Phone Numbers
Navy Employee Report of Unsafe or Unhealthful Working Conditions
Required Safety Equipment
Daily Safety Lecture Log
Accident/Near Mishap/Mishap Reports
Highlighted 29 CFR 1926
Hazardous Materials Inventory Sheet
Other Safety Forms

SECTION #5 DRAWINGS/SPECIFICATIONS

5A
*Project Plans
**Highlighted Specifications

5B
Site Layout
Shop Drawings
Detailed Slab Layout Drawings
Forming Plans
Rebar Bending Schedule
Other Sketches/Drawings
Technical Data

Figure 6-1 – Seabee project package (continued).

A flow chart, showing the sequence of planning steps, is shown in *Figure 6-2*.

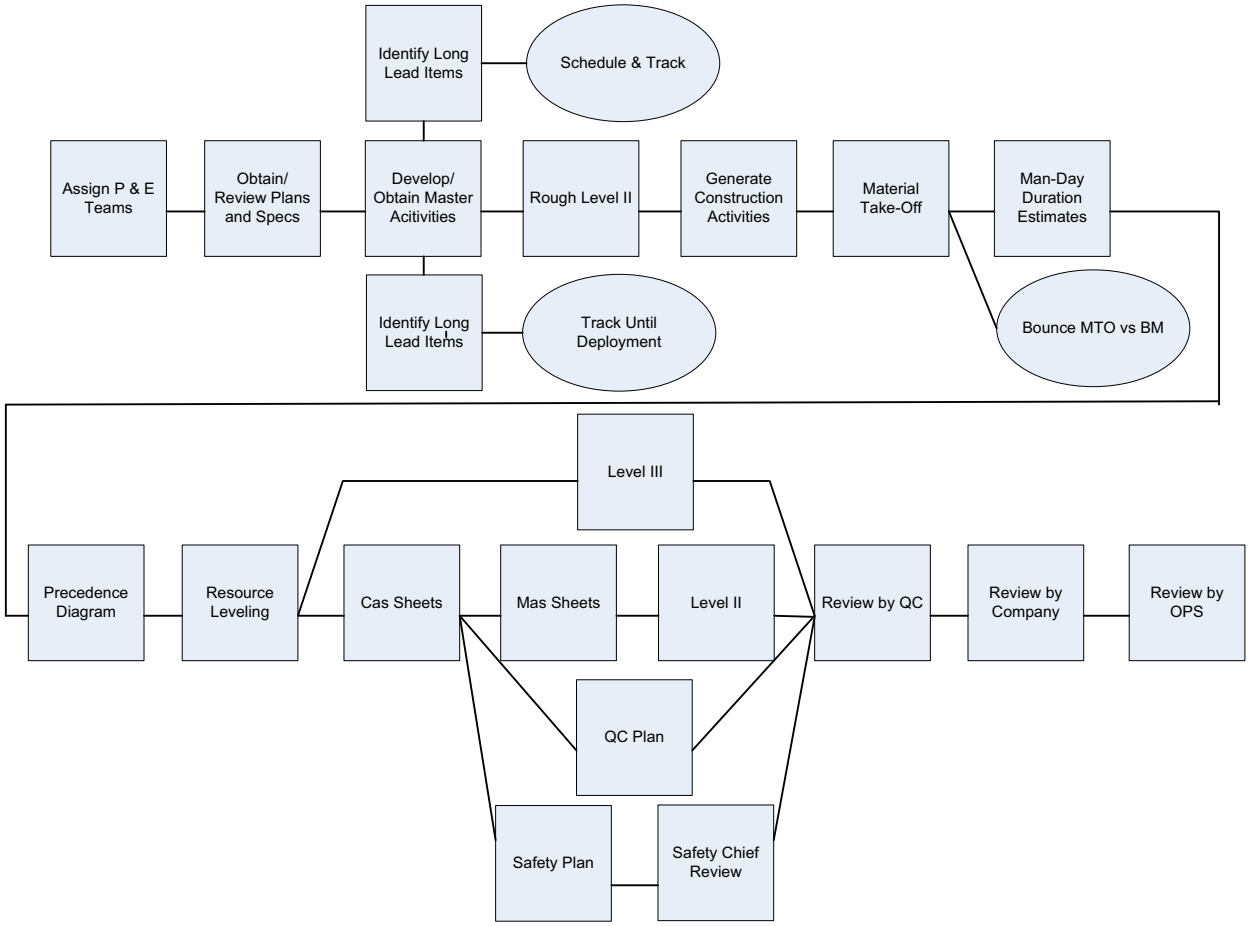


Figure 6-2 – Project planning flow chart.

These steps are also listed in the project planning milestones list (*Figure 6-3*). The operations department normally assigns this list at the beginning of homeport. Step-by-step information on how to develop a project package is outlined in the *Seabee Crewleader's Handbook.*

PROJECT PLANNING MILESTONES

Project Number: _____ Project Title: _____

MILESTONES	DATE REQUIRED	DATE COMPLETED
1. Designate Crewleader and Planning and Estimating Staff	_____	_____
2. Pre-Planning Conference	_____	_____
3. Review Plans and Specifications	_____	_____
4. Identify Long Lead Materials	_____	_____
5. Identify Required Skills and Training	_____	_____
6. Complete Project Scope Sheet	_____	_____
7. Complete Master Activity Listing	_____	_____
8. Develop Rough Level II Bar Chart	_____	_____
9. Develop Level II Logic Network	_____	_____
10. Generate Construction Activity Listing	_____	_____
11. Develop Independent Material Take-Off	_____	_____
12. Develop BM/MTO Discrepancy List	_____	_____
13. Complete Construction Activity Summary Sheets	_____	_____
14. Develop Level III Logic Network	_____	_____
15. Input Project into Computer	_____	_____
16. Resource Level Project	_____	_____
17. Develop Level III Bar Chart	_____	_____

Figure 6-3 – Project planning milestones.

1.1.0 Project Drawings

The NCF uses a variety of construction drawings to show the location of the project, as well as the boundaries, contours, and outstanding physical features of the construction site and its adjoining areas. As an Equipment Operator, you will frequently come across project drawings, which is a specific type of construction drawing.

Project drawings, also known as working drawings, furnish the information the craftsmen require to manufacture a machine part or a builder crew to erect a structure. Project drawings are prepared from a freehand sketch or a design drawing. They include all the drawings necessary for the different Seabee ratings to complete the project. They also serve the following functions:

- They provide a basis for estimating material, labor, and equipment before construction begins.
- They provide precise instructions for construction, showing the sizes and locations of various parts.
- They provide a means of coordination between the different ratings.
- They complement the specifications; one source of information is incomplete without the other.

1.1.1 Categories

Project drawings are divided into following major categories: civil, architectural, structural, mechanical, and electrical.

A complete set of project drawings consists of general drawings, detail drawings, assembly drawings, and a bill of materials.

Civil Drawings – Civil drawings encompass a variety of plans and information to include the following:

- Site preparation and site development
- Fencing
- Rigid and flexible pavements for roads and walkways
- Environmental pollution control
- Water supply units

Depending on the size of the construction project, the number of sheets/pages in a set of civil drawings may vary from a bare minimum to several sheets/ pages of related drawings. Normally, on an average-size project, the first sheet/page has a location map, soil boring log, legends, and sometimes site plans and small civil detail drawings. (Soil boring tests are conducted to determine the water table of the construction site and classify the existing soil.) For earthwork operation, you should concentrate on the civil drawings.

Architectural Drawings – Architectural drawings consist of all the drawings that describe the architectural design and composition of the building. A set of architectural drawings includes the following:

- Floor plans
- Building sections
- Exterior and interior elevations
- Millwork, door, and window details and schedules
- Interior and exterior finish schedules
- Special architectural treatments

Structural Drawings – Structural drawings consist of all the drawings that describe the structural members of the building and their relationship to each other. A set of structural drawings includes the following:

- Foundation plans and details
- Framing plans and details
- Wall sections, column, and beam details
- Other plans, sections, details, and schedules necessary to describe the structural components of the building or structure

Mechanical Drawings – Mechanical drawings consist of drawings that show the following:

- Fixtures
- Water supply
- Waste disposal lines
- Equipment and other supply and disposal sources

Electrical Drawings – Electrical drawings consist of drawings that show the following:

- Components associated with electrical distribution
- Interior wiring and the methods used in the development of an electrical plan

General Drawings – General drawings consist of “plans” (views from above) and elevations (side or front views) drawn on a relatively small defined scale, such as 1/8 inch = 1 feet or 1/4 inch = 1 feet. Most of the general drawings are drawn in ***orthographic projections***.

The site plan, shown in *Figure 6-4*, furnishes the essential data for laying out the proposed building lines. It shows the shows the contours, boundaries, roads, utilities, trees, structures, and other significant physical features on or near the construction site.

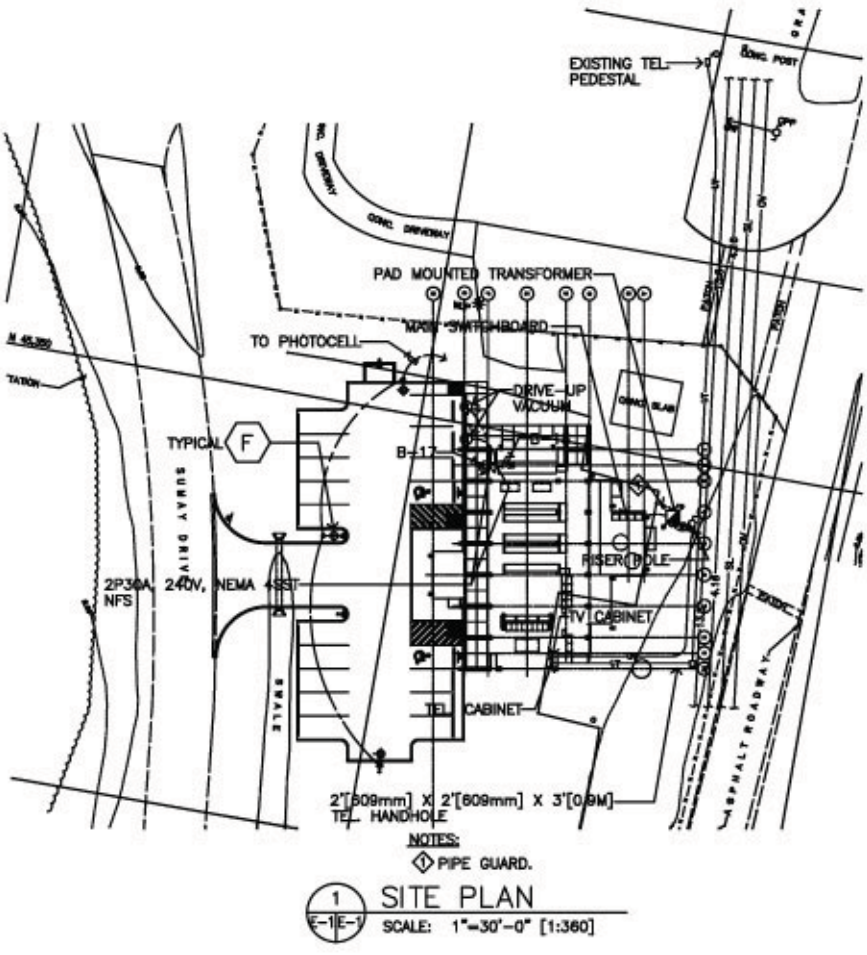


Figure 6-4 – Example of a site plan with existing utilities.

Contour lines show an imaginary line, representing a constant elevation on the earth's surface. Blueprints, or plans, use contour lines to show the final proposed elevations.

- Existing Contour Lines – Existing contour lines identify the existing elevations (*Figure 6-5*). Existing and proposed elevations are used to figure ***cut-and-fill*** operations.
- Proposed Contour Lines – Proposed contour lines are those we work toward, you use them to visualize the finished product (*Figure 6-5*).

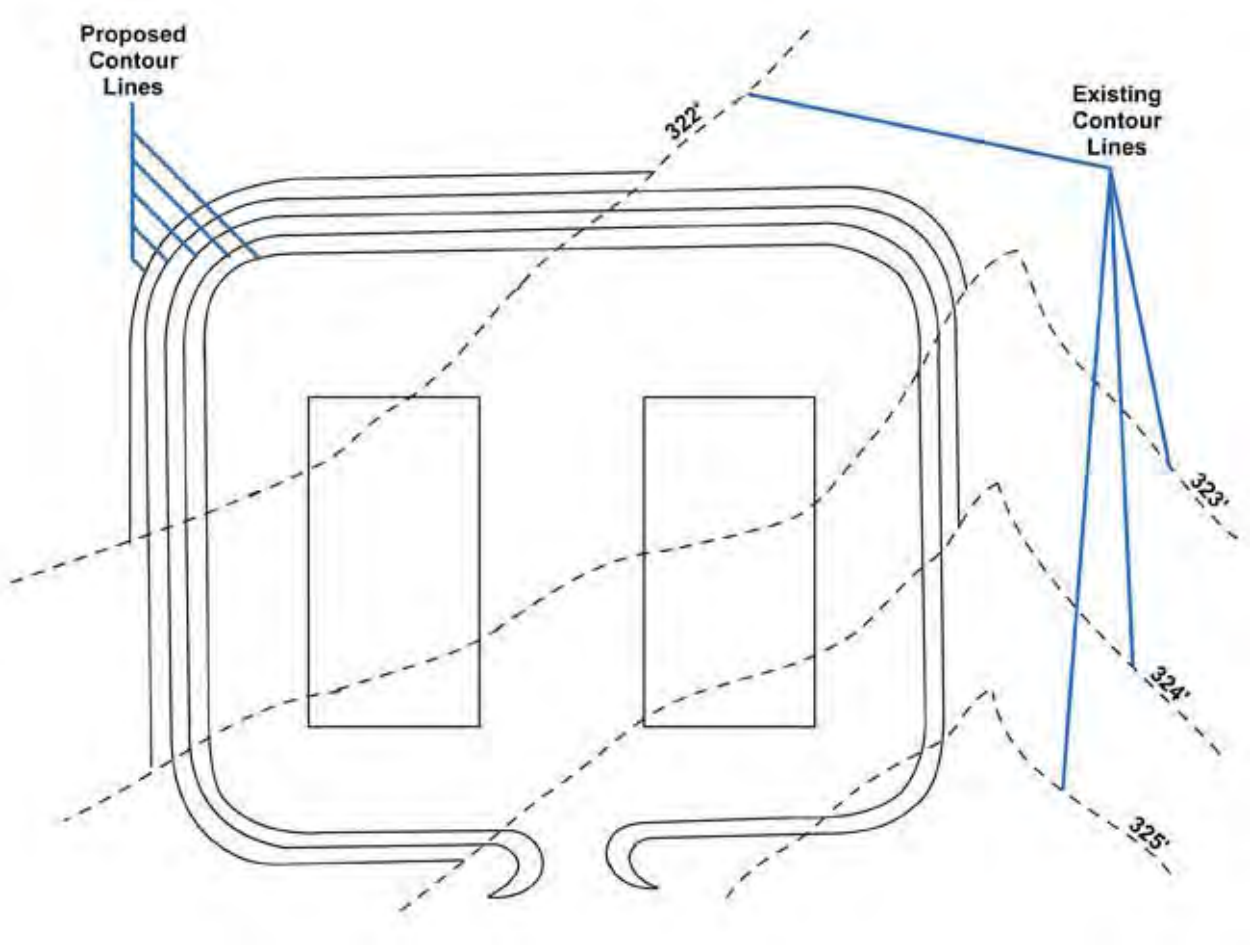


Figure 6-5 – Existing and proposed contour lines.

A plan and profile sheet (*Figure 6-6*) and a typical cross section (*Figure 6-7*) are other information found on a site plan.

