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This module is one of a series of teaching guides that cover diesel mechanics. The module contains eight instructional units that cover the following topics: (1) introduction to electrical systems; (2) electrical circuits; (3) electrical indicator circuits; (4) storage batteries; (5) starting systems and circuits; (6) ignition circuits; (7) alternator charging circuits; and (8) emergency shut-down circuits. Each instructional unit follows a standard format that includes some or all of these eight basic components: performance objectives, suggested activities for teachers and students, information sheets, assignment sheets, job sheets, visual aids, tests, and answers to tests and assignment sheets. All of the unit components focus on measurable and observable learning outcomes and are designed for use for more than one lesson or class period. Instructional task analyses; a list of tools, equipment, and materials; and 14 references are also included. (KC)

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DIESEL ELECTRICAL SYSTEMS

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# DIESEL ELECTRICAL SYSTEMS

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FOREWORD

Both the development and revision of instructional materials in diesel mechanics have been rewarding efforts because of the talented people who planned and wrote the materials. From the team of teachers and industry representatives has come a series of texts which should offer diesel mechanics students an excellent opportunity for learning required skills.

This publication, Diesel Electrical Systems, is designed to be used with the other MAVCC books related to diesel. These include: Diesel Fundamentals, Diesel Fuel Systems, Power Trains, and Hydraulics.

As complex as some mechanical activities are, the MAVCC format presents the procedures in logically ordered objectives that facilitate a comfortable learning rate. The format also frees the instructor to concentrate on reinforcing classroom instruction with films, supplemental resources, and other teaching activities that serve to maintain student interest at a high level and to motivate students to learn and do.

Every effort has been made to make this publication basic, readable, and by all means, usable. Three vital parts of instruction have been intentionally omitted from these publications: motivation, personalization, and localization. Those areas are left to the individual instructors and the instructors should capitalize on them. As these publications are used, it is hoped that student's performance will improve and that students will be better able to assume a role in diesel mechanics.

Ron Mehrer, Chairman
Board of Directors
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Appreciation is extended to those individuals who contributed their time and talent to the development of Diesel Electrical Systems.

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Special appreciation is extended to those who served on the original advisory committee representing the many MAVCC states, and to the original author, William Foutes, and to the authors of the second edition, Bill Guynes, Marvin Kukuk, and Joe Mathis.
USE OF THIS PUBLICATION

Instructional Units

Diesel Electrical Systems contains eight units of instruction. Each instructional unit includes some or all of the basic components of a unit of instruction; performance objectives, suggested activities for teachers and students, information sheets, assignment sheets, job sheets, visual aids, tests, and answers to the tests. Units are planned for more than one lesson or class period of instruction.

Careful study of each instructional unit by the teacher will help to determine:

A. The amount of material that can be covered in each class period
B. The skills which must be demonstrated
   1. Supplies needed
   2. Equipment needed
   3. Amount of practice needed
   4. Amount of class time needed for demonstrations
C. Supplementary materials such as pamphlets or filmstrips that must be ordered
D. Resource people who must be contacted

Objectives

Each unit of instruction is based on performance objectives. These objectives state the goals of the course, thus providing a sense of direction and accomplishment for the student.

Performance objectives are stated in two forms: unit objectives, stating the subject matter to be covered in a unit of instruction; and specific objectives, stating the student performance necessary to reach the unit objective.

Since the objectives of the unit provide direction for the teaching-learning process, it is important for the teacher and students to have a common understanding of the intent of the objectives. A limited number of performance terms have been used in the objectives for this curriculum to assist in promoting the effectiveness of the communication among all individuals using the materials.

Reading of the objectives by the student should be followed by a class discussion to answer any questions concerning performance requirements for each instructional unit.

Teachers should feel free to add objectives which will fit the material to the needs of the students and community. When teachers add objectives, they should remember to supply the needed information, assignment and/or job sheets, and criterion tests.
Suggested Activities for the Instructor

Each unit of instruction has a suggested activities sheet outlining steps to follow in accomplishing specific objectives. Duties of instructors will vary according to the particular unit; however, for best use of the material they should include the following: provide students with objective sheet, information sheet, assignment sheets, and job sheets; preview filmstrips, make transparencies, and arrange for resource materials and people; discuss unit and specific objectives and information sheet; give test. Teachers are encouraged to use any additional instructional activities and teaching methods to aid students in accomplishing the objectives.

Information Sheets

Information sheets provide content essential for meeting the cognitive (knowledge) objectives in the unit. The teacher will find that the information sheets serve as an excellent guide for presenting the background knowledge necessary to develop the skill specified in the unit objective.

Students should read the information sheets before the information is discussed in class. Students may take additional notes on the information sheets.

Transparency Masters

Transparency masters provide information in a special way. The students may see as well as hear the material being presented, thus reinforcing the learning process. Transparencies may present new information or they may reinforce information presented in the information sheets. They are particularly effective when identification is necessary.

Transparencies should be made and placed in the notebook where they will be immediately available for use. Transparencies direct the class's attention to the topic of discussion. They should be left on the screen only when topics shown are under discussion.

Assignment Sheets

Assignment sheets give direction to study and furnish practice for paper and pencil activities to develop the knowledge which is a necessary prerequisite to skill development. These may be given to the student for completion in class or used for homework assignments. Answer sheets are provided which may be used by the student and/or teacher for checking student progress.

Job Sheets

Job sheets are an important segment of each unit. The instructor should be able to demonstrate the skills outlined in the job sheets. Procedures outlined in the job sheets give direction to the skill being taught and allow both student and teacher to check student progress toward the accomplishment of the skill. Job sheets provide a ready outline for students to follow if they have missed a demonstration. Job sheets also furnish potential employers with a picture of the skills being taught and the performances which might reasonably be expected from a person who has had this training.
Test and Evaluation

Paper-pencil and performance tests have been constructed to measure student achievement of each objective listed in the unit of instruction. Individual test items may be pulled out and used as a short test to determine student achievement of a particular objective. This kind of testing may be used as a daily quiz and will help the teacher spot difficulties being encountered by students in their efforts to accomplish the unit objective. Test items for objectives added by the teacher should be constructed and added to the test.

Test Answers

Test answers are provided for each unit. These may be used by the teacher and/or student for checking student achievement of the objectives.
DIESEL ELECTRICAL SYSTEMS

INSTRUCTIONAL TASK ANALYSIS

RELATED INFORMATION: What the Worker Should Know
(Cognitive)

JOB TRAINING: What the Worker Should Be Able to Do
(Psychomotor)

UNIT I: INTRODUCTION TO ELECTRICAL SYSTEMS

1. Terms and definitions
2. Safety practices dealing with electrical systems
3. Particles in an atom
4. Electricity according to the atomic theory
5. Sources of electricity
6. Parts of a basic circuit
7. Conductors and insulators of electricity
8. Copper as a conductor
9. Circuit terms and units of measure
10. Basic electrical schematic symbols
11. Letter designations and terms
12. Ohm's Law formula in triangle expression
13. Ohm's Law in letter formula
14. Types of electrical circuits
15. Factors affecting resistance in a conductor
16. Characteristics of magnetism
RELATED INFORMATION: What the Worker Should Know (Cognitive)

17. Relationship between electricity and magnetism

18. Electromagnetic induction

19. Ways to induce voltage by electromagnetic induction

20. Factors that determine the magnitude of induced voltage

21. Types of electric current

22. Direct and alternating current

23. Instruments used in checking electrical circuits

24. Solve problems using Ohm's Law

UNIT II: ELECTRICAL CIRCUITS

1. Terms and definitions

2. Rules for series circuits

3. Rules for parallel circuits

4. Rules for series-parallel circuits

5. Basic electrical circuit failures

6. Voltage drop

7. Types of circuit protection

8. Selection of cable for various rewiring needs

9. Characteristics of a wiring diagram

10. Parts of a typical circuit identification code
RELATED INFORMATION: What the Worker Should Know (Cognitive)

11. Types of connectors
12. Steps in troubleshooting electrical systems

UNIT III: ELECTRICAL INDICATOR CIRCUITS

1. Terms and definitions
2. Electrical indicator circuits
3. Electric gauge operation design
4. Operation of the fuel, temperature, and oil pressure magnetic gauges
5. Sending units
6. Operation of the oil pressure and temperature indicator light circuits
7. Charging indicator circuits
8. Test gauges and sending units (tank unit method)
9. Test gauges and sending units (grounded wire method)
10. Test oil pressure indicator light
11. Test temperature indicator light