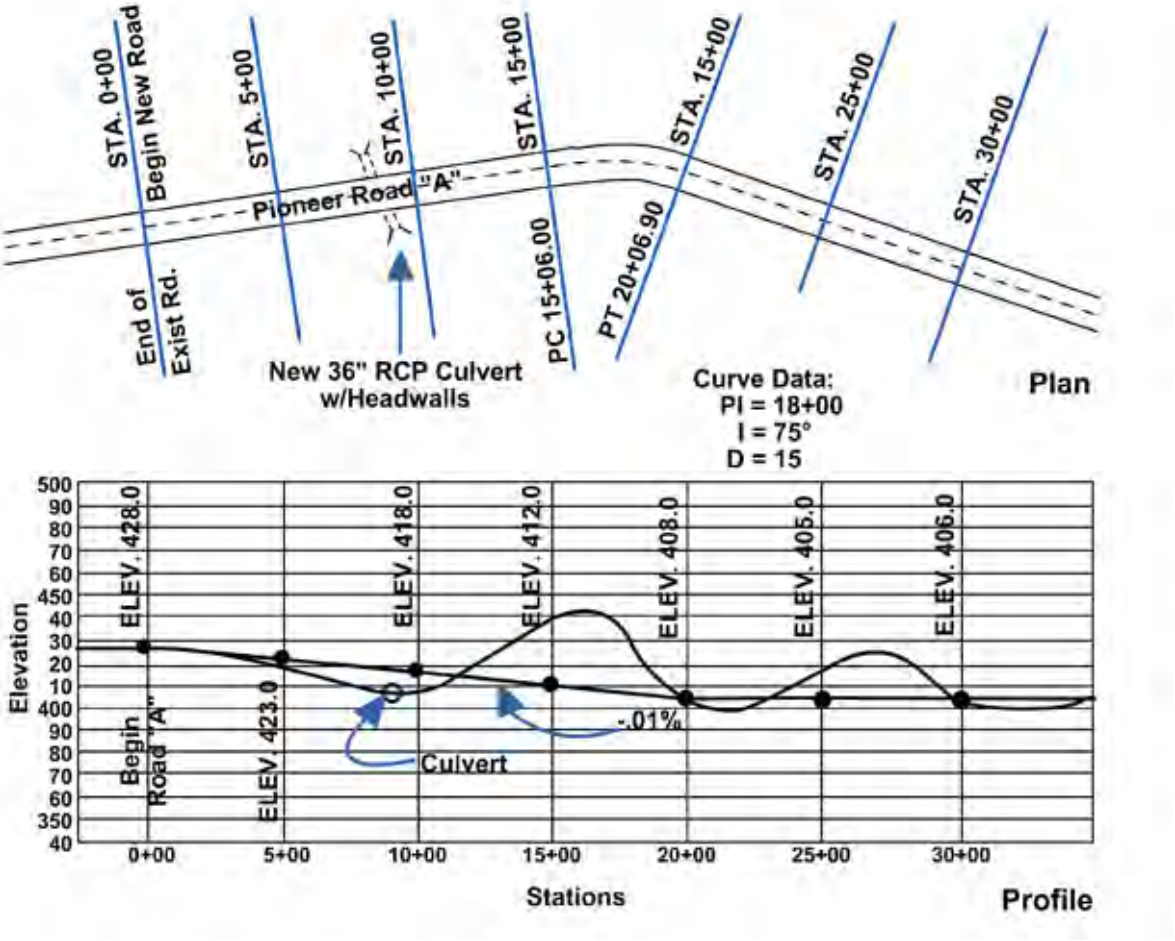


Figure 6-6 – Plan and profile sheet.

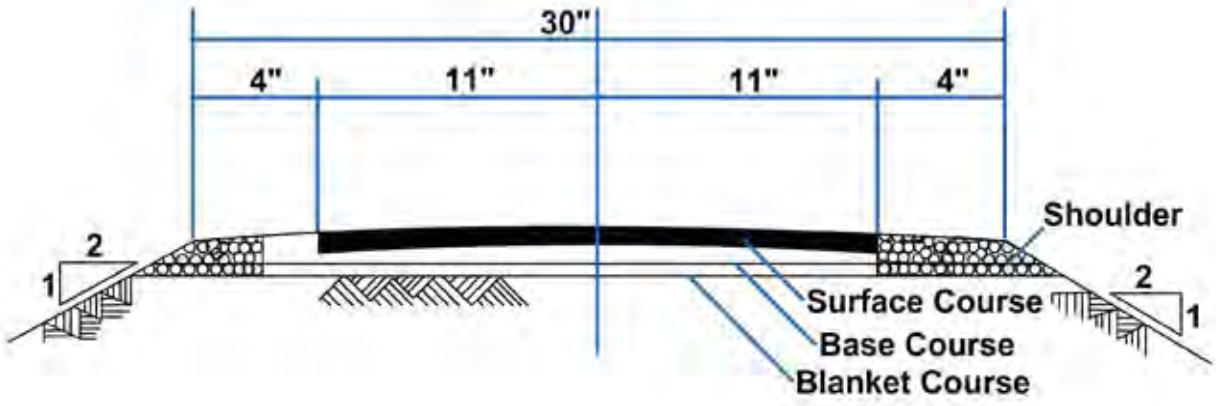


Figure 6-7 – Typical cross section.

Detail Drawings – Detail drawings show a particular item on a larger scale than that of the general drawing in which the item appears, or it may show an item too small to appear at all on a general drawing.

Assembly Drawings – Assembly drawings are either exterior or sectional views of objects showing the details in the proper relationship to one another. Usually, assembly drawings are drawn to a smaller scale than are detail drawings. This procedure provides a check on the accuracy of the design and detail drawings and often discloses errors.

Bill of Materials – Depending on the space available on the drafting sheet, a bill of materials (*Figure 6-8*) may be incorporated in the drawing; otherwise, it may be listed on a separate sheet. The bill of materials contains a list of the quantities, types, sizes, and units of the materials required to construct the object presented in the drawing.

BILL OF MATERIALS

ITEM NO.	DESCRIPTION	UNIT	ASSEMBLY OR FSN NO.	QUANTITIES	
				TROP	NORTH
3-1	LIGHTING CIRCUIT - NAVFAC DWG NO 203414	EA	3016	3	3
3-2	POWER BUS, 100A - NAV DWG NO 304131	EA	3047	1	1
3-3	RECEPTACLE CKT - NAV DWG NO 303660	EA	3019	2	2
3-4	BOX, RECEPTACLE W/CLAMP FOR NONMETALLC SHEATH WIRE	EA	5325-102-604	3	3
3-5	LAMP ELECTRIC, MED BASE, INSIDE FROSTED, 200W,120V	EA	6240-180-314	60	60
3-6	PLUG: ATTACHMENT, 3 WIRE, 15 AMP, 125 V	EA	5936-102-309	10	10
3-7	PLATE: BRASS, DUPLEX RECEPTACLE	EA	5325-100-101	5	5
3-8	RECEPTACLE, DUPLEX, 3 WIRE, 15AMP, 125V	EA	5325-100-102	5	5
3-9	RCD, GROUND, 3/4" X 10'-0"	EA	3325-800-101	12	12
3-10	WIRE NO 2 1/C STRANDED, HARD DRAWN, BARE	LB	6143-134-200	52	52
3-11	SWITCH, SAFETY, 2P, ST 30 AMP, 250 V PLUS FUSE	EA	5930-142-401	2	2
3-12	CLAMP, GROUND ROD	EA	5909-100-101	13	13
3-13	SWITCH, SAFETY, 200 AMP, 250 V, 3 P	EA	5930-201-903	1	1
3-14	FUSE, RENEWABLE 200AMP, 250V	EA	6920-100-000	6	6
3-15	LINK FUSE, 200 AMP, 250 V	EA	6920-100-001	6	6
3-16	FUSE PLUG, 30AMP, 125 V	EA	6920-100-102	12	12

Figure 6-8 – Bill of materials.

1.1.2 Pages

Most drawings have sheets/pages with designator letters (C -Civil, A-Architectural, S -Structural, M -Mechanical and E-Electrical). For example, as shown in *Figure 6-9*, the sheet designating letter and page number is the 22nd architectural page in a set of plans, so it is written A-22. The name, or title, of the project will be in the largest block on the page. For earthwork operations, concentrate on civil pages.

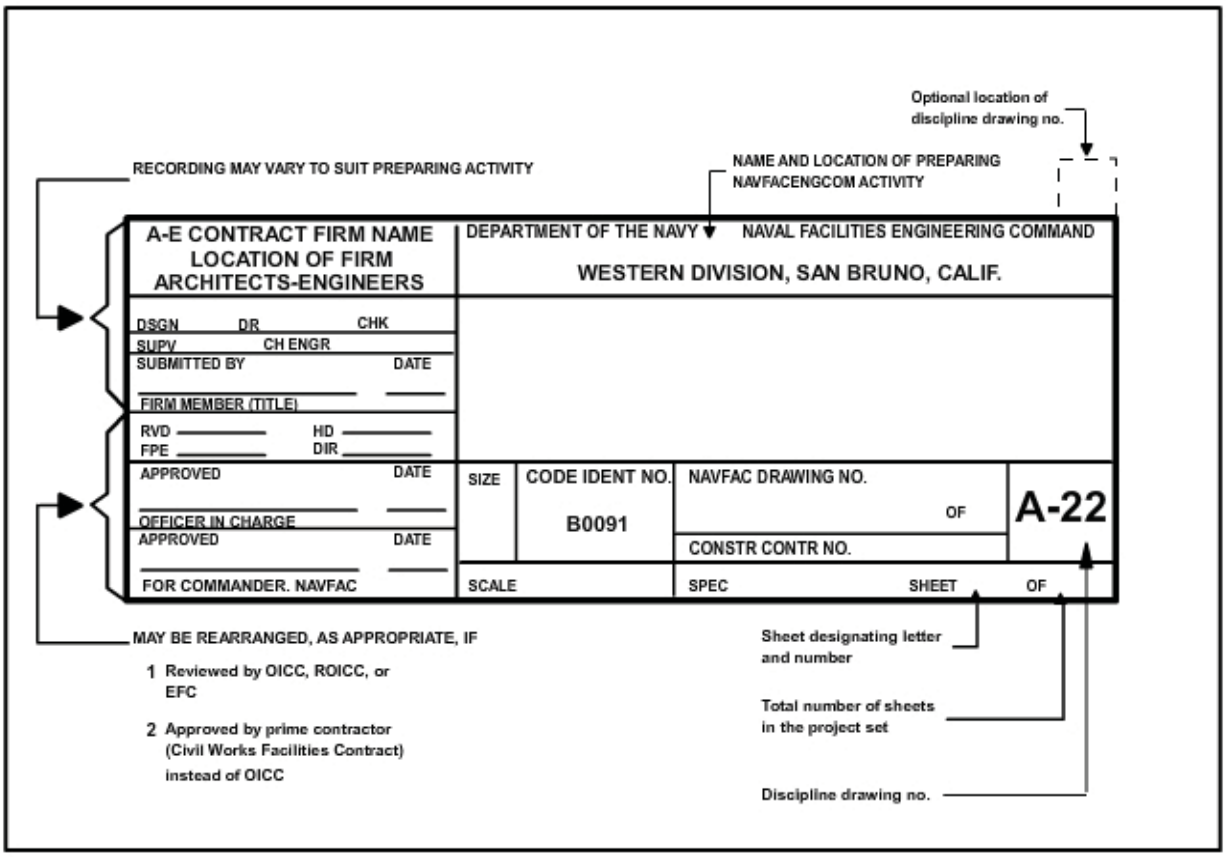


Figure 6-9 – Title block for drawings.

1.1.3 Lines

Lines in drawings can be wide, narrow, dark, light, broken or unbroken. *Figure 6-10* shows the following types of lines frequently used on drawings and what those lines indicate.

Trim Lines – Trim lines are light, continuous lines along which the tracing is trimmed to square the sheet.

Border Lines – Border lines are heavy, continuous lines that outline or border the drawing. The drawing is complete within this lined border.

Main Object Lines – Main object lines are heavy, unbroken lines used to show visible outlines or edges that would be seen by people looking at the article, house, or building. Main object lines are important because they outline the main wall lines on plans and sections. They show clearly the important parts of the construction and emphasize the outline of the elevations.

Dimension Lines – Dimension lines are light lines drawing outside the structure or detail to show the distance between two points. These lines are drawn between extension lines with an arrowhead on each end. Between the arrowheads, the distance will be given either at a break in the line or just above the line. On some drawings, the scale and the distance between the two points may not agree; in such cases, the distance will be given in a dimension line.

Extension Lines – Extension lines are lines that touch and are used with dimension lines. These lines extend out from the edge or the point at which the dimension is to be determined.

Symbol Section Lines – Symbol section lines are generally solid, although, for certain conventions, dotted lines of the same weight may be used. Section lines, evenly spaced, are used to shade surfaces shown on a drawing and by these means indicate the material used. Material section lines are standardized to a certain degree, but you will find some variations. A set of working drawings using these symbols would have a symbol schedule key showing the various materials in that particular set. This schedule is usually placed near the title box on the plan of the first floor.

Broke Lines – Broken line are lines with wavy breaks in it at intervals. They are used to indicate those parts that have been left out or to indicate that the full length of some part has not been drawn. Broken lines are used in detail drawings where only a section of the object is to be shown.

Invisible Lines – Invisible lines are lines that are made up of a series of short dashes. They are used to indicate an edge or edges hidden under some other part of the structure.

Center Lines – Center lines are lines that are made up of alternating long and short dashes. They are used to indicate the center of an object.

Break Lines – Break lines are thin solid-ruled lines with freehand zigzags. They are used to reduce the size of a drawing required to delineate an object and reduce detail.

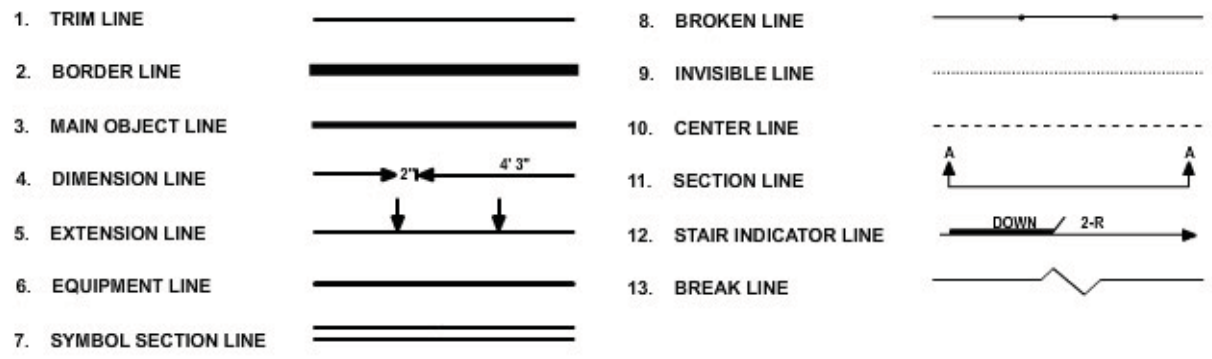


Figure 6-10 – Types of lines.

1.1.4 Symbols

Like lines, symbols are frequently used on drawings. Such symbols fall into three categories: utility, electrical, and material.

Utility Symbols – Utility symbols (*Figure 6-11*) identify utility lines and pipes.

Once you have identified all the existing underground utilities, use extreme care when working near them. Ripping up utility lines adds loss time to a project, adds to the cost of the project, and causes an inconvenience to people the utilities were supporting.

NOTE

Obtain a digging permit before performing any excavations on a project.

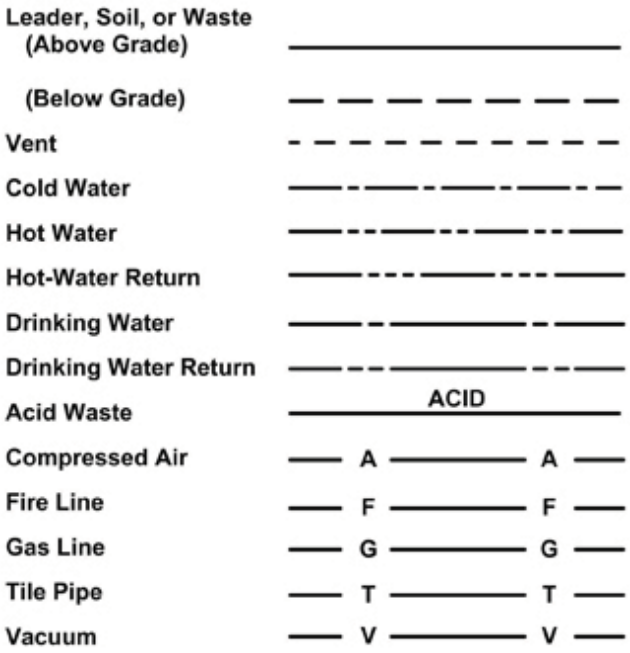


Figure 6-11 Utility symbols.

Electrical Symbols – Electrical symbols identify power distribution (*Figure 6-12*). Note the location of these lines not only for the reasons stated about utilities lines and pipes, but also because of the risk of electric shock when a machine cuts an electric line.

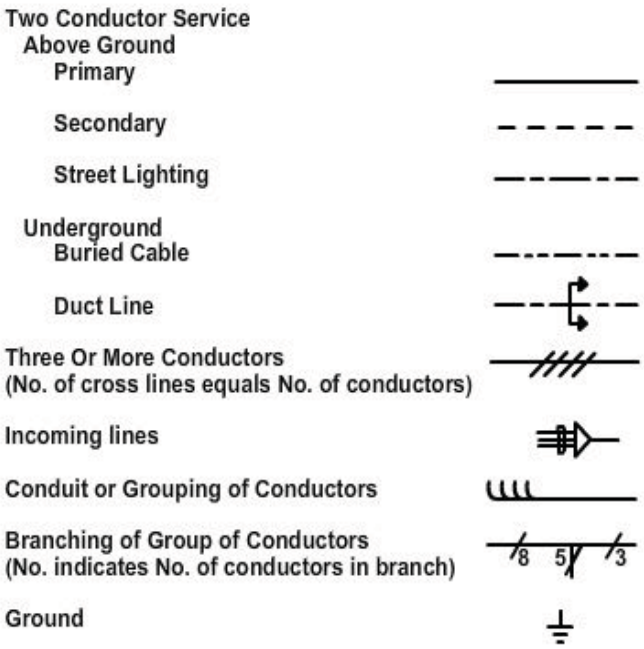


Figure 6-12 – Electrical symbols.