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)

13. Read a wiring diagram
14. Check voltage
15. Check a circuit for an open
16. Install a soldered terminal
17. Install a solderless terminal
18. Splice a wire (solder method)
RELATED INFORMATION: What the Worker Should Know (Cognitive)

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)

UNIT IV: STORAGE BATTERIES

1. Terms and definitions
2. Functions of a battery
3. Types of batteries
4. Characteristics of batteries
5. Voltage ratings of batteries
6. Ways of rotating battery capacity
7. Rules for installing batteries
8. Installation of battery cables
9. Types of battery terminal constructions
10. Safety rules to be observed during the care and maintenance of batteries
11. Troubleshoot a battery
12. Remove, service, and replace a battery
13. Measure specific gravity of a conventional battery
14. Load test a battery
15. Charge test a battery for three minutes

UNIT V: STARTING SYSTEMS AND CIRCUITS

1. Terms and definitions
2. Types of starting systems
3. Sources of compressed air for air starting motors
RELATED INFORMATION: What the Worker Should Know (Cognitive)

4. Components of a gasoline starting engine
5. Types of starting aids
6. Purpose of an electrical starting circuit
7. Major parts in an electrical starting circuit
8. Function of parts of an electrical starting circuit
9. Major parts of a starting motor
10. Component parts and their functions
11. Conversion of electrical energy into mechanical energy
12. How a starting motor is kept running
13. Current flow in an electrical starting motor circuit
14. Types of starter field circuits
15. Types of starter field circuits and current flow
16. Types of starting motor switches
17. Engaging starter drives
18. Types of electromagnetic or lever shift drives
19. Operation of a series-parallel switch
20. Operation of a transformer-rectifier unit

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)
RELATED INFORMATION: What the Worker Should Know
(Cognitive)

JOB TRAINING: What the Worker Should Be Able to Do
(Psychomotor)

21. Remove and replace a starter
22. Disassemble, test, and reassemble a starter
23. Test a starter motor (no-load)
24. Rebuild and test a starter solenoid
25. Check voltage drop in a starter circuit

UNIT VI: IGNITION CIRCUITS

1. Terms and definitions
2. Purpose of an ignition circuit
3. Components of an ignition circuit
4. Functions of an ignition circuit
5. Ignition circuit components
6. Components of a distributor
7. Operation of an ignition circuit
8. Components of a distributor with a built-in governor
9. Operation of a governed distributor
10. Transistorized and capacitive discharge ignition systems
11. Major components of an electronic ignition system and their functions
12. General safety precautions for electronic ignition systems
RELATED INFORMATION: What the Worker Should Know
(Cognitive)

JOB TRAINING: What the Worker Should Be Able to Do
(Psychomotor)

13. Remove and install a distributor

14. Remove and replace contact points and condenser

15. Adjust dwell on an externally adjustable distributor

16. Check and set ignition timing

17. Remove, service, and replace spark plugs

UNIT VII: ALTERNATOR CHARGING CIRCUITS

1. Terms and definitions

2. Purpose of the alternator charging circuit

3. Alternator charging circuit components and functions

4. Major parts of an alternator

5. Construction of stator windings

6. Types of alternator circuits

7. Characteristics of a brushless alternator

8. Operation of a brushless alternator

9. Operation of a transistorized regulator

10. Safety rules for working with alternator charging circuits
RELATED INFORMATION: What the Worker Should Know (Cognitive)

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)

11. Test the Ford alternator charging circuit with external regulator
12. Remove and replace an alternator
13. Disassemble, test, and reassemble an alternator
14. Test a transistorized regulator
15. Test an S.I. series alternator
16. Test charging circuit resistance for a GM alternator

UNIT VIII: EMERGENCY SHUT-DOWN CIRCUITS

1. Terms and definitions
2. Characteristics of a coolant temperature switch gauge
3. Characteristics of an oil pressure switch gauge
4. Steps in the operation of the magnetic switch
5. Shut-off solenoids
6. Characteristics of the overspeed contactor switch
7. Oil pressure contactor switch
8. Operation of an alarm system
9. Troubleshoot a shut-down and alarm circuit
DIESEL ELECTRICAL SYSTEMS

TOOLS, EQUIPMENT, AND MATERIALS LIST

Alternator
Alternator pulley removal tools
Alternator diode removal equipment
Alternator testing equipment
Ammeter
Armature growler with test light
Auxiliary starter button

Baking soda
Basic hand tool set
Battery
Battery anti-corrosion paste
Battery capacity tester
Battery charger
Battery clamp puller
Battery lift strap
Battery pliers
Battery post and cable cleaner
Bristle brush

Carbonpile resistor
Chalk
Circuit board
Circuit tester
Combination end wrench
Crimping pliers

Dial indicator
Distributor cam lubricant
Distributor wrenches
Dwell meter

Electrical tape
Electrical wire
Engine
Extensions, 3"-6"-10" by 3/8" drive

Feeler gauges
Fuel sending unit

Hex contact point adjusting tool
Hydrometer

Jumper wire
Ohmmeter
Point alignment tools
Ratchet
Resin core solder
Rubber apron
Rubber gloves

Safety glasses
Sandpaper, medium
Screwdriver
Service manuals
Shop towels
Soldering gun or iron
Solenoid
Spark plug starter wrench
Starter

Tachometer
Terminal
Test light
Timing light
Torque wrench

Variable resistor
V blocks
Vehicle's
Voltmeter

Wire brush
REFERENCES


M. Switchgage® Diagnostic General Catalog 1987-88. Tulsa, OK: Frank W. Murphy Manufacturer.

INTRODUCTION TO ELECTRICAL SYSTEMS
UNIT I

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify types of electrical circuits, distinguish between direct and alternating current, and solve problems using Ohm's Law. Competencies will be demonstrated by completing the assignment sheet and the unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to electrical systems with their correct definitions.
2. Select true statements concerning safety practices dealing with electrical systems.
3. Name two particles found in an atom.
4. Define electricity according to the atomic theory.
5. Identify three sources of electricity related to diesel engines.
6. Name parts of a basic circuit.
7. Distinguish between conductors and insulators of electricity.
8. Explain why copper is widely used as a conductor.
9. Match the basic circuit terms with their units of measure.
10. Match the basic electrical schematic symbols with their correct names.
OBJECTIVE SHEET

11. Match the letter designations used in Ohm's Law with their correct terms.
13. State Ohm's Law in letter formula.
14. Identify three types of electrical circuits.
15. Name three factors affecting resistance in a conductor.
16. Select from a list the characteristics of magnetism.
17. Select true statements concerning the relationship between electricity and magnetism.
18. Select true statements concerning electromagnetic induction.
19. List three ways to induce voltage by electromagnetic induction.
20. List three factors that determine the magnitude of induced voltage.
21. Name two types of electric current.
22. Distinguish between direct and alternating current.
23. Name three instruments used in checking electrical circuits.
24. Solve problems using Ohm's Law. (Assignment Sheet #1)
INTRODUCTION TO ELECTRICAL SYSTEMS
UNIT I

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information and assignment sheets.

F. Discuss information and assignment sheets.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Integrate the following activities throughout the teaching of this unit:
   1. Demonstrate magnetic lines of force by using iron filings and a conductor.
   2. Demonstrate how to make an electromagnet using 5’ of electrical wire, a soft iron bar, and a 1.5 volt battery.
   3. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

H. Give test.

I. Evaluate test.

J. Reteach If necessary.

REFERENCES USED IN DEVELOPING THIS UNIT


**SUGGESTED SUPPLEMENTAL RESOURCES**

**A. Texts**

   Erich J. Schulz
   Text, 1983, 496 pages (055639-3)
   Workbook (055640-7)
   Gregg/McGraw-Hill
   P.O. Box 996
   Norcross, GA 30091

2. *Fundamentals of Electricity and Magnetism, Training Chart Manual*
   Technical Literature Department
   Delco-Remy Division
   General Motors Corporation
   Anderson, IN 46018

**B. Filmstrips**

1. *Basic Automotive Electricity — #A5037*
   (NOTE: To obtain material and correct prices, contact your nearest Mack Branch or distributor)

   1 cassette, 1 filmstrip (29 frames), 1 worksheet
   Teaching Aids Incorporated
   P.O. Box 1798
   Costa Mesa, CA 92628-0798
INTRODUCTION TO ELECTRICAL SYSTEMS
UNIT I

INFORMATION SHEET

I. Terms and definitions

A. Alternator (alternating current generator) — Voltage and current produced by a rotating magnetic field cutting across stationary conductors

B. Atom — Smallest unit of all matter

C. Conductor — Any material that permits passage of electric current

D. Counter emf — Voltage induced in a conductor which is moving through a magnetic field in opposition to the source of voltage
   (NOTE: This is a generator action developed in every motor.)

E. Current — Flow of electrons through a conductor, measured in amperes

F. Electrochemical — Stored chemical energy which can be converted to electrical current

G. Electrons — Particles with a negative charge in orbit around a core of protons

H. Electromagnet — A wire carrying electric current wound into a coil around an iron core creating a magnetic field

I. Electromagnetic induction — Inducing voltage in a conductor that moves across a magnetic field

J. Emf — Electromotive force or voltage

K. Insulator — Material with an extremely high resistance to current flow

L. Mutual induction — Occurs when changing current in one coil induces voltage in a second coil

M. Parallel circuit — Current has more than one path to take

N. Protons — Particles with a positive charge that make up the nucleus of the atom

O. Resistance — Opposition to current flow in a conductor

P. Self Induction — Voltage which occurs in a coil when there is a change of current

Q. Semiconductor — An element which has four electrons in outer ring; used to make diodes and transistors; not a good conductor or insulator
INFORMATION SHEET

R. Series circuit — Current has only one path it can take

S. Series-parallel circuit — A circuit consisting of both series and parallel components

T. Thermocouple — Thermoelectric device used to measure temperature accurately

U. Thermoelectric — Electricity generated by heat

V. Voltage — Potential difference that causes flow of current

W. Voltage drop — Voltage loss due to resistance

X. Watt — Electrical measurement of rate of doing work

(NOTE: 746 watts = 1 horsepower)

II. Safety practices dealing with electrical systems

A. When working on electrical system that is connected to the battery, remove all jewelry.

B. When disconnecting battery cables, remove the ground cable first.

C. If you are using an ohmmeter, disconnect the battery.

D. Never leave the ignition switch on when installing a distributor.

E. Never ground the output terminal of the alternator.

F. Never lay any conductor across the battery terminals.
INFORMATION SHEET

G. When replacing an electrical component, always disconnect the battery first.

H. Never apply full battery voltage to the fuel tank sending unit.

I. When using jumper cables, always connect ground to the frame or engine.

J. When using a battery charger, make your connections before plugging the charger in.

K. When adding accessories, make sure they match the vehicle's ground.

L. When replacing a conductor, always use the same size (gauge) conductor.

M. When adding accessories, be sure not to exceed the charging system output.

(NOTE: The charging system should have an output of 10% above total current draw.)

III. Particles in an atom (Transparency 1)

A. Electron

B. Proton

(NOTE: These are the particles involved in the electron theory)

IV. Electricity — The flow of electrons from atom to atom in a conductor. (Transparency 2)

V. Sources of electricity related to diesel engines (Transparency 3)

A. Thermoelectric

B. Electrochemical

C. Electromagnetic
VI. Parts of a basic circuit

A. Voltage
   Example: Battery

B. Resistor
   Example: Light bulb

C. Conductor
   Example: Copper wire

D. Control device
   Example: Switch

VII. Conductors and Insulators of electricity

A. Conductors
   1. Silver
      (NOTE: Silver has the least resistance to current flow.)
   2. Copper
   3. Gold
   4. Aluminum
INFORMATION SHEET

5. Tungsten
6. Zinc
7. Brass
8. Platinum
9. Iron
10. Nickel
11. Tin
12. Steel
13. Lead
14. Mercury
15. Nichrome

(NOTE: Nichrome has the highest resistance to current flow.)

B. Insulators
1. Glass
2. Rubber
3. Plastic
4. Wood
5. Ceramic
6. Mica

VIII. Copper as a conductor — Copper has only one electron in outer ring and is comparatively cheaper than other metals which may have the same properties. (Transparency 1)
INFORMATION SHEET

IX. Circuit terms and units of measure
A. Current — Amperes
B. Voltage — Volts

![Diagram of pressure (voltage) and current]

C. Resistance — Ohms

![Diagram of resistance (ohms) and current]

X. Basic electrical schematic symbols
A. Resistance or load

![Resistance symbol]

B. Ohms of resistance

![Ohms symbol]

C. Inductor (coil)

![Inductor symbol]

D. Inductor (solenoid)

![Inductor (solenoid) symbol]
INFORMATION SHEET

U. Transistor

V. Voltmeter

W. Ammeter

X. Positive terminal

Y. Negative terminal

Z. Gauge (temperature or fuel)

AA. Voltage limiter (for instrument panel)

XI. Letter designations and terms

A. E — Electromotive force in volts
B. I — Intensity (current) in amps
C. R — Resistance in ohms

XII. Ohm’s Law formula in triangle expression (Transparency 4)

(Note: E.I.R. formula reminder is the phrase “Even I Remember”)
XIII. Ohm's Law in letter formula (Transparency 5)

A. \( E = I \times R \) or Volts = Amps \times Ohms

B. \( I = \frac{E}{R} \) or Amps = Volts \div Ohms

C. \( R = \frac{E}{I} \) or Ohms = Volts \div Amps

XIV. Types of electrical circuits (Transparency 6)

A. Series

(NOTE: In a series circuit the voltage will drop along the circuit. The total voltage drop in a series circuit will always be equal to the applied voltage.)

B. Parallel

(NOTE: The voltage will be the same at all points along a parallel circuit.)

C. Series-parallel

(NOTE: The circuit is a combination of a series circuit and a parallel circuit. It has medium resistance.)

XV. Factors affecting resistance in a conductor

A. Length of wire

\[
\begin{align*}
R_0 & \quad R_0 \\
2 \times R_0 & \\
\end{align*}
\]

Resistance Proportional to Length

A Longer Wire Creates More Resistance

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B. Diameter of wire

\[
\begin{align*}
R_0 & \quad \frac{R_0}{2} \\
\end{align*}
\]

A Smaller Wire Creates More Resistance

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INFORMATION SHEET

C. Temperature of wire

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>70°F</td>
<td>0.04Ω</td>
</tr>
<tr>
<td>170°F</td>
<td>0.08Ω</td>
</tr>
</tbody>
</table>

A Hotter Wire Creates More Resistance

XVI. Characteristics of magnetism (Transparency 7)

A. Every magnet has a north and south pole.
B. Unlike poles (charges) attract and like poles (charges) repel.
C. Every magnet has a field of force surrounding it.
D. Magnetic materials are acted upon when located in a field of force.

XVII. Relationship between electricity and magnetism (Transparency 8)

A. Current passed through a wire (conductor) creates a magnetic field around the wire.
B. Magnetic lines have direction and change direction when the current flow changes from one direction to another.

(NOTE: The Right Hand Rule for a straight conductor can be used to find the direction of the lines of force around the wire. To apply the rule, grasp the wire with the thumb extended in the direction of conventional current flow (positive to negative); the fingers will then point in the direction in which the lines of force surround the conductor. These lines of force are always at right angles to the conductor.)

C. Two conductors on an armature, carrying current in opposite directions, create a strong and weak field on opposite sides causing conductors to move apart or an armature to rotate.

(NOTE: The downward movement or rotation is caused by current flowing in the conductor. This is the principle by which a cranking motor operates.)
XVIII. Electromagnetic Induction (Transparency 9)

A. Conductor moving across a magnetic field will have a voltage (emf) induced in it.

B. Voltage polarity and the current flow direction are determined by the direction of wire movement and direction of the lines of force.

(NOTE: The conductor can move or the magnetic field can move.)