NOTE

Occasionally, certain items such as buried telephone cables, electrical lines, waterlines, and fuel lines are mistakenly left on new drawings. Because of this, always compare older drawings with new ones and with your freehand sketches.

Material Symbols – Material symbols for building material are shown in *Figure 6-13*. These symbols are used in cross sections or cutaway views. They also label new or existing material.

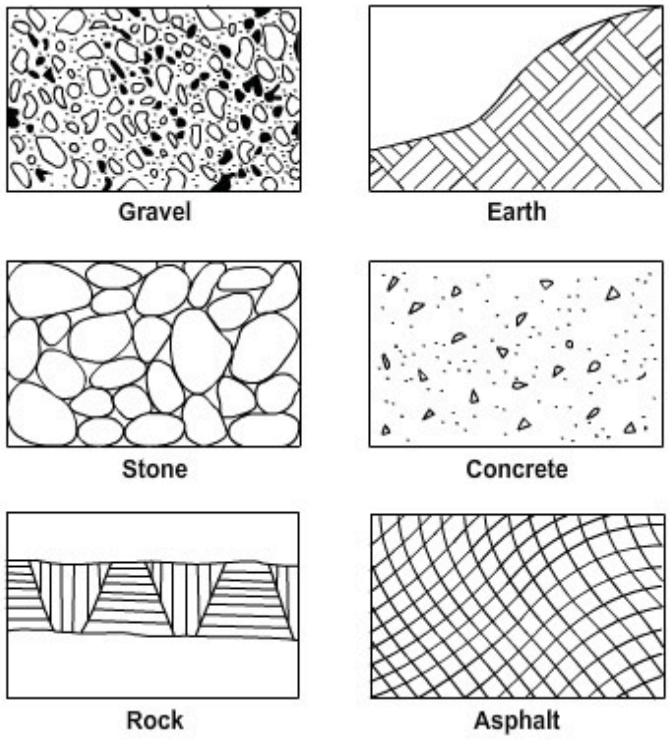


Figure 6-13 – Material symbols.

1.1.5 Sketches

Freehand sketches are drawings made without the use of mechanical aids or devices. Sketches may be drawn on graph paper, traced, or drawn with a straightedge. A sketch may be of an object, an idea, or a combination of both. The ability to make quick, accurate sketches is helpful in conveying your ideas to others.

Two examples of freehand sketches are shown in *Figures 6-14 and 6-15*. These sketches were developed from the original plan and profile sheet of a typical road project. They depict different earthwork phases the Equipment Operator must consider when engaging in earthmoving operations.

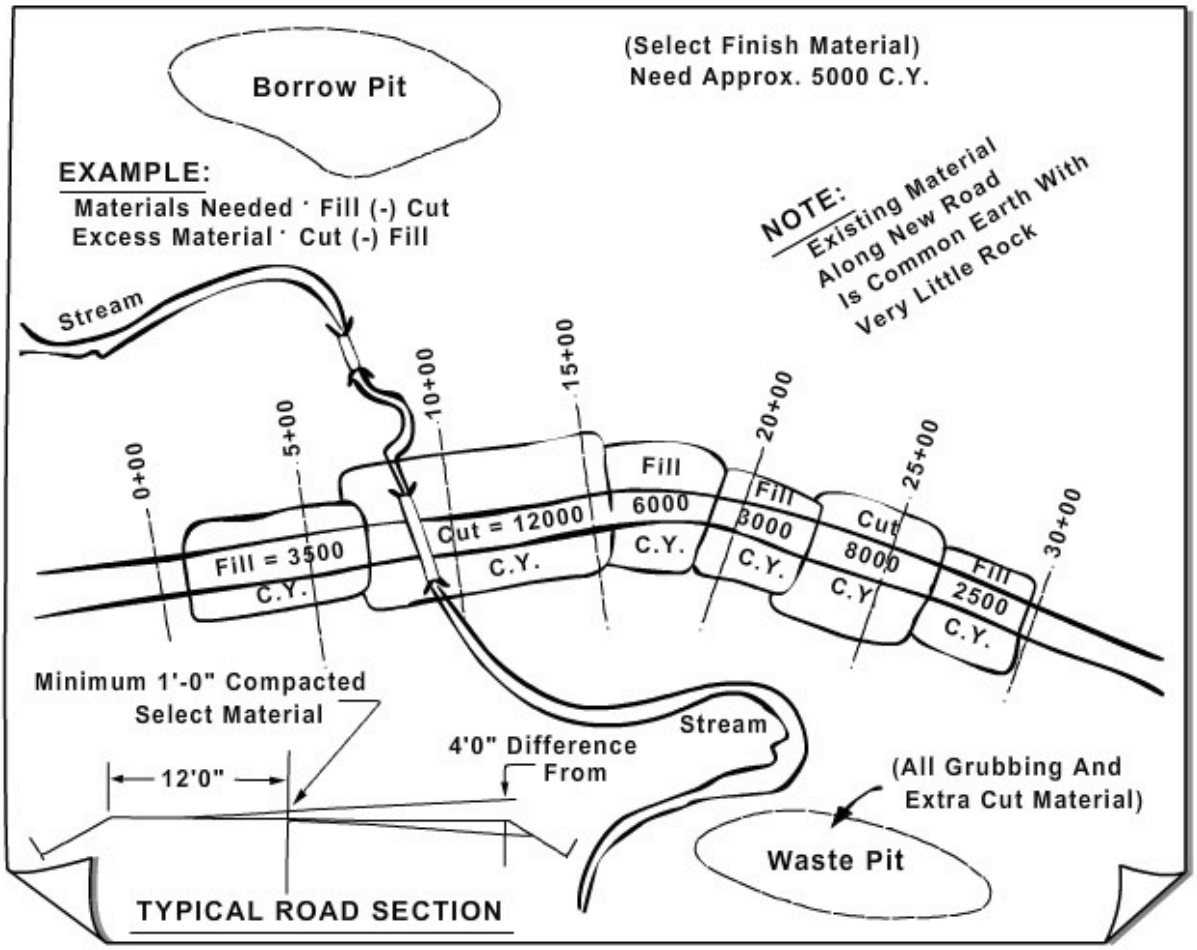


Figure 6-14 – Overlay plan sketch, emphasizing cut-and-fill areas.

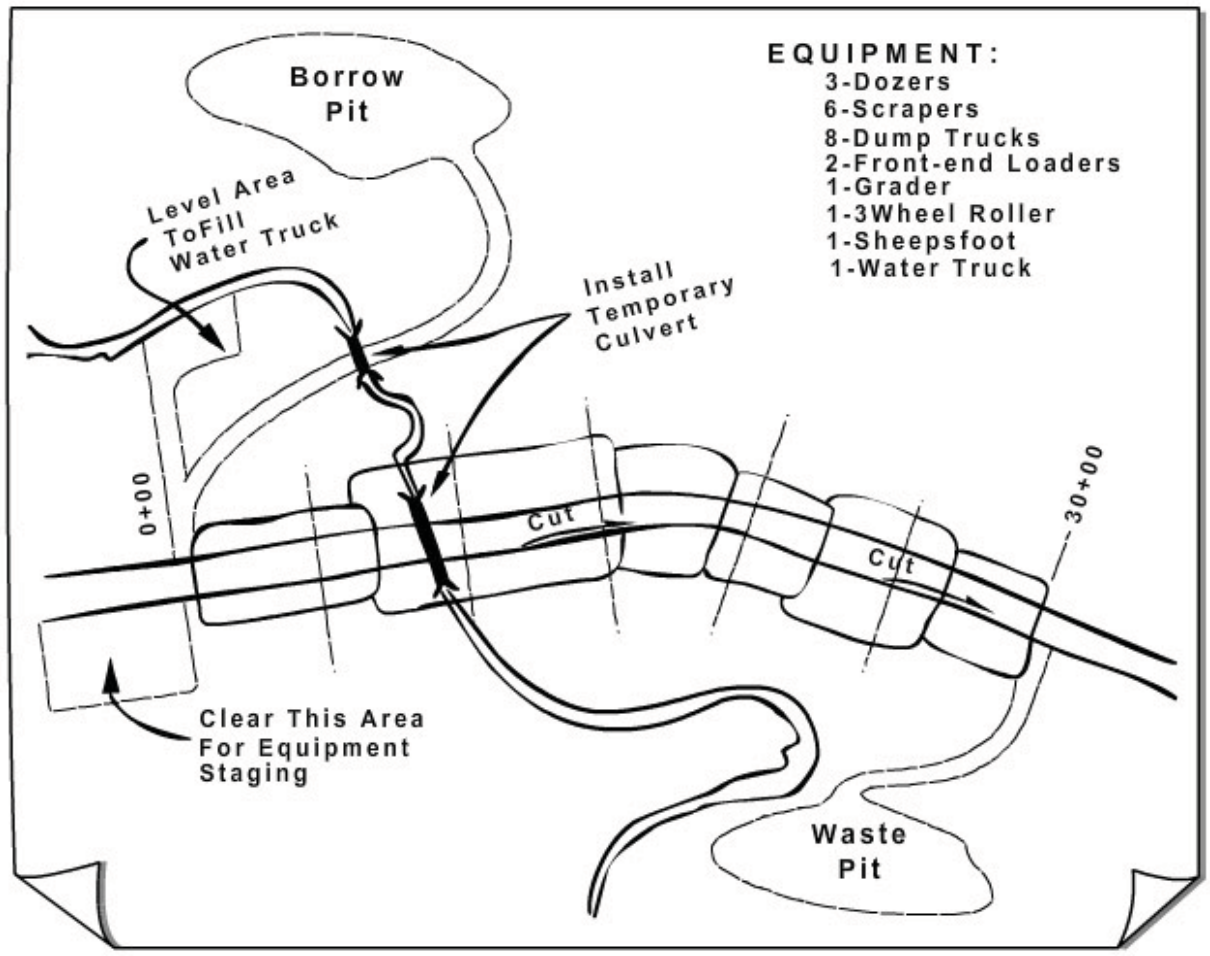


Figure 6-15 – Overlay sketch, emphasizing temporary road and culvert.

Both sketches shown were prepared by placing a piece of tracing paper directly over the plan and profile sheet and tracing the new road and stations. Information was added that was not included on the original plan and profile sheet, such as borrow pit, waste pit, stream, temporary haul road, temporary ***culverts***, equipment area, planned cut-and-fill areas, and a typical road section. Any information may be included that allows you to visualize the finished product.

Test your Knowledge (Select the Correct Response)

1. Which of the following construction phases are documented in the Seabee Project Package?

   A. Initial planning
   B. Execution
   C. Closeout
   D. All of the above

2. Which of the following disadvantages occur when utility lines are ripped up?

   A. Loss of project time
   B. Increased project cost
   C. People supported by the utilities are inconvenienced
   D. All of the above

2.0.0 EARTHWORK COMPUTATIONS

Earthwork computations are the calculations of earthwork volumes or quantities to determine final ***grades***, to balance cut and fill, and to plan the most economical movement of material.

2.1.0 Volume

The volume (v) of any solid, liquid or gas is how much three-dimensional space it occupies. Volumes of straight edged and circular shapes are calculated using an arithmetic formula based on length times width times height (L x W x H). Volume is measured in cubic units (cu), as shown in *Table 6-1*.

Table 6-1 – Cubic Measurements.

Cubic Measure	Full Expression	Abbreviation
Cubic inch	1 inch x 1 inch x 1 inch	$inch^3$
Cubic foot	1 foot x 1 foot x 1 foot	$foot^3$
Cubic yard	1 yard x 1 yard x 1 yard	$yard^3$

2.1.1 Volume Conversion

Most earthmoving is computed in cubic yards (cu yd). A cubic yard is a cube 3 feet long, 3 feet wide and 3 feet high.

To convert cubic feet (cu ft) to cubic yards, divide the cubic feet by 27 (there are 27 cubic feet in one cubic yard). It is also possible to divide the original linear measurement by 3 to convert the numbers to into yards, and then multiply. However, this may lead to working in fractions, decimals, and mixed numbers. *Figure 6-16* shows an example of converting cubic feet into cubic yards.

1. Figure the volume.
   V = 6 feet x 6 feet x 6 feet = 216 cubic feet

2. Convert cubic feet to cubic yards.

   216 cubic feet ÷ 27 cubic feet / cubic yard = 8 cubic yards

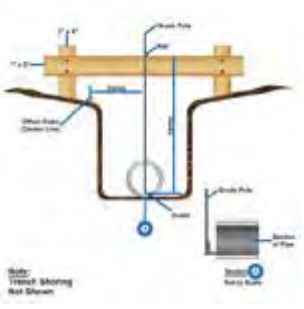


Figure 6-16 – Volume of a cube.

Cubic yards of material can be in-place, loose, or compacted. Material, excavated from its natural state increase in volume, a process commonly known as swell. The volume of undisturbed material is measured as in-place cubic yards. The volume of material loosened by handling is measured as loose cubic yards. The volume of compacted material is measured as compacted cubic yards.

NOTE

When calculating estimates from project drawings, estimate cuts as in-place cubic yards and fills as compacted cubic yards.

To calculate the correct amount of material to be handled, convert the present soil conditions by using *Table 6-2*.

Table 6-2 – Volume changes.

Soil Type	Present Soil Condition	Converted To:		
		In-place	Loose	Compacted
Sand	In-place	1.00	1.11	0.95
	Loose	0.90	1.00	0.86
	Compacted	1.05	1.17	1.00
Common Earth	In-place	1.00	1.25	0.90
	Loose	0.80	1.00	0.72
	Compacted	1.11	1.39	1.00
Clay	In-place	1.00	1.43	0.90
	Loose	0.70	1.00	0.63
	Compacted	1.11	1.59	1.00
Rock	In-place	1.00	1.30 - 2.00	1.25 - 1.50
	Loose	0.50 - 0.77	1.00	0.75 - 0.96
	Compacted	0.67 - 0.80	1.04 - 1.33	1.00

Figure 6-17 shows an example of one cubic yard of in-place common earth converted to loose and compacted.

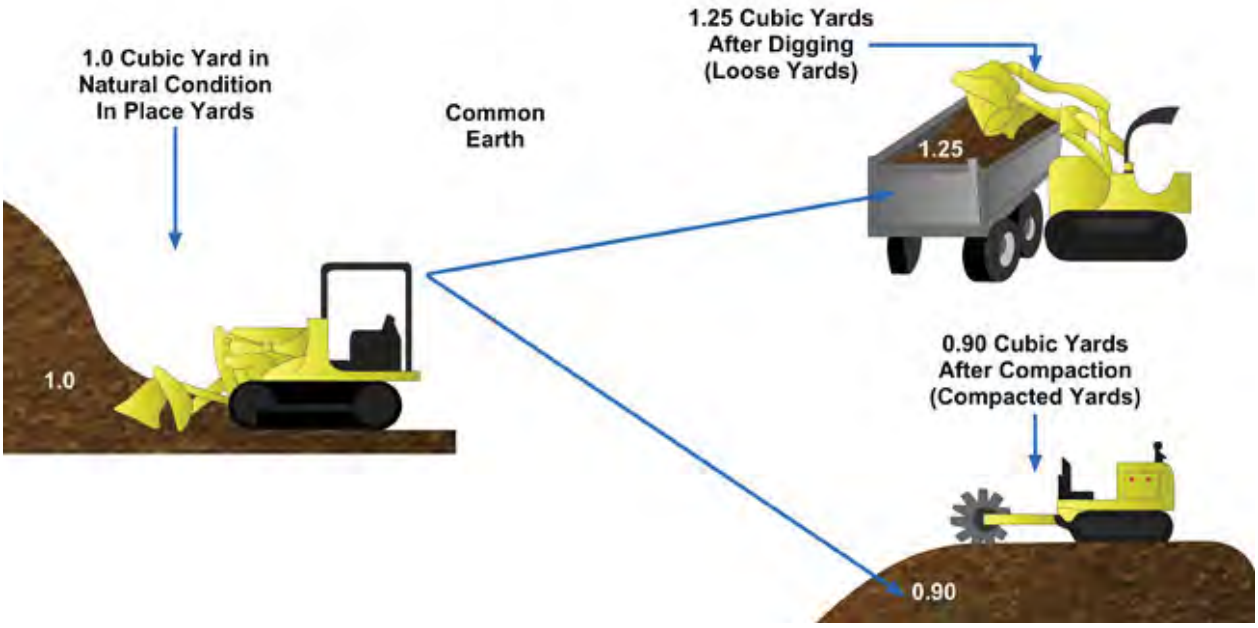


Figure 6-17 – Volume changes.