XIX. Ways to induce voltage by electromagnetic induction

A. Generated voltage by electromagnetic induction
   Examples: Generators and alternators

B. Self induction voltage created by a change of current in the conductor
   Example: Primary of ignition coils

C. Mutual induction voltage which occurs when changing current in one coil induces voltage in a second coil.
   Example: Two windings of ignition coils

XX. Factors that determine the magnitude of induced voltage

A. Strength of the magnetic field

B. Speed at which lines of force are cutting across the conductor

C. Number of conductors that are cutting across the lines of force

XXI. Types of electric current

A. Direct

B. Alternating
INFORMATION SHEET

XXII. Direct and alternating current

A. Direct current
   1. Supplied by
      a. Generator
      b. Battery
         1) Dry cell
         2) Wet cell
   2. Flows in one direction only
   3. Abbreviated as DC

B. Alternating current
   1. Supplied by an alternating current generator (alternator)
   2. Flows in one direction then reverses and flows in the opposite direction
   3. Abbreviated as AC

XXIII. Instruments used in checking electrical circuits (Transparency 10)

A. Ammeter
B. Voltmeter
C. Ohmmeter

(NOTE: Modern testers often combine the voltmeter, ammeter, and ohmmeter in one test unit, such as a battery-starter tester.)
Structure of Atoms

Electron
- Proton

Hydrogen Atom
1 Electron
1 Proton

Copper Atom
29 Electrons
29 Protons

Uranium Atom
92 Electrons
92 Protons

NOTE: Count the Number of Electrons in the Outer Ring of the Atom.
Electron Flow

Positive Charge

Negative Charge

Copper Wire

Electron Flow
Sources of Electricity

Thermocouple
Thermoelectric Source

Generator
Electromagnetic Source

Battery
Electrochemical Source
Ohm's Law in Triangle Expression

NOTE: Solve for Volts, Amps, or Resistance by Covering the Unknown

Example: Cover E, then $E = I \times R$
Cover I, then $I = E \div R$
Cover R, then $R = E \div I$
Ohm’s Law in Letter Formula

In the formula of Ohm’s law, 
I = amperage, E = voltage, and R = resistance in ohms.

\[
\begin{align*}
\text{Amperes} &= \frac{\text{Volts}}{\text{Ohms}} \\
\text{Ohms} &= \frac{\text{Volts}}{\text{Amperes}} \\
\text{Volts} &= \text{Amperes} \times \text{Ohms}
\end{align*}
\]

(Note: If you cover the quantity you wish to calculate (voltage, current, or resistance), the remaining parts of the memory circle will show you which form of Ohm’s law you must use.)
Types of Electrical Circuits

Series Circuit

Parallel Circuit

Series-Parallel Circuit
Magnetism and Field of Force

Magnetic Lines of Force

Leads From Battery

Unmagnetized Iron Filings
Electricity and Magnetism Relationship

Strong Field Between Conductors

Conductors Tend To Move Apart

Right Hand Rule For Straight Conductor
Arrows Show Direction Of Field Of Force

Motor Principle
Electromagnetic Inductions

Basic Generator Operation

Basic Alternator Operation

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Measuring Instruments

Electric "pressure" is measured in volts with a voltmeter.

Resistance is measured in ohms with an ohmimeter.

Electric current is measured in amperes with an ammeter.

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INTRODUCTION TO ELECTRICAL SYSTEMS
UNIT I

ASSIGNMENT SHEET #1 -- SOLVE PROBLEMS USING OHM'S LAW

NAME ___________________________________________  SCORE ________

Directions: Read the problems and use the triangle expression of Ohm's Law to solve for the unknown value in each problem.

Example: Cover the unknown in the triangle and solve

(NOTE: E = Voltage; I = Amperes; R = Resistance.)

Show your work on each problem. Turn in to instructor after completion.

1. The starter of an automobile has a resistance of 0.12 ohms. How much current must a 12.6-volt storage battery supply to start the car?

2. A fan motor in an air conditioner has an internal resistance of 180 ohms. What will be the amperage draw of the motor, on a 12-volt system?
ASSIGNMENT SHEET #1

3. Calculate the battery voltage needed to drive a current of 150 amperes through the starter of a car. The starter's resistance is 0.08 ohms.

4. Solve for the unknown voltage.

\[ E = \text{V} \]

Circuit with known current and resistance, but unknown voltage.

5. Solve for the unknown resistance.

\[ R = \Omega \]

Circuit with known voltage and current, but unknown resistance.
INTRODUCTION TO ELECTRICAL SYSTEMS
UNIT I

ANSWERS TO ASSIGNMENT SHEET

1. 105 amperes
2. 0.067 amperes
3. 12-volts
4. 12-volts
5. 4-ohms
INTRODUCTION TO ELECTRICAL SYSTEMS
UNIT I

NAME _________________________ SCORE ______________________

TEST

1. Match the terms on the right with their correct definitions.

(NOTE: Terms and definitions are continued on the following page.)

a. Smallest unit of all matter
   1. Alternator

b. Particles with a negative charge in orbit around a core of protons
   2. Atom

c. Particles with a positive charge that make up the nucleus of the atom
   3. Conductor

d. Flow of electrons through a conductor, measured in amperes
   4. Counter emf

e. Any material that permits passage of electric current
   5. Current

f. An element which has four electrons in outer ring; used to make diodes and transistors; not a good conductor or insulator
   6. Electrochemical

ɡ. Potential difference that causes flow of current
   7. Electromagnet

h. Opposition to current flow in a conductor
   8. Electromagnetic induction

i. Material with an extremely high resistance to current flow
   9. Electrons

j. Stored chemical energy which can be converted to electrical current
   10. Emf

k. Electricity generated by heat
   11. Insulator

l. Thermoelectric device used to measure temperature accurately
   12. Mutual induction

m. Inducing voltage in a conductor that moves across a magnetic field
   13. Parallel circuit
TEST

____.n. Occurs when changing current in one coil induces voltage in a second coil

____.o. Voltage which occurs in a coil when there is a change of current

____.p. Voltage and current produced by a rotating magnetic field cutting across stationary conductors

____.q. Electrical measurement of rate of doing work

____.r. Electromotive force or voltage

____.s. Voltage induced in a conductor which is moving through a magnetic field in opposition to the source of voltage

____.t. Current has more than one path to take

____.u. Current has only one path it can take

____.v. A circuit consisting of both series and parallel components

____.w. A wire carrying electric current wound into a coil around an iron core creating a magnetic field

____.x. Voltage loss due to resistance

14. Protons

15. Resistance

16. Self induction

17. Semiconductor

18. Series circuit

19. Series-parallel circuit

20. Thermocouple

21. Thermoelectric

22. Voltage

23. Voltage drop

24. Watt

2. Select true statements concerning safety practices dealing with electrical systems by placing an "X" beside each statement that is true.

____.a. When working on electrical system that is connected to the battery, remove all jewelry.

____.b. When disconnecting battery cables, remove the positive cable first.

____.c. If you are using an ohmmeter, disconnect the battery.

____.d. Never leave the ignition switch on when installing a distributor.

____.e. Never ground the output terminal of the alternator.

____.f. Never lay any conductor across the battery terminals.

____.g. When replacing an electrical component, always disconnect the battery first.
TEST

h. Never apply full battery voltage to the fuel tank sending unit.

i. When using jumper cables, always connect ground to the frame or engine.

j. When using a battery charger, make your connections before plugging the charger in.

k. When adding accessories, make sure they match the vehicle's ground.

l. When replacing a conductor, always use the same size (gauge) conductor.

m. When adding accessories, be sure not to exceed the charging system output.

3. Name two particles found in an atom.
   a. 
   b. 

4. Define electricity according to the atomic theory.

5. Identify three sources of electricity related to diesel engines.

   a. 
   b. 
   c. 

   ![Diagram of electricity sources]
6. Name three parts of a basic circuit.
   a. 
   b. 
   c. 

7. Distinguish between conductors and insulators of electricity by placing a "C" in front of the items that are conductors and an "I" in front of the insulators.
   _____a. Mercury
   _____b. Br__sid
   _____c. Rubber
   _____d. Glass
   _____e. Wood
   _____f. Nickel
   _____g. Plastic
   _____h. Nichrome
   _____i. Silver
   _____j. Gold
   _____k. Ceramic
   _____l. Aluminum

8. Explain why copper is widely used as a conductor.

9. Match the basic circuit terms on the right with their units of measure.
   _____a. Volts  1. Current
   _____b. Ohms  2. Voltage
   _____c. Amperes  3. Resistance
10. Match the basic electrical schematic symbols with their correct names.