2.2.0 Road Nomenclature

Figure 6-18 shows a cross-sectional view of a road and its components.

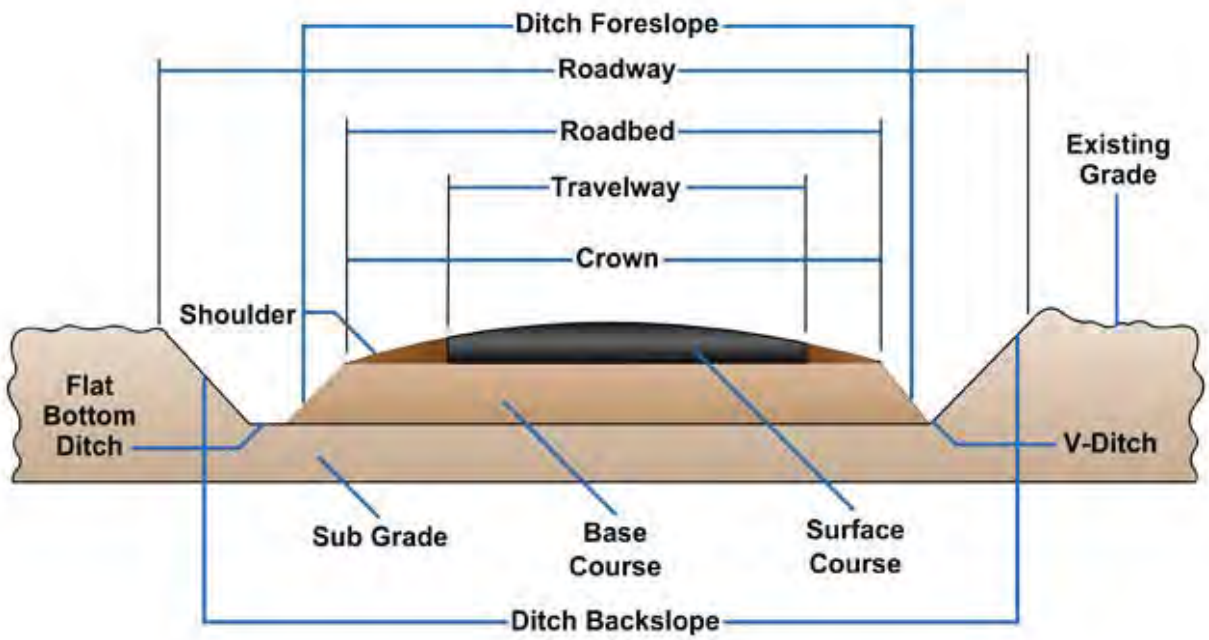


Figure 6-18 – Road nomenclature.

2.2.1 Existing Grade

The elevation of the project site before construction is known as existing grade. The driving surface of an existing road that is to be replaced is also known as the existing grade.

2.2.2 Sub Grade

The sub grade of a road is a prepared base for the placement of base-course materials.

2.2.3 Base Course

The base course is a select layer of well compacted soil placed in compacted lifts on top of the subgrade. This compaction can be by mechanical stabilization or chemical stabilization. The base course may be composed of crushed stone, crushed slag, crushed or uncrushed gravel and sand, or combinations of these materials. It also may be bound with asphalt.

2.2.4 Surface Course and Shoulders

The surface course and the shoulders complete the road. The surface course is usually made of asphalt (flexible pavement), concrete (rigid pavement), or crushed stone. It is part of the road which the vehicle travels.

The shoulder of the road performs as a retainer on each side of the surface course and provides an emergency parking area.

2.2.5 Roadbed

The roadbed is the section that includes the surface course and both shoulders.

2.2.6 Travelway

The travelway is the surface course on which the vehicle travels.

2.2.7 Crown

The crown of the road is an established slope from the center line of a roadbed to the outside of the shoulders and allows for excess water to drain from the surface into ditches.

2.2.8 Ditches

Figure 6-18 shows two different types of ditches: the V-type ditch and flat bottom ditch.

V-Type Ditch – The V-type ditch a basic type of ditch. This type of ditch is usually used for unpaved roads or where the amount of runoff water is minimal and space is limited.

Flat Bottom Ditch – The flat bottom ditch, also called trapezoidal ditch, is difficult to construct. This type of ditch is usually for permanent roads with asphalt or concrete surfaces or where the amount of runoff water is great.

Ditches consist of three parts; an inslope, backslope and bottom. The inslope, sometimes called foreslope, extends from outside of the shoulder to bottom of the ditch. The backslope extends from the top of the cut at the existing grade to the bottom of the ditch. The backslope is constructed to be steeper than the inslope, so that there will be minimal erosion.

2.2.9 Roadway

The roadway is the area that covers the entire width of the road project, including the ditches.

2.3.0 Slope Ratio

The steepness of inslopes and backslopes is often described as a ratio of the horizontal distance (base) to vertical distance (height). This ratio is also known as run over rise.

In *Figure 6-19*, the slope's horizontal distance is 3 feet. Its vertical distance is 1 foot. Therefore, its slope ratio is 3:1.

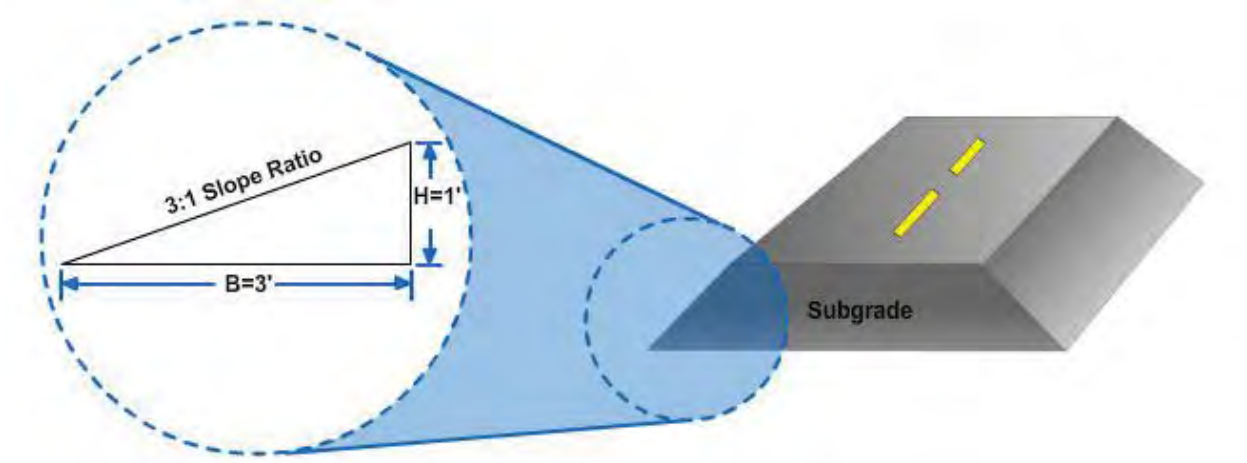


Figure 6-19 – 3:1 slope ratio.

The following are equations to compute slope ratio:

If the base and the height are known factors, but not the slope, use the following equation:
Base ÷ Height = Slope

This equation can also be written as follows*:*
B ÷ H = S

Example; shown in *Figure 6-20*:
Base (8 feet) ÷ Height (2 feet) = 4:1 Slope

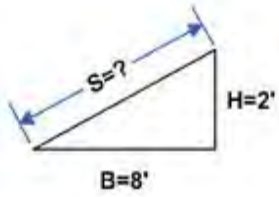


Figure 6-20 – Determining slope.

If the slope ratio and the height are known factors, but not the base, use the following equation:
Slope x Height = Base

This equation can also be written as follows:
S x H = B

Example; shown in *Figure 6-21*:
Slope (2:1) x Height (2 feet) = 4 foot Base

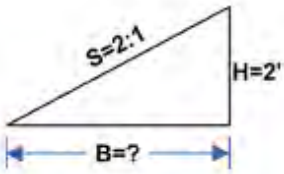


Figure 6-21 – Determining base.

If the base and the slope ratio are known factors, but not the height, use the following:
Base ÷ Slope = Height

This equation can also be written as follows*:*
B ÷ S = H

Example; shown in *Figure 6-22*:
Base (4 feet) ÷ Slope (2:1) = 2 foot Height

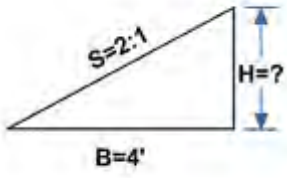


Figure 6-22 – Determining height.

2.4.0 Cross Sections and Area

A cross-sectional view (*Figure 6-23*) that is given for a road project is a cutaway end view of a proposed station between the left slope and the right slope. Typical cross sections are plotted at any intermediate place where there is a distance change in slope along the center line where the natural ground profile and grade line correspond. The cross section displays the slope limits, the slope ratio, and the horizontal distance between centerline stakes and shoulder stakes. It also shows the vertical distance of the proposed cut or fill requirement at the shoulder and centerline stakes.

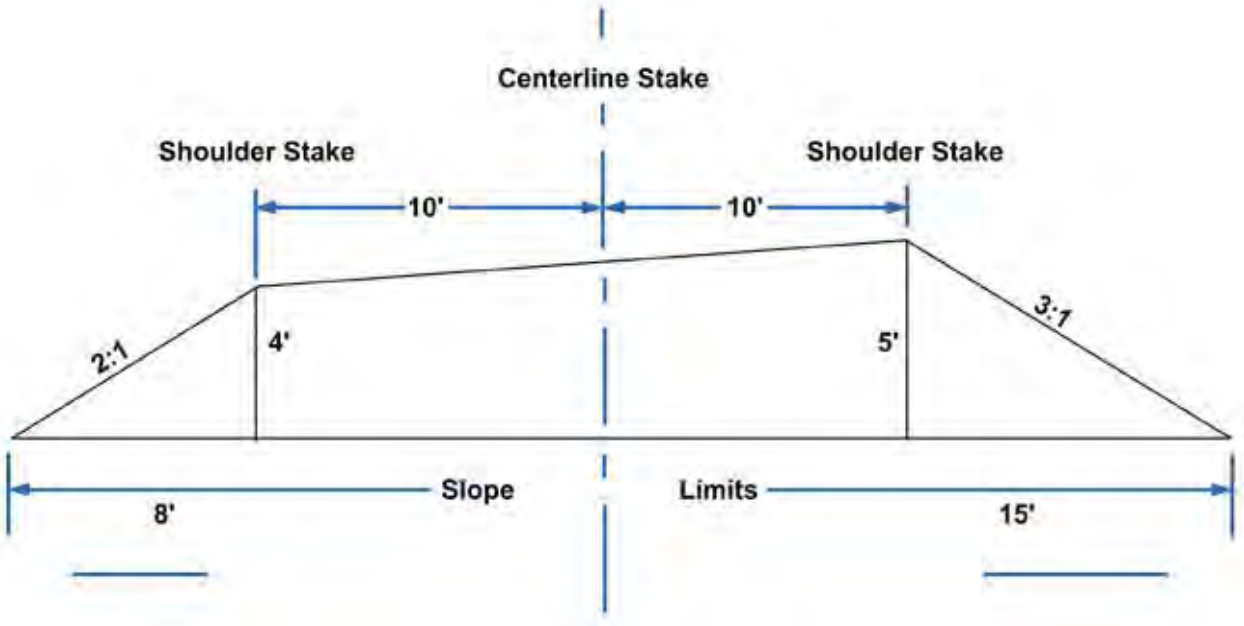


Figure 6-23 – Cross section.

To compute the area of a cross section, you must first break it down into geometric figures such as squares, rectangles, and triangles, as shown in *Figure 6-24.* Compute each area separately, and then total the results to obtain the total square feet (sq ft).

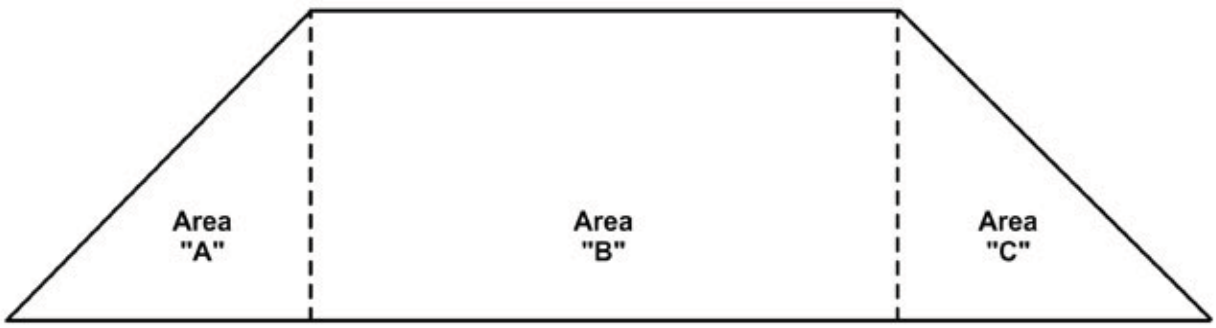


Figure 6-24 – Geometric sections of a cross section.

2.4.1 Square and Rectangle

To compute the area of a square in square feet, use the following equation:
Base x *Height* = *Area*

Example; shown in *Figure 6-25*:
Base(2 feet) x Height (2 feet) = 4 square foot area

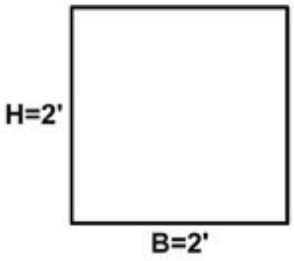


Figure 6-25 – Area of a square.

Use the same equation to compute the area of a rectangle in square feet.

Example; shown in *Figure 6-26*:
Base(6 feet) x Height (3 feet) = 18 square foot area

Figure 6-26 – Area of a rectangle.

2.4.2 Triangle

Since a right triangle is a square or rectangle cut in half diagonally, the same equation can be used to compute the area and the result divided by 2. The equation is as follows:

$$\frac{Base \times Height}{2} = Triangle\ area\ is\ square\ feet$$

Example; shown *Figure 6-27*:

Base 4 feet
x Height 3 feet

$2\overline{)12} = 6$ square feet

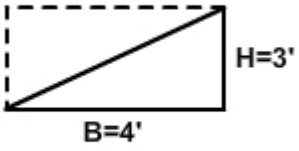


Figure 6-27 – Area of a triangle.

2.4.3 Trapezoid

Another geometric figure you may encounter in a cross section is a trapezoid. The equation to compute the area of a trapezoid is as follows:

$$\left(\frac{H_1 + H_2}{2}\right) x\ L = \textit{Trapezoid area in square feet}$$

Example: shown in Figure 6-28:

H_1 = 6 feet
+ H_2 = 3 feet
$2\overline{)9}$ = 4.5 x 30 feet = 135 square feet

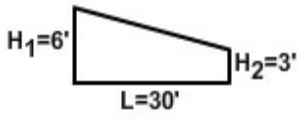


Figure 6-28 – Area of a trapezoid.

2.4.4 Total Area

The next step is to compute the total area in the cross section. This is accomplished by adding the results of each geometric figure in the cross section. This value is the total end area of the cross sectional view.

To compute the amount of cubic yards between two cross sections, use the following equation: *(A_1 + A_2) 1.85 x Distance =Cubic yards*

It is important to remember that Distance (D) between two end areas must be changed to a decimal form; for example, 250 feet = 2.50, 125 feet = 1.25, and 75 feet = .75

To compute the equation, take the area of one end section (cross section) plus the area of the other end and multiply the sum of the two areas by a constant factor of 1.85. This value should now be multiplied by the distance between the two end areas to determine the number of cubic yards.

Example: shown in *Figure 6-29.*

A_1 = 210 square feet
+ A_2 = 200 square feet
410
x 1.85 Factor
2050
3280
410
758.50
x 2.25 Distance
379250
151700
151700
1706.6250
1706.63 Cubic Yards

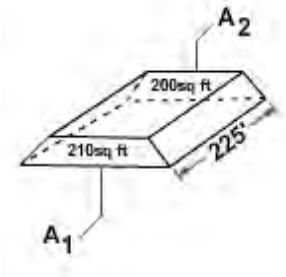


Figure 6-29 – Computing cubic yards of cross sections.

Test your Knowledge (Select the Correct Response)

3. Earthwork computations are the calculations of earthwork volumes used to determine which of the following factors?

   A. The final grade
   B. A balanced cut and fill
   C. A plan for the most economical movement of material
   D. All of the above

4. What term is used to describe a selected layer of well–compacted soil that is placed in compacted lifts on top of the subgrade?

   A. Crown
   B. Base course
   C. Surface course
   D. Backslope

3.0.0 CONSTRUCTION (GRADE) STAKES

Grade work is the plotting of irregularities of the ground (making cuts or fills) to a definite limit of grade and alignment. This is performed by reading information placed on construction (grade) stakes.