(NOTE: Schematic symbols and names are continued on the following page.)

____a. (_) 1. Ammeter
____b. (+) 2. Battery
____c. (_) 3. Cable — not connected
____d. (_) 4. Circuit breaker
____e. (_) 5. Condenser or capacitor
____f. (_) 6. Connection
____g. (_) 7. Connectors — separable, engaged
____h. (_) 8. Diode
____i. (_) 9. Direction of current
____j. (_) 10. Double-throw switch
____k. (_) 11. Fuse
____l. (_) 12. Fusible link or wire
____m. (_) 13. Ground
____n. (_) 14. Inductor (coil)
TEST

15. Inductor (solenoid)
16. Lamp
17. Negative terminal
18. Ohms of resistance
19. Positive terminal
20. Resistance or load
21. Switch — single throw
22. Temperature or fuel gauge
23. Termination
24. Transistor
25. Variable resistance
26. Voltage limiter
27. Voltmeter
11. Match the letter designations used in Ohm's Law with the correct terms.

   a. Electromotive force in volts  1. R
   b. Intensity (current) in amps  2. I
   c. Resistance in ohms  3. E


13. State Ohm's Law in letter formula.

   a. ________________________________
   b. ________________________________
   c. ________________________________

14. Identify three types of electrical circuits.

   a. ________________________________
   b. ________________________________
   c. ________________________________
15. Name three factors affecting resistance in a conductor.
   a. ____________________________________________________________
   b. ____________________________________________________________
   c. ____________________________________________________________

16. Select from the following list characteristics of magnetism by placing an “X” beside each characteristic.
   ____a. Every magnet has a north and south pole.
   ____b. Like poles attract and unlike poles repel.
   ____c. Magnetic materials are acted upon when located in a field of force.
   ____d. Every magnet has a field of force surrounding it.
   ____e. Unlike poles attract and like poles repel.

17. Select true statements concerning the relationship between electricity and magnetism by placing an “X” beside each statement that is true.
   ____a. Current passed through a wire creates a magnetic field around the wire.
   ____b. Magnetic lines never change direction when the current flow changes direction.
   ____c. Two conductors on an armature, carrying current in opposite directions, create a strong and weak field on opposite sides causing conductors to move apart or armature to rotate.

18. Select true statements concerning electromagnetic induction by placing an “X” beside each statement that is true.
   ____a. Conductor moving across a magnetic field will have a voltage (emf) induced in it.
   ____b. Voltage polarity and the current flow direction are determined by the direction of wire movement and direction of the lines of force.

19. List three ways to induce voltage by electromagnetic induction.
   a. ____________________________________________________________
   b. ____________________________________________________________
   c. ____________________________________________________________
20. List three factors that determine the magnitude of induced voltage.
   a. 
   b. 
   c. 

21. Name two types of electric current.
   a. 
   b. 

22. Distinguish between direct and alternating current by placing "DC" in front of the items that refer to direct current and "AC" in front of the items that refer to alternating current.
   a. _____ Flows in one direction then reverses and flows in the opposite direction
   b. _____ Dry cell battery
   c. _____ Supplied by an alternating current generator (alternator)
   d. _____ Flows in one direction only
   e. _____ Supplied by a generator

23. Name three instruments used in checking electrical circuits.
   a. 
   b. 
   c. 

24. Solve problems using Ohm's Law. (Assignment Sheet #1)
# INTRODUCTION TO ELECTRICAL SYSTEMS
## UNIT I

## ANSWERS TO TEST

1. a. 2  
   b. 9  
   c. 14  
   d. 5  
   e. 3  
   f. 17  
   g. 22  
   h. 15  

2. l. 11  
   j. 6  
   k. 21  
   l. 20  
   m. 8  
   n. 12  
   o. 16  
   p. 1  
   q. 24  
   r. 10  
   s. 4  
   t. 13  
   u. 18  
   v. 19  
   w. 7  
   x. 23  

2. a, c, d, e, f, g, h, j, k, l, m  

3. a. Electron  
   b. Proton  

4. The flow of electrons from atom to atom in a conductor  

5. a. Thermoelectric  
   b. Electrochemical  
   c. Electromagnetic  

6. Any three of the following:  
   a. Voltage  
   b. Resistor  
   c. Conductor  
   d. Control device  

7. a. C  
   b. C  
   c. l  
   d. I  
   e. I  
   f. C  

8. g. l  
   h. C  
   i. C  
   j. C  
   k. l  
   l. C  

8. Copper has only one electron in outer ring and is comparatively cheaper than other metals which may have the same properties.  

9. a. 2  
   b. 3  
   c. 1  

10. a. 20  
    b. 19  
    c. 25  
    d. 7  
    e. 18  
    f. 10  
    g. 1  

    h. 22  
    i. 3  
    j. 13  
    k. 4  
    l. 8  
    m. 11  
    n. 5  

    o. 26  
    p. 24  
    q. 18  
    r. 9  
    s. 6  
    t. 27  
    u. 12  

    v. 14  
    w. 15  
    x. 2  
    y. 21  
    z. 23  
    aa. 17
ANSWERS TO TEST

11. a. 3
    b. 2
    c. 1

12.

13. a. \(E = I \times R\)
    b. \(I = E/R\)
    c. \(R = E/I\)

14. a. Parallel
    b. Series-parallel
    c. Series

15. a. Length of wire
    b. Diameter of wire
    c. Temperature of wire

16. a, c, d, e

17. a, c

18. a, b

19. a. Generated voltage by relative motion
    b. Self induction voltage created by a change of current in the conductor
    c. Mutual induction voltage which occurs when changing current in one coil induces voltage in a second coil

20. a. Strength of the magnetic field
    b. Speed at which lines of force are cutting across the conductor
    c. Number of conductors that are cutting across the lines of force

21. a. Direct
    b. Alternating

22. a. AC
    b. DC
    c. AC
    d. DC
    e. DC
ANSWERS TO TEST

23.  a. Ammeter
     b. Voltmeter
     c. Ohmmeter

24. Evaluated to satisfaction of instructor
ELECTRICAL CIRCUITS
UNIT II

UNIT OBJECTIVE

After completion of this unit, the student should be able to read a wiring diagram, check circuits, install wire terminals, and splice a wire. Competencies will be demonstrated by completing the assignment sheet, job sheets, and the unit tests with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to electrical circuits with their correct definitions.
2. Calculate voltage drop across resistors in a series circuit.
3. Calculate current in a parallel circuit.
5. Match the basic electrical circuit failures with the correct causes.
6. Select true statements concerning voltage drop.
7. Name three types of circuit protection.
8. Complete statements concerning selection of cable for rewiring needs.
9. Select from a list characteristics of a wiring diagram.
10. Label parts of a circuit identification code.
OBJECTIVE SHEET

11. Match types of connectors with their correct names.

12. Arrange in order the steps in troubleshooting electrical systems.

13. Read a wiring diagram. (Assignment Sheet #1)

14. Demonstrate the ability to:
   a. Check voltage. (Job Sheet #1)
   b. Check a circuit for an open. (Job Sheet #2)
   c. Install a soldered terminal. (Job Sheet #3)
   d. Install a solderless terminal. (Job Sheet #4)
   e. Splice a wire (solder method). (Job Sheet #5)
ELECTRICAL CIRCUITS
UNIT II

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(Note: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information and assignment sheets and handout.

F. Discuss information and assignment sheets and handout.

(Note: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheets.