Construction stakes, sometimes referred to as grade stakes, are the guides and reference markers for earthwork operations to show cuts, fills, drainage, alignment, and boundaries of the construction area. The number of stakes, the information contained on them, and whether they are temporary or permanent will vary with the project. A three- to five-person survey party usually places stakes using a level, a level rod, a tape, and range poles.

A stake is any wooden lath, or hub. They are used primarily for well-defined surveyors' ***reference points***, with the red and blue tops used in finished grade work. Stakes will vary in shape and size according to their use and the materials available for their manufacture. Several stakes are shown in *Figure 6-30*.

Stakes range in size from the ordinary rough plaster lath to 1- by 2- by 3-inch cross-sectional lumber with lengths varying from 18 inches to 48 inches.

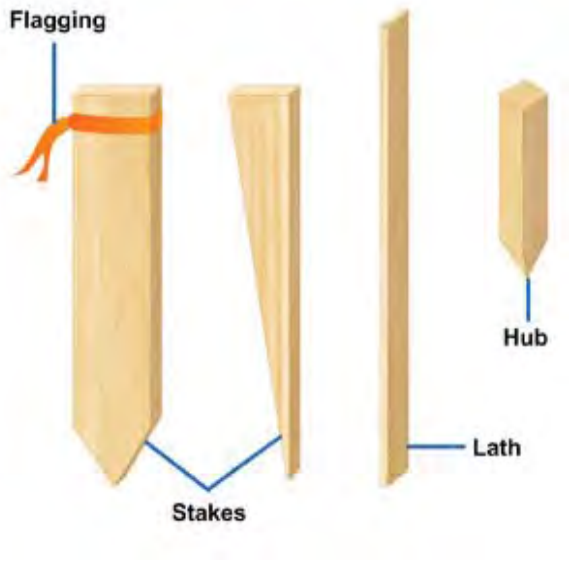


Figure 6-30 – Types of stakes.

All stakes and hubs, as established by the Engineering Aids (EAs) for project control or alignment, are identified and protected by guard stakes. Guard stakes are used as a means of locating the reference points needed. Some color of bunting or flagging (a narrow strip of cloth or plastic) may be tied around the top of the stake. Station identification is placed on the front of the guard stake and any other pertinent data on the back.

In some situations, the survey crew will establish grades only on the centerline stakes, while edge-of-road and slope stakes are set by the project supervisor and helpers. Alignment, shoulder, and slope stakes should be 1 inch by 2 inches in cross section, smooth on four sides, and about 2 feet in length. Actual grade desired is indicated by a reference mark called a crowfoot and numbers to show the amount of cut or fill.

These stakes should be marked with the following information:

- The stationing or location of any part of the road, runway, or taxiway relative to a starting point or reference
- The amount of cut and fill from the existing ground surface or reference mark on the stake
- The distance from the center line to the stake location and from the center line to the ditch line

In most earthwork, measurements are made and written in the decimal system used in construction engineering. Most markings on construction stakes are in feet and tenths of a foot. A stake marked C35 means that a cut must be made 3.5 feet. To convert .5 foot to inches, multiply the decimal fraction by 12. For example: .5 x 12 inches = 6 inches; .25 x 12 inches = 3 inches.

3.1.0 Starting Point

The “starting point” of a survey is also called the starting station and is numbered 0 + 00. The next station is 100 feet farther away and is numbered starting station 1 + 00. The next station, which is 200 feet beyond the starting point, is then numbered 2 + 00, and so forth. All stations that end with 00 are called full stations. As shown in *Figure 6-21*, stations may be abbreviated STA on the stakes.

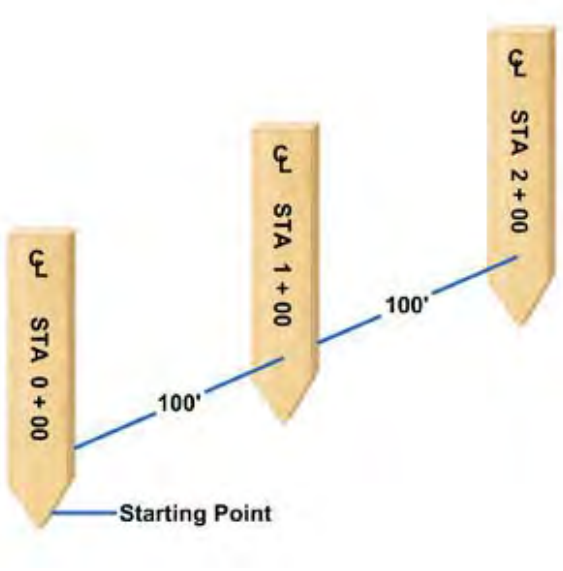


Figure 6-31 – Starting point.

On sharp curves or on rough ground, the stakes may be closer together than on the straightaway. Stations located at a distance shorter than 100 feet from the preceding station are known as plus stations, such as 3 + 25, 3 + 53, and 3 + 77. These examples are plus stations of station 3 + 00 as shown in *Figure 6-32*.

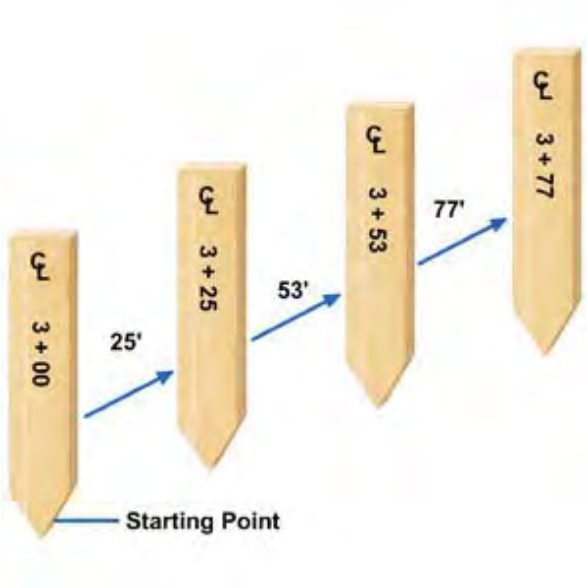


Figure 6-32 – Plus stations.

3.2.0 Line Stakes

Line (or alignment) stakes mark the horizontal location of the earthwork to be completed and give the direction of the proposed construction.

Running over stakes or otherwise damaging them before they have served their purpose results in many hours of extra work to replace them and delays completion of the project. Rough alignment stakes are placed far ahead of the clearing crew to mark boundaries of the area to be cleared and grubbed. These stakes, or markers, are not controlled and their loss is expected. On some stakes, the alignment information and the grade requirement are combined on the same stake, as shown in *Figure 6-33*.

Figure 6-33 – Stakes with alignment information and grade requirement.

3.3.0 Centerline Stakes

Identified by the symbol ℄, centerline stakes are set along the center line of a project (*Figure 6-34)*. Most stakes are marked on both the front and back.

On centerline stakes, the station number is written on the front of the stake, such as 0 + 00, 1 + 00, 4 + 75, and 5 + 25 (*Figure 6-35*).

Figure 6-34 – Centerline stake symbol.

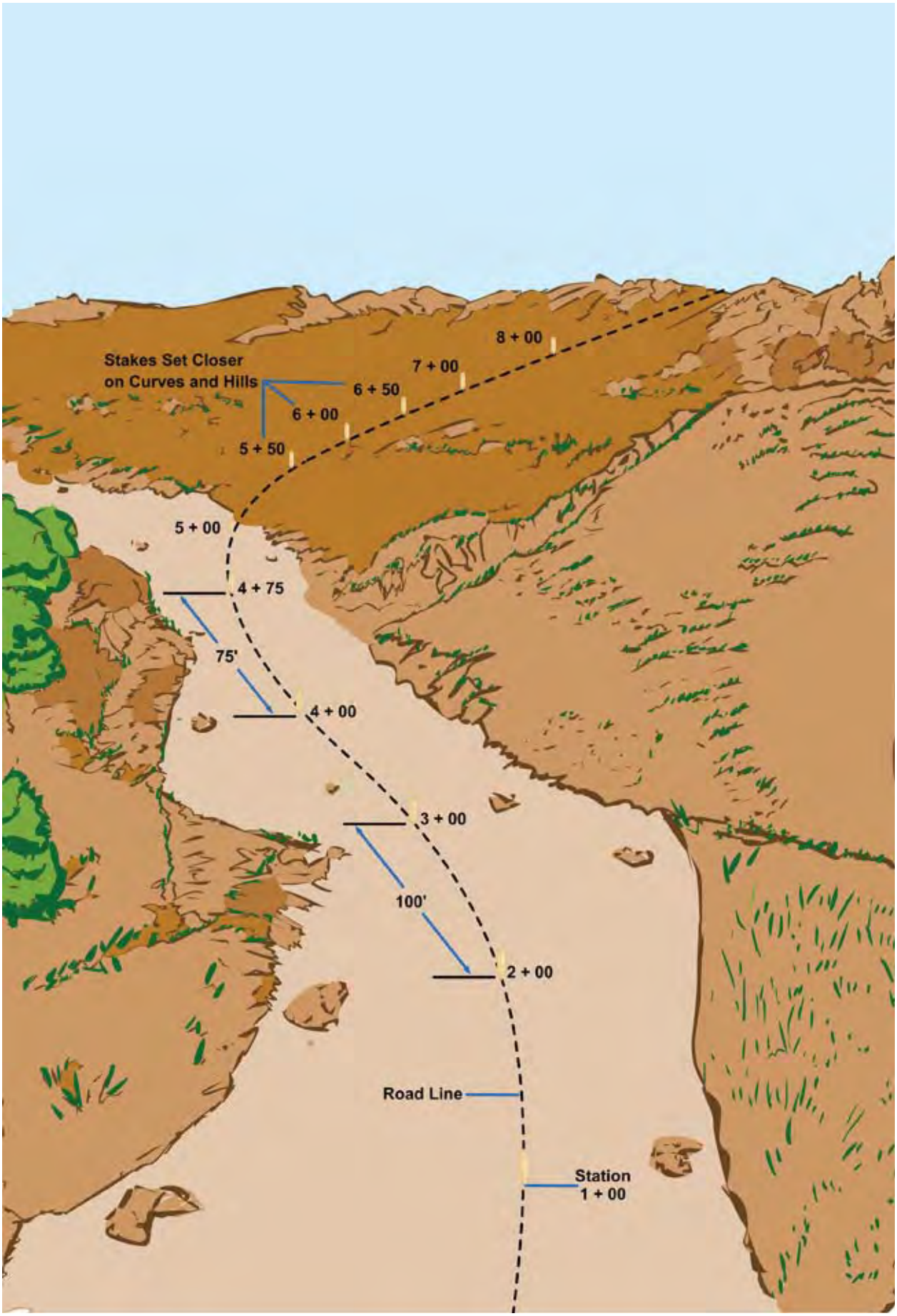


Figure 6-35 – Station numbers.

The desired grade is always established at the center line of the project. The amount of elevation change in order to accomplish the desired grade is written on the back of the centerline stake. It is also indicated by a reference mark called a crowfoot (*Figure 6-36*).

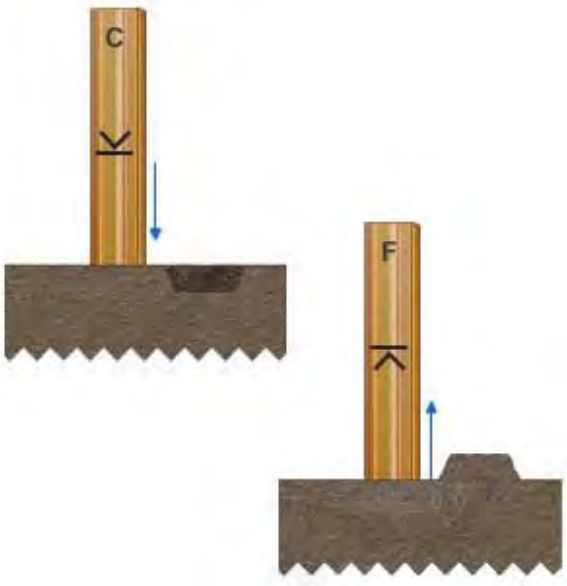


Figure 6-36 – Cut-and-fill crowfoot symbol.

3.4.0 Shoulder Stakes

Stakes set on a line parallel (same direction and interval) with the center line are called shoulder stakes and are identified by the symbol SH at the top of the stake (*Figure 6-37*).

Shoulder stakes mark the outer edge of the shoulders and are set with the broad side facing the center line of the road on the shoulder line. Shoulder stakes carry the same station number as the centerline stake to which they are set, but the station number is on the back of the stake (the side facing away from the center line). The amount of cut or fill required at that location is marked on the front of the stake (the side facing towards the center line). The horizontal distance from the shoulder stake to the center line is sometimes placed beneath the cut-or-fill figure.

Figure 6-37 – Shoulder stake symbol.

The basic difference between centerline and shoulder stakes is that centerline stakes are set along the center line of the project and shoulder stakes are set parallel with the center line defining the shoulder of the road or runway and face the center line (*Figure 6-38*).

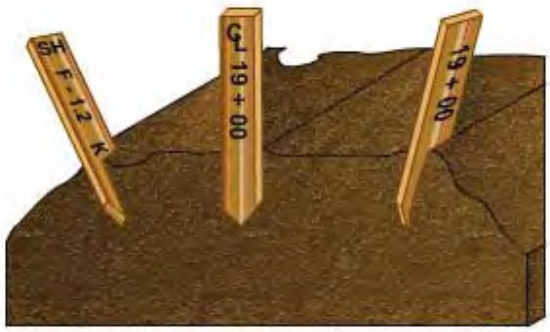


Figure 6-38 – Centerline and shoulder stakes.

3.5.0 Cut-and-Fill Stakes

Lowering the elevation of a grade is known as making a cut. Cut stakes are designated by the letter C written on the stake. The numerals following the letter C indicate the amount of ground to be cut to obtain the desired grade and are measured from the crowfoot down.

Raising the elevation of the ground is known as making a fill. A fill stake is designated by the letter F written on the stake. The numerals that follow the letter F indicate the amount of ground material needed to bring the existing ground to the desired grade and are measured upward from the crowfoot mark.

When going from a cut to a fill or vice versa, there may be one or more stakes representing points on the desired grade, as shown in *Figure 6-39.* These stakes are marked with GRADE or GRD, and a crowfoot mark even with the desired grade.

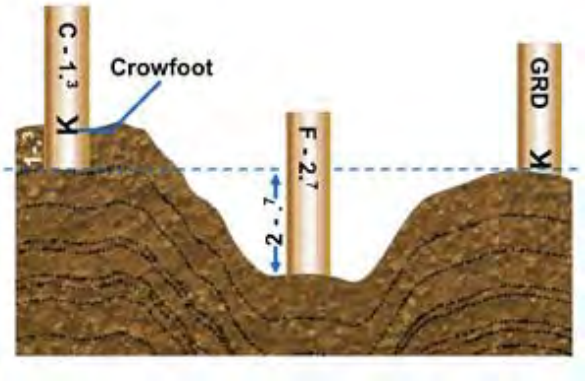


Figure 6-39 – Cut, fill, and on-grade stakes.

Basically, the difference in cut, fill, or on-grade stakes is as follows:

- Cut stakes indicate a lowering of the ground or elevation.
- Fill stakes indicate raising the ground or elevation.
- On-grade stakes indicate the ground is at the desired grade and does not need a cut or fill.

3.6.0 Offset Stakes

After completing a survey of a project and setting and marking the stakes are set, use the information on these stakes to determine the required amount of work needed to complete the job. Since this information has to be used often during construction and the original stakes can be destroyed or covered up by carelessness or inexperienced operators, you must document this information. To prevent the loss of reference information, transfer the required information from the stake located in the immediate area of construction to a new stake. Set this stake far enough away so that it will not be damaged or destroyed by equipment being operated in the construction area. This new stake is called an offset stake and is identified by the symbol OF or O (*Figure 6-40*).