H. Discuss and demonstrate the procedures outlined in the job sheets.

I. Integrate the following activities throughout the teaching of this unit:
   1. Take a field trip to a shop where electrical work is performed.
   2. Make a circuit board of a simple lighting system.
   3. Have students draw wiring diagrams.
   4. Demonstrate safety practices on electrical systems.
   5. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.
REFERENCES USED IN DEVELOPING THIS UNIT


SUGGESTED SUPPLEMENTAL RESOURCES

Text

*Chilton's Guide to Electronic Engine Controls Manual*
Teaching Aids Incorporated
Order #CH 7535
Box 1798
Costa Mesa, CA 92628-0798
1-800-345-1214
ELECTRICAL CIRCUIT
UNIT II

INFORMATION SHEET

I. Terms and definitions

A. Cable — Stranded conductor usually covered with insulating material

B. Circuit — Continuous path along a conductor through which electrical current can flow from a source, through a load, and back to the source

C. Continuity light — A self powered light, used to check for open circuits

(CAUTION: Do not hook into live circuit.)

D. Crimping tool — A tool used to crimp terminals to wires

E. Double filament bulb — Bulb with two lighting elements

F. Gauge — Determines the diameter and the capacity of a wire or cable

(NOTE: The heavier the wire, the smaller the gauge number.)

G. Ground — Uninsulated side of a circuit which is in a vehicle

H. Integrated circuit (IC) — Sealed unit containing resistors, diodes, and transistors

I. Junction block — A multiple connection point for current or ground which can also be used as a test point

J. Jumper wire — Wire, usually with alligator clips, that is used to provide current or ground to an electrical device

K. Polarity — Refers to the grounded battery terminal or to an electrical circuit or to the north and south pole of a magnet

L. Single filament bulb — Bulb with only one lighting element

M. Solder — A tin lead alloy with a low melting point; used to fuse electrical connections

N. Soldering iron — A tool that delivers high temperatures; used to melt solder

O. Switch — A device that opens and closes a circuit

P. Terminal — Type of screw, post, pin, or socket at the end of a wire or cable

Q. Test light — A test instrument used to find current flow
INFORMATION SHEET

R. Wiring diagram (schematic) — Drawing that uses electrical symbols and lines to show electrical circuits

S. Wiring harness — Any system of wires which are taped together for electrical distribution throughout the vehicle

II. Rules for series circuits (Transparency 1)
A. Current through each resistor is the same.
B. Voltage drops across each resistor will be different if the resistance values are different.
C. Sum of the voltage drops equals the source voltage.

III. Rules for parallel circuits (Transparency 2)
A. Voltage across each resistor is the same.
B. Current through each resistor will be different if the resistance values are different.
C. Sum of the separate currents equals the total circuit current.

IV. Rules for series-parallel circuits (Transparency 3)
A. Current in the circuit is equal to the total voltage divided by the total resistance.

(NOTE: Two resistors in a parallel circuit equal the product divided by the sum.)

Example: \[ \frac{2 \times 3}{6 + 3} = 2 \text{ ohms}. \]

B. The resistor in series is calculated first, leaving the remaining voltage equally distributed across the resistors in parallel.

C. Sum of the separate currents in the parallel resistors equals the total circuit current.

V. Basic electrical circuit failures (Transparency 4)
A. Open circuit — Break in an electrical circuit which causes extremely high resistance

(NOTE: Usually, no current will flow through an open circuit.)

B. Shorted circuit — Unwanted connection, usually copper to copper, that allows current to bypass all or part of the circuit
C. Grounded circuit — Unwanted connection that bypasses all or part of the circuit from the insulated side to the grounded side of the circuit

(NOTE: A grounded circuit is usually a copper-to-iron connection.)

D. High resistance circuit — Failure caused by poor or corroded connections or damaged wires which reduces current flow in the circuit

VI. Voltage drop

A. Voltage drop occurs when electricity flows through a resistance.

B. Voltage drop can be measured directly by connecting the voltmeter across the component with the circuit operating.

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(NOTE: To determine if there is high resistance, compare voltmeter reading against specifications.)

C. Voltage drop can be measured by connecting a voltmeter on each end of the component or wire to ground.

(NOTE: The difference between the two readings is the voltage drop.)

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(NOTE: This method is used on long wires where the voltmeter leads are too short.)

D. Voltage drop adds up when connected in series with the load.
INFORMATION SHEET

VII. Types of circuit protection

A. Fuses

(NOTE: Each type fuse has a metal element that is designed to melt (or blow) at a specific current level, opening the circuit and protecting it from damage.)

![Fuse Diagram]

B. Circuit breaker

(NOTE: The circuit offers protection equal to a fuse with the added benefit that it can be used again. Rather than burn open, it has a set of contacts that open when its current rating is exceeded.)

![Circuit Breaker Diagram]
INFORMATION SHEET

C. Fusible links

(NOTE: A fusible link is a short piece of wire that is smaller in diameter than the wire it is connected to. Should a short occur, the link will burn open long before the larger circuit, protecting the rest of the circuit.)

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VIII. Selection of cable for various rewiring needs

A. Cable should be of proper gauge size to handle maximum required electrical loads. (Handout #1)

B. Cable should feature insulating and covering materials which provide the longest cable life possible.

IX. Characteristics of a wiring diagram (Transparency 5, Assignment Sheet #1)

(NOTE: Reading a wiring diagram is something like reading a road map. A road map shows routes that connect one place with another; a wiring diagram shows routes, too. The lines represent actual wires, which are identified by numbers much like highways are identified on a road map.)

A. Lines represent wires.

B. Wires have identification numbers.

C. Wires are color-coded.

D. Components are represented by symbols.

E. Symbols indicate locations of circuits or components in the vehicle.

F. Wiring diagrams are needed by all mechanics.

(NOTE: Because of the constant change in electrical requirements, even experienced mechanics have to rely on wiring diagrams.)
INFORMATION SHEET

X. Parts of a typical circuit identification code

J 2A 18 BL/Y

Main Circuit Identification Color of Wire (Blue with Yellow Stripe)

Part of Main Circuit Gauge of Wire (18 Gauge)

XI. Types of connectors

A. Ring (eyelet)

B. Roll

C. Female snap on

D. Lug

E. Slotted-flange bay

F. Insulated butt

G. Slotted hook

H. Three way
INFORMATION SHEET

i. Male slide

J. Female slide

K. Male plug (bullet)

L. Female plug (bullet connector)

XII. Steps in troubleshooting electrical systems

A. Know the system...
   Example: Study service manual and service bulletins.

B. Ask the operator.
   (NOTE: Often a passing comment by the operator may provide the key to the problem.)

C. Inspect the system.
   (NOTE: Many times the problem can be detected without turning on the switch or starting the machine.)

   Inspection Checklist — Electrical

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bare wires or shorts</td>
<td>□</td>
</tr>
<tr>
<td>Loose wires or opens</td>
<td>□</td>
</tr>
<tr>
<td>Poor connections</td>
<td>□</td>
</tr>
<tr>
<td>Battery electrolyte level</td>
<td>□</td>
</tr>
<tr>
<td>Generating belt tension</td>
<td>□</td>
</tr>
<tr>
<td>Overheated components</td>
<td>□</td>
</tr>
<tr>
<td>Other trouble signs</td>
<td>□</td>
</tr>
</tbody>
</table>

D. Operate the machine if possible.
   (NOTE: Operate all electrical circuits and look for sparks or smoke which might indicate the trouble.)

E. List the possible causes.
INFORMATION SHEET

F. Reach a conclusion.

(NOTE: Scan your list of possible causes to determine the most likely causes and those which are easiest to verify.)