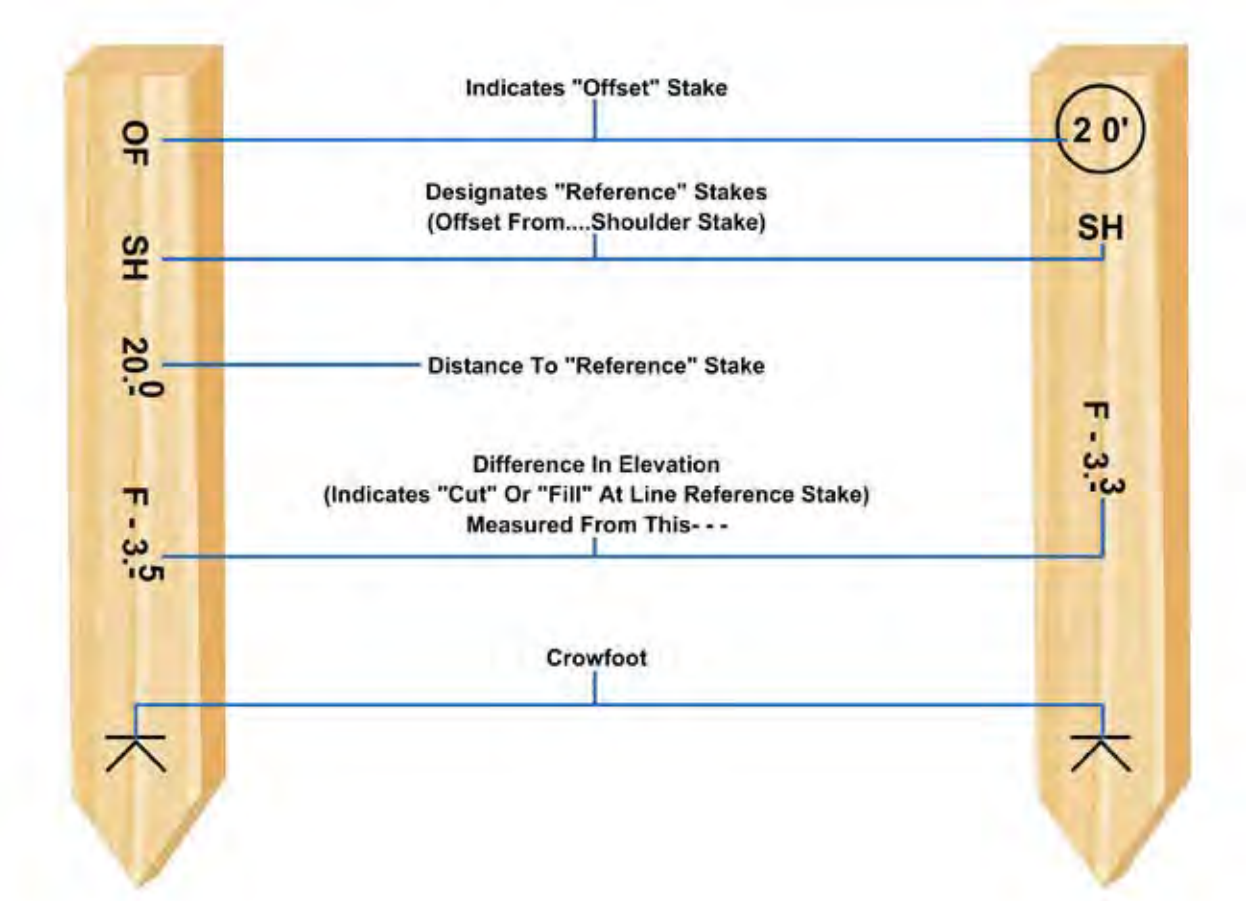


Figure 6-40 – Reference information found on an offset stake.

Note the number of linear feet separating the offset stake from the original reference stake. This is written on the offset stake below the OF or within the circle, followed by the required amount of cut or fill, in feet. A stake marked “OF 35’ CL C1°” means that the stake is offset 35 feet from the centerline stake and that a cut of 1 foot is required to attain the desired final grade.

The difference in elevation must be noted on the offset stake. The symbol, representing the stake from which the information was originally transferred, is also noted on the offset stake. If the offset stake was offset from a shoulder stake, the symbol is SH instead of ℄ .

The amount of cut or fill, if any, must be noted on the offset stake. However, because of existing terrain, this information on the offset stake may not be the same as that on the original stake. In *Figure 6-41*, you can see that the offset stake reads for a cut to be made to reach a desired elevation at the center line, while a centerline stake would be marked for a fill to reach the same elevation.

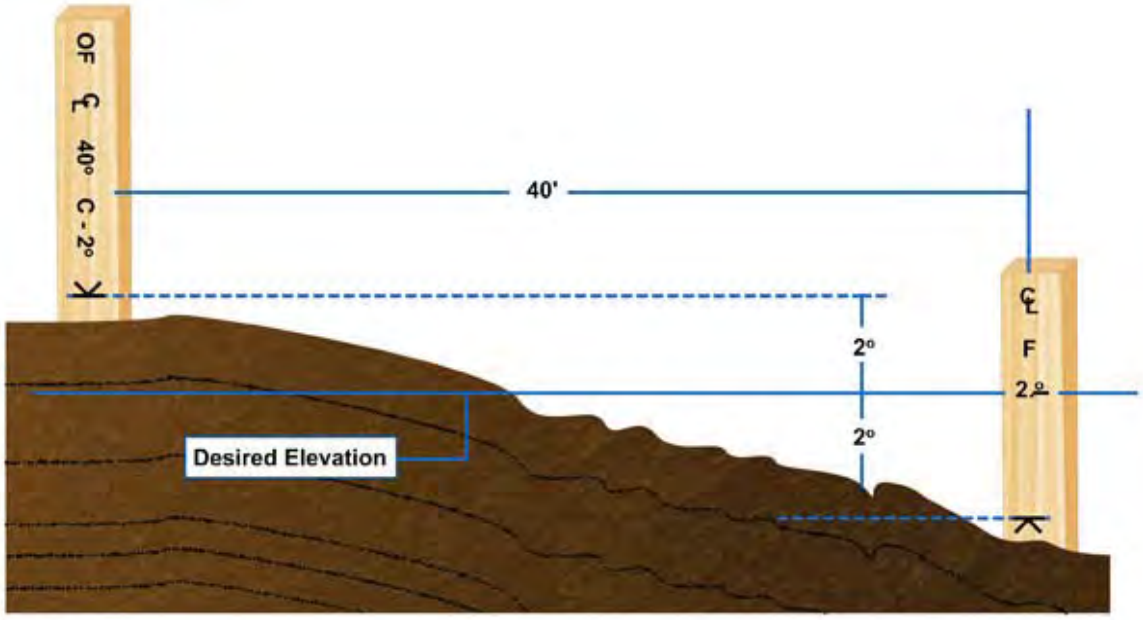


Figure 6-41 – Difference in elevation between the offset stake crowfoot and desired grade at center stake.

3.7.0 Slope Stakes

The identification markings on slope stakes may vary according to survey parties; however, the symbol SS is the most commonly used slope stake symbol. The information normally found on a slope stake (*Figure 6-42*) is any cut-or-fill requirements, the distance from the center line, and the slope ratio.

Figure 6-42 – Slope stake.

When offsetting the slope stake becomes necessary, write the offset distance from where the slope stake should be at the bottom of the offset stake. Slope stakes indicate the intersection of the cut-or-fill slope with the existing natural groundline and limit of earthwork on each side of the center line (*Figure 6-43*).

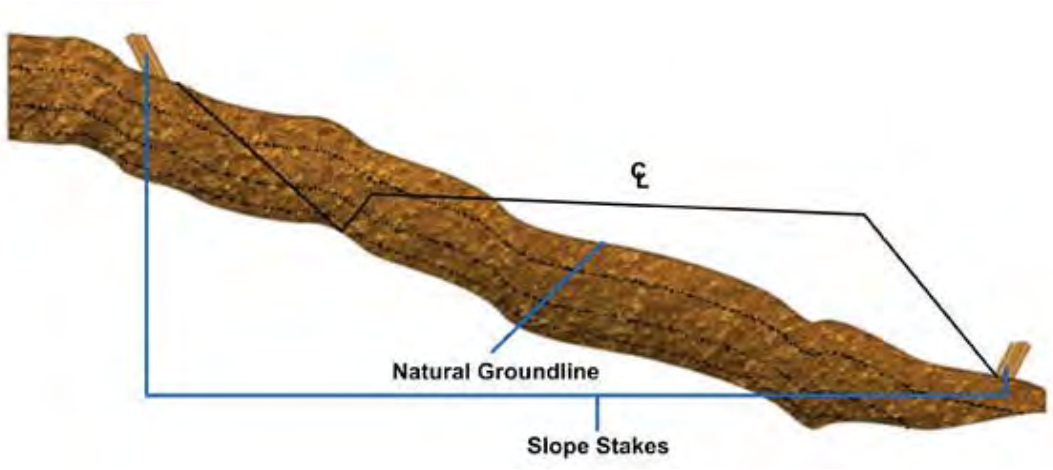


Figure 6-43 – Slope stake set in existing natural groundline.

3.8.0 Right-of-Way Stakes

Stakes set on the property line of a construction site are known as right-of-way stakes. These stakes mark the boundaries of the site or project. Do not operate equipment outside the property line defined by the right-of-way stakes.

The right-of-way stakes are usually marked with colored cloth (bunting) or flagging. Occasionally right-of-way stakes may be marked with the symbol R/W (*Figure 6-44*).

Figure 6-44 – Right-of-way stake symbol.

3.9.0 Finish Grade Stakes

When performing final grading, you are likely to work with stakes called blue tops. These are hub stakes, which are usually 2 inches by 2 inches by 6 inches. These hubs are driven into the ground until the top is at the exact elevation of the finished grade as determined by the surveying crew. They are colored with a blue lumber crayon (keel) to identify them as finish grade stakes. Red crayon is normally used to indicate the subgrade elevation.

Blue top stakes are placed when the existing grade is within 0.2 feet (2.4 inches) above the final or desired grade. The desired grade is obtained by lowering or raising the compacted grade with a ***grader*** until it is flush or even with the top of the hub (*Figure 6-45*).

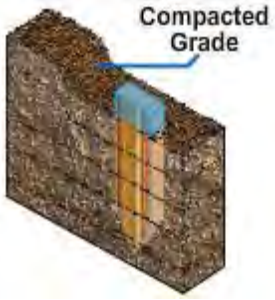


Figure 6-45 – Finish grade.

Test your Knowledge (Select the Correct Response)

5. Which of the following describes grade work?

   A. Making cuts or fills with any limit of grade and alignment
   B. Making cuts or fill to a definite limit alignment of grade and alignment
   C. Aligning survey stakes on a construction project
   D. Taking the ground irregularities of a project and plotting them on a blueprint

6. What information should be marked on the face of a shoulder stake that is facing the center line of a road?

   A. Cut and fill data
   B. Station number
   C. Distance across the road
   D. Right-of-way data

7. Rough alignment stakes are used for what purpose?

   A. To mark the project boundaries
   B. To mark trees that are not to be cleared
   C. To mark the control points for the survey crew
   D. To mark the straightaway

8. What term is used to describe raising the elevation of the ground?

   A. Raise
   B. Lift
   C. Fill
   D. Elevation adjustment

4.0.0 LEVELING EQUIPMENT

To set, use, and compute grade stake measurements, you must be able to measure the vertical distance from one point to another, a process called leveling. This process requires leveling equipment such as levels, Jacob' staffs, tripods, and rods.

4.1.0 Hand Level

A level is an instrument used for measuring vertical distances. All levels have a line of sight with a bubble device, called a level vial, for maintaining the instrument in a ***horizontal plane***. Levels vary in accuracy according to the quality and magnification power of the lens.

The hand level is generally a round metal tube about 6 inches long with an eyepiece at one end; a cross hair, called the index line, at the other end of a glass lens, and a level vial on top. Part of the cross-hair end is covered with a mirror set at a 45° angle that reflects the image of the bubble to the viewer. This permits the observer, looking through the tube to see the object, the position of the level bubble in the vial, and the index line at the same time. *Figure 6-46* shows a Locke level, a specific type of hand level.

Figure 6-46 – Locke level.

To use the hand level, look through the eyepiece end at the rod with the level vial on top. Tilt the entire hand level until the bubble is centered on the cross hair while looking through the eyepiece comparing different points against the same reference point.

The hand level is used for checking grade during the rough or early part of a construction project and is not used at distances greater than about 50 feet or even lesser distances if an accuracy of more than 2 or 3 tenths is required.

4.2.0 Jacob's Staff

It is sometimes necessary to know the height of the level above the ground where you are standing. This may be accomplished by resting the level on a stick of known length. This stick is known as a Jacob's staff (*Figure 6-47).*

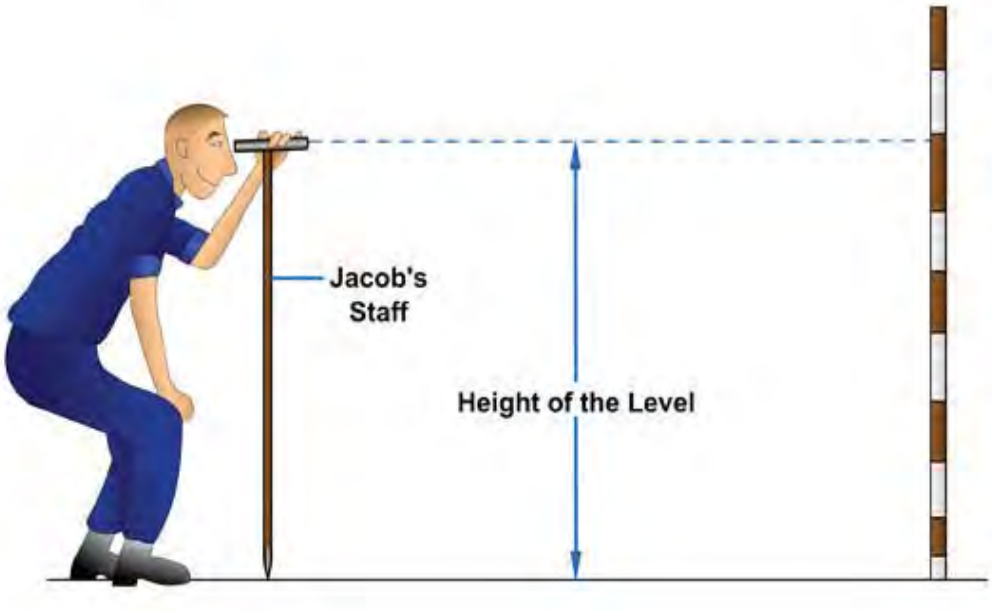


Figure 6-47 – Using a Jacob's staff with a hand level.

For rough work, you may ignore the use of a Jacob's staff and merely use the height of your eye above the ground in your normal standing position; however, you must know the height of your eye.

4.3.0 Dumpy Level

The dumpy level (*Figure 6-48*) has a telescope rigidly attached to a level bar, which supports an adjustable, highly sensitive level vial. The cross hairs are brought into focus by rotating both the eyepiece and focusing knob. The telescope can be exactly trained on the level rod by lightly tightening the azimuth clamp and manipulating the azimuth tangent screw.

Depending on atmospheric conditions, the dumpy level can be used to measure vertical distances accurately at distances of 300 feet or less. When used for alignment, it is accurate at distances up to 1,000 feet. In addition, it is capable of rotating 360 degrees for sighting in any direction.

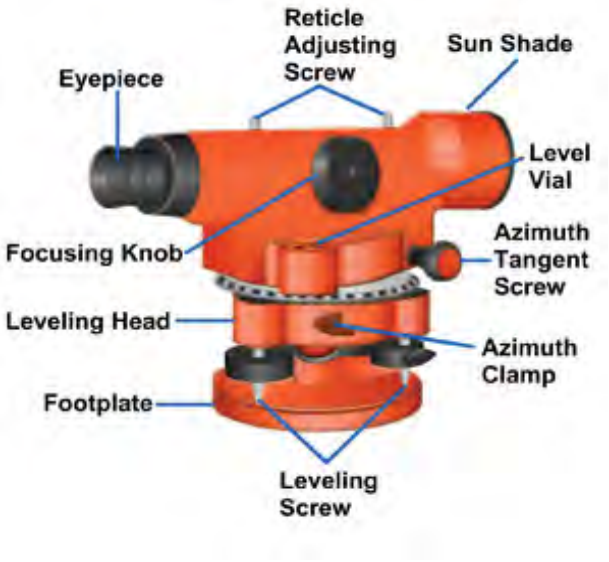


Figure 6-48 – Dumpy Level.

4.4.0 Self-Leveling Level

The self-leveling level (*Figure 6-49*) is a precise, time-saving leveling instrument. It is equipped with three leveling screws and a small bull's-eye level. The leveling screws, which are on a triangular foot plate, are used to center the bubble of the bull's-eye level.

The line of sight automatically becomes and remains horizontal as long as the bubble is centered. This is made possible by a ***prismatic*** device, called a compensator (*Figure 6-50*). The compensator is suspended on fine, nonmagnetic wires. The action of the gravity on the compensator causes the optical system to swing into the position that defines a horizontal line of sight. The system maintains this horizontal line of sight even if the telescope becomes slightly out of level or a slight disturbance occurs on the instrument.

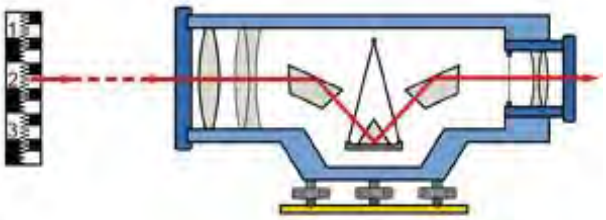


Figure 6-49 – Self-leveling level.