G. Test your conclusion.

(NOTE: Guessing is time-consuming and expensive.)
Series Circuit Rules

A. \( I = \frac{E}{R} \)
   \( = \frac{12}{6} = 2 \text{ Amperes} \)

B. \( E = IR \)
   \( E = 2 \times 2 = 4 \text{ Volts} \)
   \( E = 2 \times 4 = 8 \text{ Volts} \)

C. \( 4 + 8 = 12 \text{ Volts} \)
Parallel Circuit Rules

A. Battery voltage across each resistor = 12 Volts

B. \( I = \frac{E}{R} = \frac{12}{6} \)
   \( = 2 \) Amperes

C. \( I = \frac{6 \text{ Amps}}{R} = \frac{E}{I} \)
   \( = \frac{12}{6} = 2 \) Ohms
**Series-Parallel Circuit Rules**

A. Resistors in parallel
   Resistor in series
   Total resistance
   \[ I = \frac{12}{4} = 3 \text{ amps} \]

B. Resistor in series
   \[ E = IR = 3 \times 2 = 6 \text{ volts} \]
   Resistor in parallel
   \[ 12 - 6 = 6 \text{ volts} \]

C. 6 ohm resistor
   \[ I = \frac{E}{R} = \frac{6}{6} = 1 \text{ amp} \]
   3 ohm resistor
   \[ I = \frac{E}{R} = \frac{6}{6} = 2 \text{ amps} \]
Causes of Electrical Failures

Open Circuit

- Open
- No Electrical Flow

Shorted Circuit

- Short
- Increased Electrical Flow

Grounded Circuit

- Ground
- Increased Electrical Flow
- No Electrical Flow

High Resistance Circuit

- Poor or Loose Connections
- Corroded Connections
- Damaged Wires
- Lost Energy Through Heat
Typical Engine Compartment Wiring Diagram

(Courtesy of Chevrolet Motor Division of General Motors Corporation)
## HANDOUT #1 — WIRE GAUGE RECOMMENDATIONS

### TRACTOR CIRCUITS

Cable gauge recommendations for rewiring

<table>
<thead>
<tr>
<th>CIRCUIT</th>
<th>12-Volt Gauge</th>
<th>6-Volt Gauge</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMMETER TO:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Starter Motor</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>Ignition Switch</td>
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<tr>
<td>Light Switch</td>
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<td>Voltage Reg. (Batt.)</td>
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<td>Horn Relay</td>
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<td>BACK-UP LAMP</td>
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<tr>
<td>BATTERY CABLES (See Note Below)</td>
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<tr>
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<td>Distributor</td>
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<td>DOME LAMP TO:</td>
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<td>Feed</td>
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<td>Direction Indicator Lamps</td>
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<td>Regulator (Field)</td>
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<td>Ground (Regulator)</td>
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<td>HORN RELAY TO:</td>
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<td>Switch</td>
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<td>LIGHT SWITCH TO:</td>
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<td>Tail Lamps</td>
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<td>License Lamp</td>
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<td>Instrument Lights</td>
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<td>TRAILER-CONNECTOR CORD:</td>
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<tr>
<td>7 Conductor</td>
<td>(6/12 and 11/10)</td>
<td></td>
</tr>
<tr>
<td>6 Conductor</td>
<td>16</td>
<td>14</td>
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<tr>
<td>4 Conductor</td>
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<tr>
<td>UNDER HOOD LAMP</td>
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</table>

**NOTE:** Battery Cable — Ampere draw of starter motor depends on many factors. It is advisable to use the same size cable recommended by the vehicle manufacturer.

### Tractor and Trailer Ampere and Candlepower Requirements

<table>
<thead>
<tr>
<th>ELECTRICAL UNIT</th>
<th>12-VOLT UNITS</th>
<th>8-VOLT UNITS</th>
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<tbody>
<tr>
<td></td>
<td>Maximum Amperes</td>
<td>Design Voltage</td>
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<td>12.5</td>
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<tr>
<td>Coil</td>
<td>4.5</td>
<td>14.0</td>
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<td>Directional Signal Lamps</td>
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<td>12.8</td>
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<tr>
<td>Dome Lamps</td>
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<td>Gas Gauge</td>
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<td>Head Lamps — Upper</td>
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<tr>
<td>— Lower</td>
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<td>Horn</td>
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<td>License Lamp</td>
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<td>12.5</td>
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<tr>
<td>Parking Lamps</td>
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<tr>
<td>Spot Lamp</td>
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<td>12.0</td>
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<td>Stop Lamp</td>
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<td>12.8</td>
</tr>
<tr>
<td>Tail Lamp</td>
<td>.8</td>
<td>14.0</td>
</tr>
</tbody>
</table>

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**Handout #1**

- **Front Identification Lamps** (12 ga. brown)
- **Front Top Clearance and Front Top Side-Marker Lamps** (12 ga. black)
- **Hear Top Side-Marker and Rear Top Clearance Lamps** (12 ga. black)
- **Middle Side Marker Lamps** (12 ga. brown)
- **Rear Lower Side-Marker Lamps** (12 ga. brown)
- **R.H. Turn and Disability Lamp** (12 ga. green)
- **Stop Lamp** (12 ga. red)
- **Rear Identification Lamps** (12 ga. brown)
- **Tail and License Lamps** (12 ga. brown)
- **Stop Lamp** (12 ga. red)
- **L.H. Turn and Disability Lamp** (12 ga. yellow)

**Seven Conductor Cord Wiring Diagram**

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**Delco Cable Numbers for Trailer Wiring**

<table>
<thead>
<tr>
<th>Connector Pin No.</th>
<th>Code</th>
<th>Color</th>
<th>Plastic Covered</th>
<th>Insulex</th>
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<tr>
<td>6</td>
<td>954</td>
<td>Brown</td>
<td>812X</td>
<td></td>
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<td>2</td>
<td>954-B</td>
<td>Black</td>
<td>812-BX</td>
<td></td>
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<td>5</td>
<td>954-G</td>
<td>Green</td>
<td>812-GX</td>
<td></td>
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<td>4</td>
<td>954-R</td>
<td>Red</td>
<td>812-RX</td>
<td></td>
</tr>
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<td>7</td>
<td>954-U</td>
<td>Blue</td>
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<td>3</td>
<td>954-Y</td>
<td>Yellow</td>
<td>812-YX</td>
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<tr>
<td>1</td>
<td>954-W</td>
<td>White</td>
<td>812-WX</td>
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Directions: Use the wiring diagram to complete the questions below. List the wire size and color for the following components.

1. Temperature sender switch
2. Oil pressure sender switch
3. Alternator battery wire
4. Headlight ground wire
5. Heater blower motor feed wire

<table>
<thead>
<tr>
<th>Component</th>
<th>Gauge of Wire</th>
<th>Color of Wire</th>
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<tbody>
<tr>
<td>Temperature sender switch</td>
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<td></td>
</tr>
<tr>
<td>Oil pressure sender switch</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alternator battery wire</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Headlight ground wire</td>
<td></td>
<td></td>
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<tr>
<td>Heater blower motor feed</td>
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# ELECTRICAL CIRCUITS
## UNIT II

### ANSWERS TO ASSIGNMENT SHEET

<p>| | | | |</p>
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<tr>
<td>1</td>
<td>20 gauge</td>
<td>Dark green</td>
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<tr>
<td>2</td>
<td>16 gauge</td>
<td>Dark blue</td>
<td></td>
</tr>
<tr>
<td>3</td>
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<td>Black</td>
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</tr>
<tr>
<td>5</td>
<td>14 gauge</td>
<td>Orange</td>
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</table>
ELECTRICAL CIRCUITS
UNIT II

JOB SHEET #1 — CHECK VOLTAGE

A. Tools and materials
   1. Battery
   2. Voltmeter
   3. Appropriate service manual

B. Procedure
   (CAUTION: Remove all jewelry before working on any electrical circuit, and follow all shop safety procedures.)
   1. Connect negative lead from voltmeter to negative (−) battery terminal.
   2. Connect positive lead to positive terminal (+). (Figure 1)

   FIGURE 1

   3. Read voltmeter scale to see if you have battery rated voltage.
   4. Charge battery to its rating before performing any other electrical tests if you don’t have normal battery voltage.
ELECTRICAL CIRCUITS
UNIT II

JOB SHEET #2 — CHECK A CIRCUIT FOR AN OPEN

A. Tools and materials
   1. Circuit board or vehicle
   2. Voltmeter
   3. Ohmmeter
   4. Test light

B. Procedure
   (CAUTION: Remove all jewelry before working on any electrical circuit, and follow all shop safety procedures.)
   1. Check an open circuit using voltmeter.
      a. Connect the circuit to a battery source so current can flow through each component.
      b. Connect voltmeter leads on each side of the component.
c. Read voltmeter.

1) If all the components in a circuit are good, each one will drop a portion of battery voltage. (Figure 1)

FIGURE 1

In a closed circuit, each component drops a portion of source voltage.

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2) If one component burns out and creates an open, it will have battery voltage across its leads. The other components will have zero voltage across their leads. (Figure 2)

FIGURE 2

Source voltage is measured across the open in an open circuit.