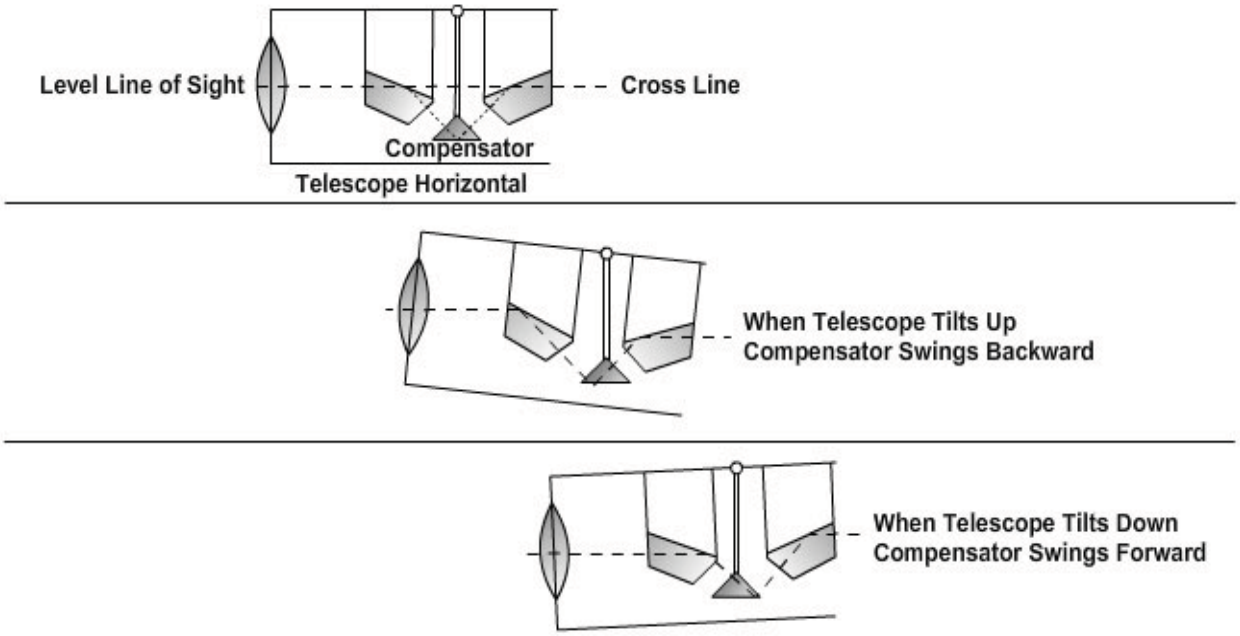


Figure 6-50 – Self-leveling level compensator.

4.5.0 Tripod

The tripod (*Figure 6-51*) is the base or foundation that supports the level instrument and keeps it stable during observations. A tripod consists of a head to which the instrument is mounted, three wooden or metal legs that are hinged at the head, and pointed metal shoes on each leg to be pressed or anchored into the ground to set the tripod up firmly.

Figure 6-51 – Tripod.

To set up the tripod, loosen the restraining strap from around the three legs. An effective way to set the tripod down is to grip two of the legs close to your body while standing over the point where the setup is required. Using one hand, push the third leg out away from your body until it is about 50 to 60 degrees from the horizontal. Lower the tripod until the third leg is on the ground. Place one hand on each of the first two legs, and spread them while taking a short backward step, using the third leg as a pivot point. When the two legs look about as far away from the mark as the third one and all three are equally spaced, lower the two legs and press them into the ground. Make any slight adjustments to level the head further by moving the third leg a few inches in or out before pressing it into the ground.

When placing the instrument onto the tripod, grip it firmly to avoid dropping it while you are mounting it on the tripod. Screw the instrument down to a firm bearing, but not so tightly that it binds or the screw threads strip.

4.6.0 Level Rod

Vertical distances are actually measured by sighting on a graduated rod, called a level rod. Like other surveying equipment used for measuring distances, level rods usually are graduated in feet, tenths, and hundredths.

The most often used level rod is the Philadelphia rod, shown in *Figure 6-52*. It is a graduated wooden rod, made of two sections. It can be extended from 7.10 feet to 13.10 feet. Each foot is subdivided into hundredths of a foot.

In direct readings, the person at the instrument, known as the levelman reads, the graduation on the rod intercepted by the cross hair through the telescope. In target readings, the person holding the rod, known as the rodman reads the graduation on the face of the rod intercepted by a target.

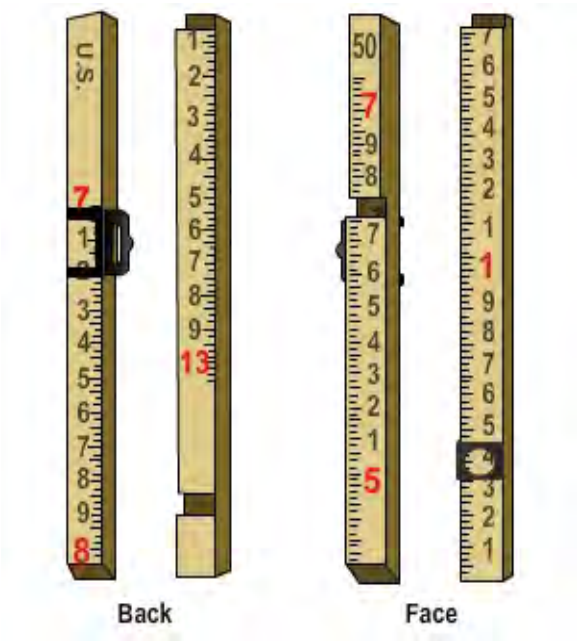


Figure 6-52 – Back and face of a Philadelphia rod.

In *Figure 6-52*, the target does not appear; however, it is shown in *Figure 6-53.* As you can see, it is a sliding, circular device that can be moved up or down the rod and clamped in position. The rodman places it on signals from the levelman.

The rod in *Figure 6-53* is graduated in feet. Each even foot is marked with a large red numeral, and, between each pair of adjacent red numerals, the intermediate tenths of a foot are marked with smaller black numerals. Each intermediate hundredth of a foot between each pair of adjacent tenths is indicated by the top or bottom of one of the short, black dash graduations.

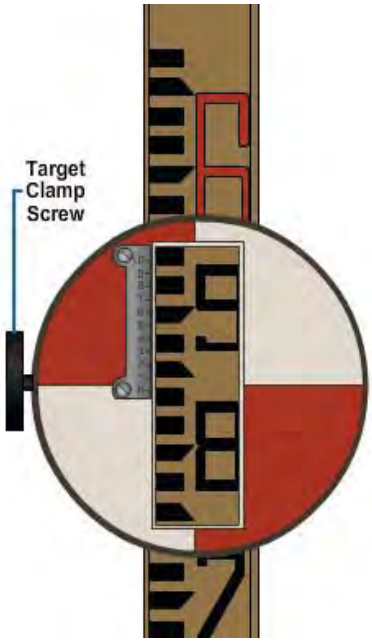


Figure 6-53 – Philadelphia rod set for target reading of less than 7,000 feet.

4.6.1 Direct Reading

As the levelman, you can make direct readings on a self-reading rod held plumb on the point by the rodman. If you are working to tenths of a foot, it is relatively simple to read the footmark below the cross hair and the tenth mark closest to the cross hair. If you require greater precision and must work to hundredths, the reading is more complicated (*Figure 6-54*).

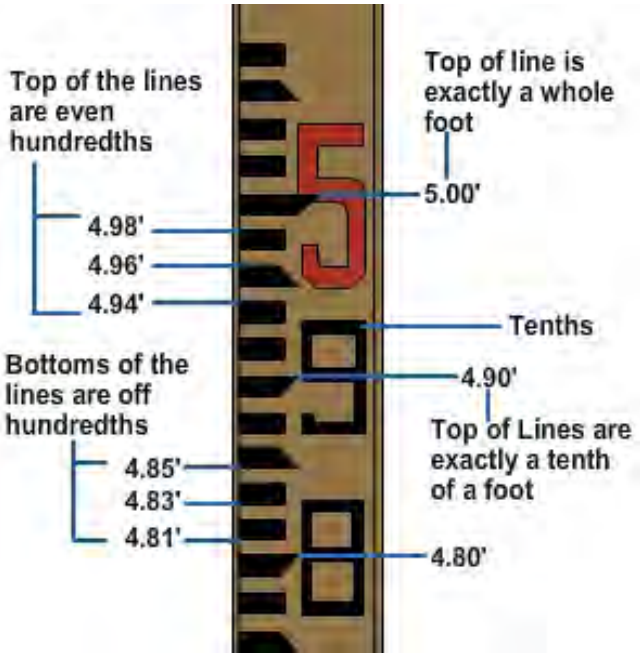


Figure 6-54 – Philadelphia rod marking.

Suppose you are making a direct reading that should come out to 5.67 feet. If you are using a Philadelphia rod, the interval between the top and the bottom of each black graduation and the interval between black graduations (*Figure 6-55*) each represent 0.01 foot. For a reading of 5.76 feet, there are three black graduations between the 5.70-foot mark and the 5.76-foot mark. Since there are three graduations, a beginner may have a tendency to misread 5.76 feet as 5.73 feet.

As you can see, neither the 5-foot mark nor the 6-foot mark is shown in *Figure 6-55*. Sighting through the telescope, you might not be able to see the foot marks to which you must refer for the reading. When you cannot see the next lower foot mark through the telescope, order the rodman to “raise the red.” On the Philadelphia rod, whole feet numerals are in red. Upon hearing this order, the rodman slowly raises the rod until the next lower red figure comes into view.

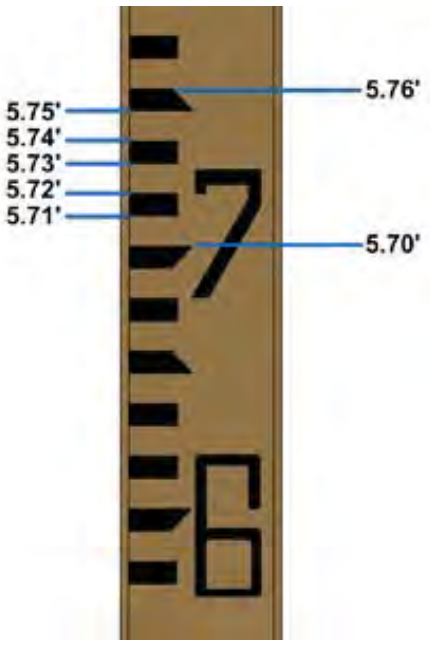


Figure 6-55 – Direct reading of 5.76 ft on a Philadelphia rod.

4.6.2 Target Reading

Conditions that hinder direct reading, such as poor visibility, long sights, and partially obstructed sights, as through brush or leaves, sometimes necessitate use of targets. The target is also used to mark a rod reading when numerous points are set to the same elevation from one instrument setup.

Targets on a Philadelphia rod are usually oval, with the long axis at right angles to the rod, and the quadrants of the target painted alternately red and white (*Figure 6-56*). A C-clamp and a thumbscrew hold the target in place. A lever on the face of the target is used for fine adjustment of the target to the line of sight of the level. The targets have rectangular openings approximately the width of the rod and 0.15 feet high through which the face of the rod may be seen. A linear vernier scale is mounted on the edge of the opening with the zero on the horizontal line of the target for reading to thousandths of a foot. When the target is used, the rodman takes the rod reading.

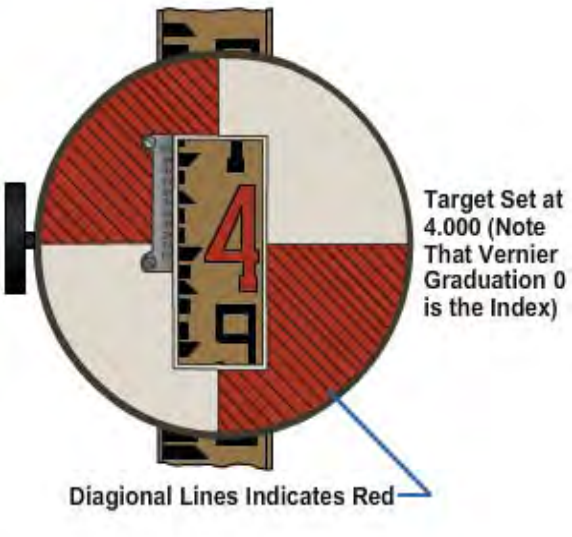


Figure 6-56 – Target on a Philadelphia rod.

When sighting through the level instrument, the levelman motions either up or down so that the rodman can place the horizontal separation of the target in line with the horizontal cross hair of the instrument. When the horizontal separation and the horizontal cross hair coincide, the levelman waves ALL RIGHT.

After the levelman signals the all right, the rodman tightens the target clamp. Then the rodman holds the rod on the point again to ensure the target has not slipped and "waves" the rod by pushing it about a foot away from and towards his body to see if the rod was initially held in an absolutely vertical position. The levelman should recheck the target reading. If the horizontal cross hairs do not coincide, the target must be reset. The rodman reads the target to feet, tenths, and hundredths of the nearest foot gradation below the horizontal quadrant separation line of the target. Equipment Operators seldom use the vernier scale in earthwork operation.

4.7.0 Leveling

The vertical distance, measured during leveling, is the difference of elevation between two points. The term elevation refers to the height of a point or a particular spot above or below a reference line, called a datum plane or zero elevation point.

There are two types of datum planes: actual and assumed. An actual datum plane is mean sea level, shown in (*Figure 6-57)*. Mean sea level (MSL) is defined as the average height of the sea for all stages of the tide after long periods of observations.

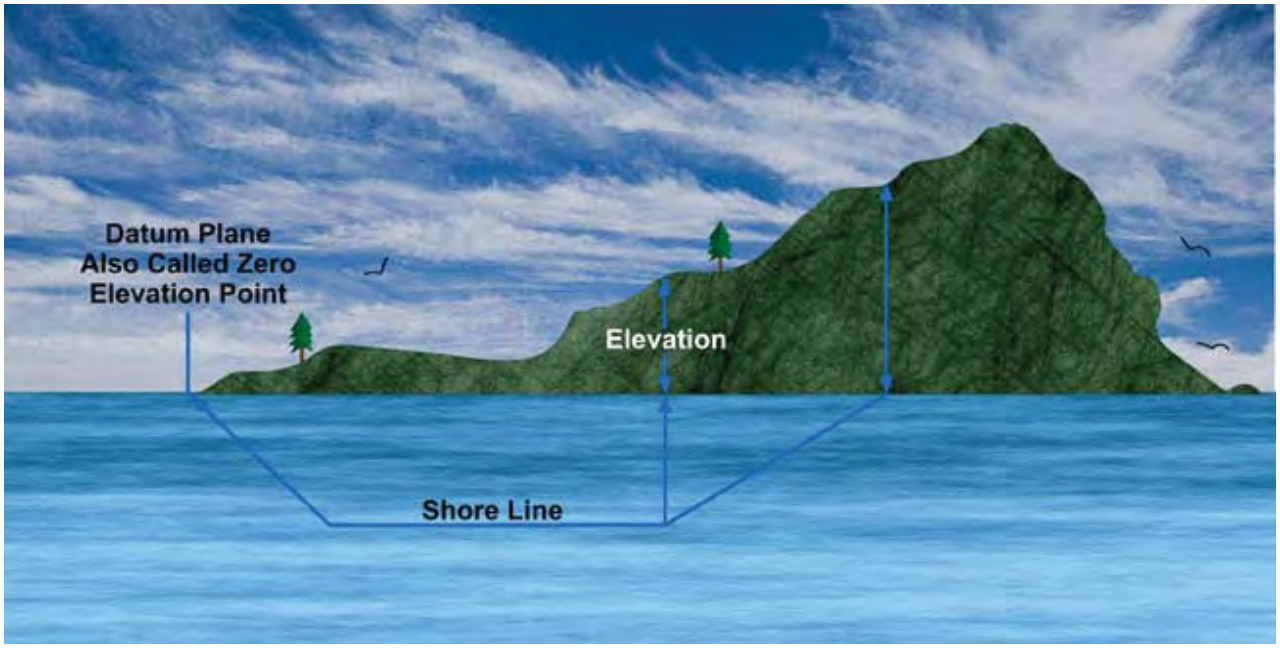


Figure 6-57 – Actual datum plane.

An assumed datum plane is an imaginary level surface assumed to have an elevation of zero. It is used as a convenience in leveling procedures.

4.7.1 Bench Marks

A reference point whose elevation is known and marked is called a bench mark (B.M.). It is used either as the starting point in leveling or as a point of closure in checking the accuracy of your work. Like stakes and hubs, bench marks are protected by guard stakes.

Bench marks are classified as temporary or permanent. Temporary bench marks (T. B. M.) are established for the use of a particular job and are retained for the duration of that job.

Permanent bench marks are established by various governmental agencies. These identification markers are set in stone, iron pipe, or concrete and are sometimes marked with the elevation above sea level. Typical markers are shown in *Figure 6-58.*

Figure 6-58 – Federal bench marks.

Any substantial object may be used as a bench mark, as shown in *Figure 6-59*. Typical monuments set to mark important alignment points may also be used as bench marks (*Figure 6-59 A*). When driven into posts, power poles, trees, or roots, spikes can be used as bench marks as well (*Figure 6-59 B and C*) Bench marks can also be spray painted or chiseled onto flat surfaces of stone or concrete structures (*Figure 6-59 D*).

The location, elevation, and description of bench marks are usually shown on the project drawings or in the surveyor's field notes.

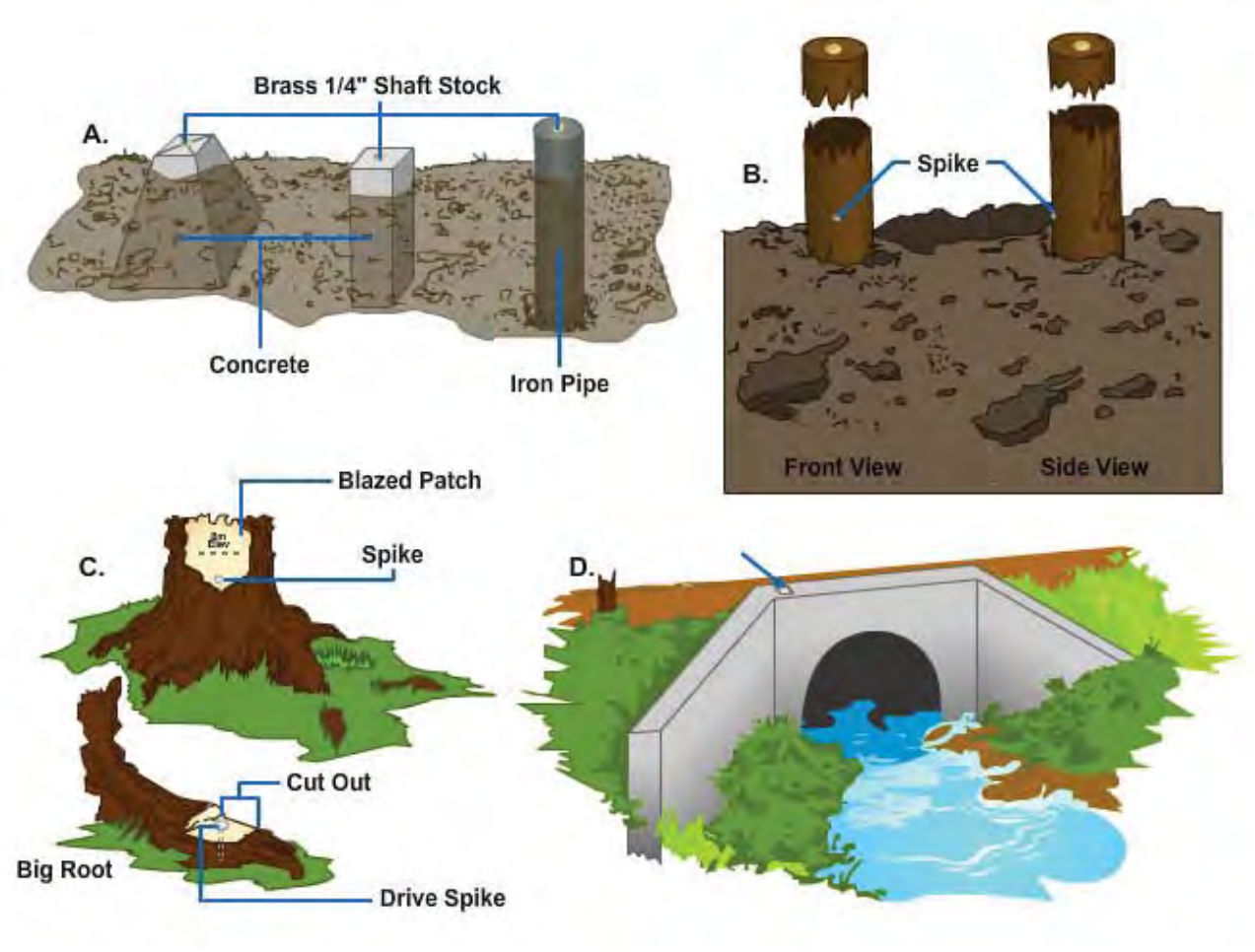


Figure 6-59 – Temporary bench marks.

4.7.2 Determining Elevations

Once a bench mark is established, you can use certain formulas to determine elevations. First, figure the height of the instrument by taking a reading on a level rod placed on a known elevation, such as a bench mark. This is known as a backsight (BS).

To determine the height (HI) of the instrument, add the bench mark (BM) elevation to the backsight (BS) reading from the level rod. This formula is written as BM + BS = HI.

As an example, in *Figure 6-60*, the bench mark elevation is 100.00 feet. The backsight reading is 5.5 feet. The bench mark elevation, added to the backsight reading, gives an instrument height of 105.5 feet.

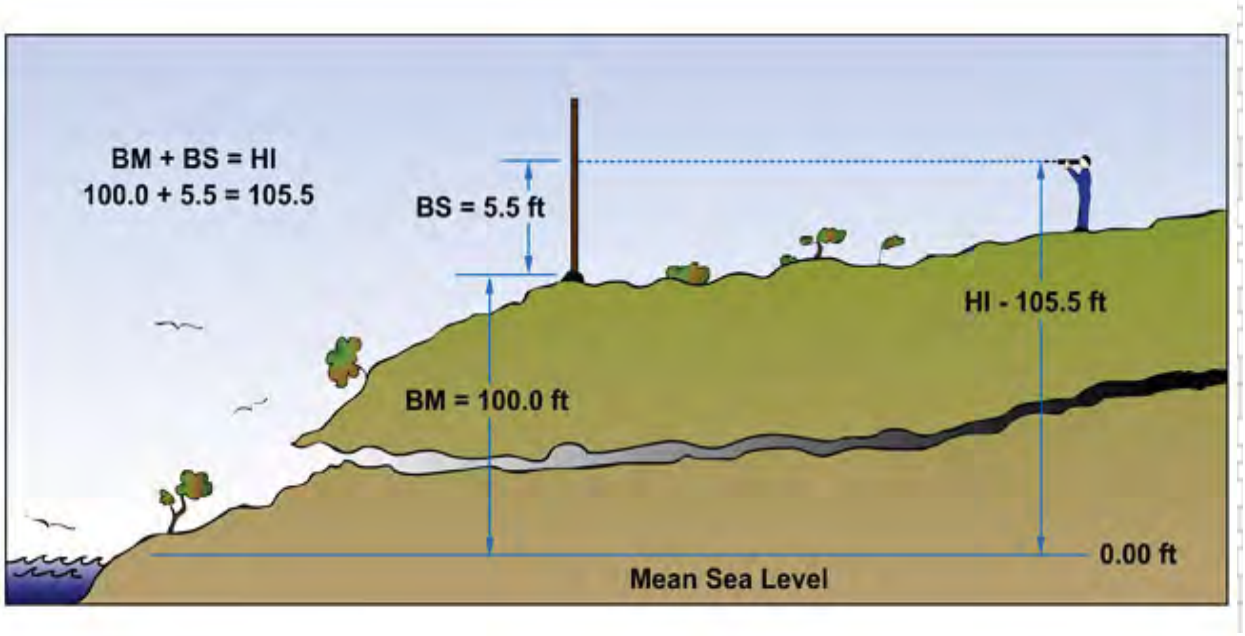


Figure 6-60 – Backsight reading to determine instrument height.

NOTE

Since the backsight (BS) reading is added to the elevation of the bench mark (BM) to obtain the instrument height, it is usually called a plus (+) sight.

After establishing the height (HI) of the instrument, you can determine the elevation of any point within the instrument range.

To determine the elevation of a point after establishing the height (HI), place the level rod on the point in question and take a reading through the level. This sighting is called the foresight (FS) reading. Subtract it from the height to obtain the elevation of the point. The formula for determining elevation is as follows: HI - FS = EL

In the example shown in *Figure 6-61*, the height (HI) of the instrument is 105.5 feet. The foresight (FS) reading is 2.3 feet. The instrument height minus the foresight reading gives that point an elevation of 103.2 feet.

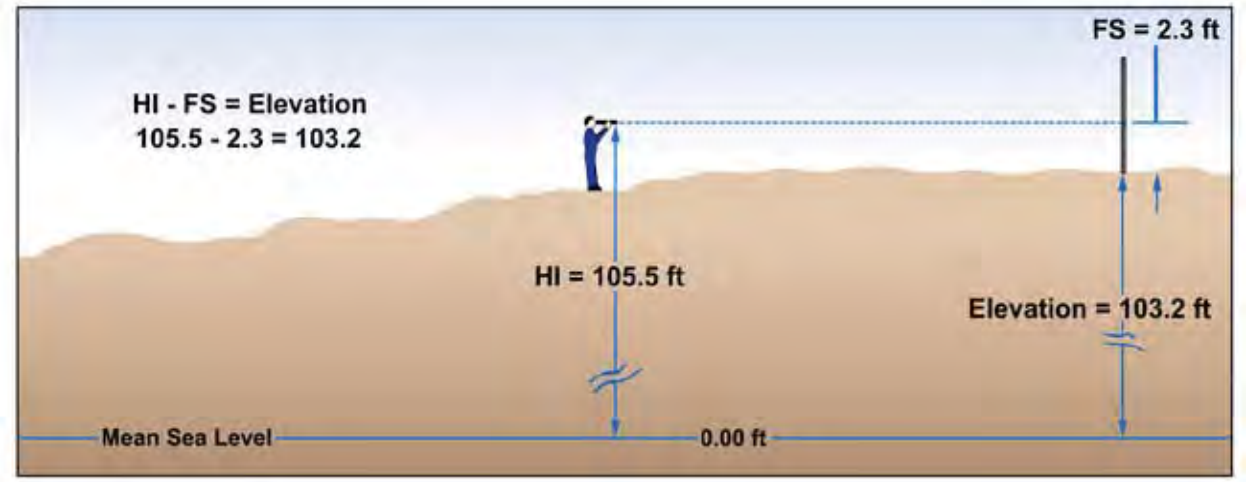


Figure 6-61 – Foresight reading to determine elevation.

4.7.3 Checking Grade with a Level Instrument

Examples of checking ground spots for desired grade with a level instrument are shown in *Figures 6-62* and *6-63*. Please note that the hubs and stakes at the side of the construction represent offset grade stakes.

In *Figure 6-62*, the grade stake calls for a cut of 7.5 feet. Set up your level and take two readings: first on the hub and then on the excavation. Your first reading is 5.0 feet. Since the excavation is supposed to be 7.5 feet below the hub, your second reading should be 12.5 (5.0 plus 7.5 as shown). But the rod reads only 12.2; therefore, you must cut 0.3 feet more to get to finished subgrade.

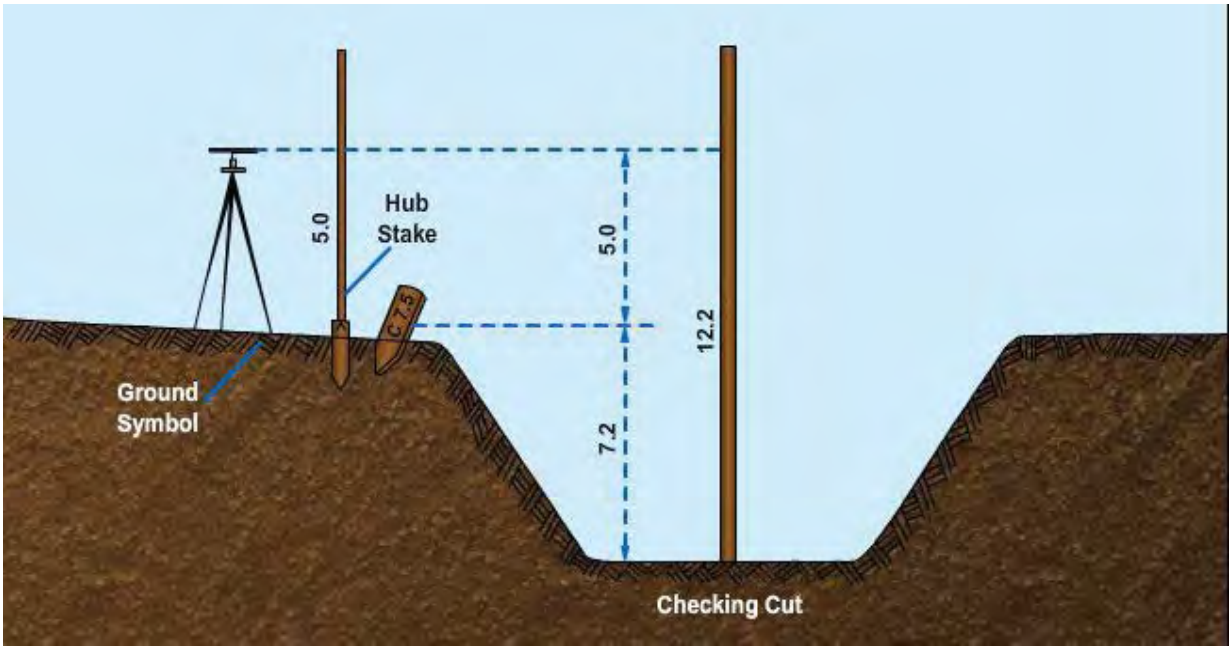


Figure 6-62 – Checking cut.

In *Figure 6-63*, your first reading is 12.0 feet on the hub. Since the stake calls for F 7.0, you should read 5.0 on the completed fill. But the rod reads 5.5; therefore, you must fill another 0.5 feet to finish the subgrade.

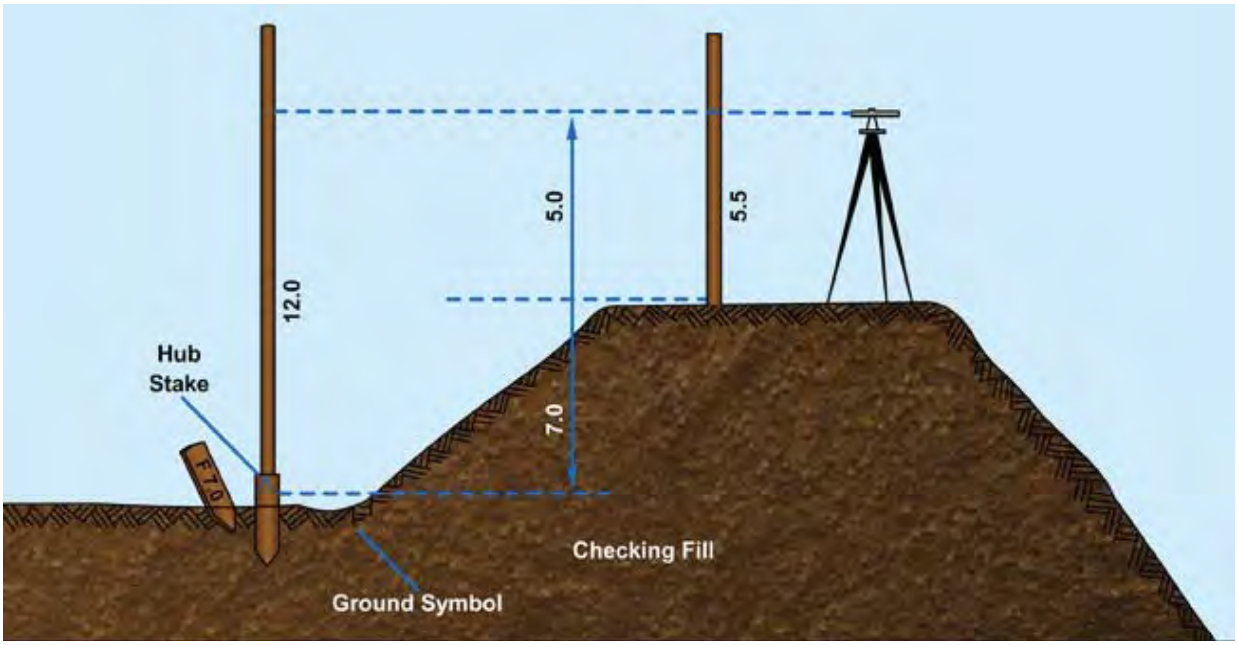


Figure 6-63 – Checking fill.

Missing Grade Stake – Another leveling procedure is to compute a cut-or-fill requirement from a missing grade stake. In *Figure 6-64*, the finish elevation from the project drawings at point B is supposed to be 378.75.

Set up your level; take a backsight shot on the bench mark at point A, and get a direct reading of 11.56 feet. The 11.56 feet backsight reading plus the bench mark elevation of 365.01 feet gives you an instrument height of 376.57 feet. Then take a foresight shot at point B, and get a direct reading of 1.42 feet. Now subtract the foresight reading of 1.42 feet from the instrument height of 376.57, and find that the existing ground is at elevation 375.15. You now take the required finish elevation of 378.75 and subtract the existing elevation of 375.15 and get a fill requirement of 3.6 feet at point B. If the existing elevation is greater than the required finish elevation, you would be required to cut.