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JOB SHEET #2

2. Check an open circuit using an ohmmeter.

   (CAUTION: When an ohmmeter is used to locate an open, the battery must be disconnected. See Figure 3.)

   FIGURE 3

   ![Current flow through an ohmmeter can damage the ohmmeter.]

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   a. Connect the ohmmeter to each side of the component.
   b. Read ohmmeter scale.

   (NOTE: The ohmmeter indicates an open circuit with a reading of infinite resistance.)

3. Check an open circuit using a test lamp.

   a. Connect the clip wire to one terminal of the battery. (Figure 4)
   b. Touch the probe at various points beginning at the other battery terminal.

   (NOTE: Each time the probe touches the circuit between the terminal and the open, its lamp will light. When it goes past the open, the test lamp will no longer light. See Figure 4.)

   FIGURE 4

   ![Locating an open with a test lamp.]

   Reprinted with permission from the Heath Company.
A. Tools and equipment
1. Soldering gun or iron
2. Resin core solder
3. Medium sandpaper
4. Terminal
5. Electrical wire
6. Electrical tape
7. Safety glasses

B. Procedure
1. Strip and of insulation back from wire to permit installation of terminal. (Figure 1)
   (NOTE: Always use the same size wire as originally used by the manufacturer)

   **Figure 1**

   ![Diagram of terminal and wire]

   2. Clean terminal with sandpaper.
3. Place wire in terminal and bend ears of terminal around wire. (Figure 2)

4. Solder terminal to wire. (Figure 3)

(CAUTION: Use only resin core solder on electrical connections.)

5. Tape connection. (Figure 4)

(NOTE: The purpose of the soldering iron is not to melt the solder itself but to heat the parts being soldered to a temperature high enough to melt solder when it is touched to the work.)
ELECTRICAL CIRCUITS
UNIT II

JOB SHEET #4 — INSTALL A SOLDERLESS TERMINAL

A. Tools and equipment
   1. Crimping pliers
   2. Terminal

B. Procedure
   1. Strip insulation from wire to fit terminal. (Figure 1)

FIGURE 1
2. Insert wire into terminal. (Figure 2)

FIGURE 2

(NOTE: Always use the terminal that fits the wire properly.)

3. Crimp the terminal to the wire.

(NOTE: Use the correct crimper opening when crimping the terminal to the wire.)

4. Connect terminal and wire to power source.

(NOTE: Always use the proper size wire when making a repair.)
ELECTRICAL CIRCUITS
UNIT II

JOB SHEET #11E — SPLIC E A WIRE (SOLDER METHOD)

A. Tools and equipment
   1. Soldering gun or iron
   2. Electrical wire
   3. Resin core solder
   4. Electrical tape
   5. Safety glasses

B. Procedure
   1. Strip back insulation one inch (25.4 mm) from ends of wire. (Figure 1)
      FIGURE 1
      Strip Insulation from Wire
      Insulated Wire
      1" (25.4 mm)
      Wire
      Insulated Wire

   2. Intertwine the wire ends together.
   3. Twist the strands together.
   4. Solder the wires. (Figure 2)
      FIGURE 2
      Soldering Gun Tip
      Wire
      Wire
      Splice

   (NOTE: Allow the soldering iron to heat the wire first, then apply solder as shown. Only flow enough solder on splice to hold wire securely. Do not waste solder or build up joint. If splice has too much solder, the splice joint will break.)

   5. Tape splice by wrapping neatly with electrical tape.
ELECTRICAL CIRCUITS
UNIT II

PRACTICAL TEST
JOB SHEET #1 — CHECK VOLTAGE

STUDENT’S NAME ___________________________ DATE __________

EVALUATOR’S NAME ___________________________ ATTEMPT NO. _____

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under “Process Evaluation” must receive a “Yes” for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the “Yes” or “No” blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

1. Checked out proper tools and materials. YES NO
2. Connected voltmeter leads to the battery correctly. ___ ___
3. Read voltmeter scale. ___ ___
4. Checked in/put away tools and materials. ___ ___
5. Cleaned the work area. ___ ___
6. Used proper tools correctly. ___ ___
7. Performed steps in a timely manner (___hrs. ___min. ___sec.) ___ ___
8. Practiced safety rules throughout procedure. ___ ___
9. Provided satisfactory responses to questions asked. ___ ___

EVALUATOR’S COMMENTS: ____________________________________________________

________________________________________________________
JOB SHEET #1 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a “3” for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

<table>
<thead>
<tr>
<th>4</th>
<th>3</th>
<th>2</th>
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Evaluation of battery condition

EVALUATOR'S COMMENTS:

PERFORMANCE EVALUATION KEY

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<th>Score</th>
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<tbody>
<tr>
<td>4</td>
<td>Skilled — Can perform job with no additional training.</td>
</tr>
<tr>
<td>3</td>
<td>Moderately skilled — Has performed job during training program; limited additional training may be required.</td>
</tr>
<tr>
<td>2</td>
<td>Limited skill — Has performed job during training program; additional training is required to develop skill.</td>
</tr>
<tr>
<td>1</td>
<td>Unskilled — Is familiar with process, but is unable to perform job.</td>
</tr>
</tbody>
</table>

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in “Product Evaluation” and divide by the total number of criteria.)
ELECTRICAL CIRCUITS
UNIT II

PRACTICAL TEST
JOB SHEET #2 — CHECK A CIRCUIT FOR AN OPEN

STUDENT'S NAME ___________________________ DATE __________

EVALUATOR'S NAME ___________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the pro-
cedure and complete this form. All items listed under “Process Evaluation” must receive a
“Yes” for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the “Yes” or “No” blanks to designate whether or
not the student has satisfactorily achieved each step in this procedure. If the student is
unable to achieve this competency, have the student review the materials and try again.)

The student:

1. Checked out proper tools and materials. YES NO
2. Checked for an open circuit using a voltmeter. ______ ______
3. Checked for an open circuit using an ohmmeter. ______ ______
4. Checked for an open circuit using a test lamp. ______ ______
5. Checked in/put away tools and materials. ______ ______
6. Cleaned the work area. ______ ______
7. Used proper tools correctly. ______ ______
8. Performed steps in a timely manner (___hrs. ___min. ___sec.) ______ ______
9. Practiced safety rules throughout procedure. ______ ______
10. Provided satisfactory responses to questions asked. ______ ______

EVALUATOR'S COMMENTS: ______________________________________________________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________
JOB SHEET #2 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

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<th>4</th>
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Found the open

EVALUATOR'S COMMENTS:

PERFORMANCE EVALUATION KEY

<p>| | |</p>
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<tr>
<td>4 — Skilled — Can perform job with no additional training.</td>
<td></td>
</tr>
<tr>
<td>3 — Moderately skilled — Has performed job during training program; limited additional training may be required.</td>
<td></td>
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<tr>
<td>2 — Limited skill — Has performed job during training program; additional training is required to develop skill.</td>
<td></td>
</tr>
<tr>
<td>1 — Unskilled — Is familiar with process, but is unable to perform job.</td>
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(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)
ELECTRICAL CIRCUITS
UNIT II

PRACTICAL TEST
JOB SHEET #3 — INSTALL A SOLDERED TERMINAL

STUDENT'S NAME ______________________________
DATE __________________

EVALUATOR'S NAME ______________________________
ATTEMPT NO. _____

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

1. Checked out proper tools and materials. YES NO
2. Stripped end of insulation back from wire. YES NO
3. Cleaned terminal. YES NO
4. Soldered terminal to wire. YES NO
5. Taped connection. YES NO
6. Checked in/put away tools and materials. YES NO
7. Cleaned the work area. YES NO
8. Used proper tools correctly. YES NO
9. Performed steps in a timely manner (_ _ hrs. _ _ min. _ _ sec.) YES NO
10. Practiced safety rules throughout procedure. YES NO
11. Provided satisfactory responses to questions asked. YES NO

EVALUATOR'S COMMENTS: ________________________________________________________________

____________________________________________________________________________________

____________________________________________________________________________________
JOB SHEET #3 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a “3” for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

<table>
<thead>
<tr>
<th>Used correct amount of solder</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connection soldered properly</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

EVALUATOR'S COMMENTS:

PERFORMANCE EVALUATION KEY

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Skilled — Can perform job with no additional training.</td>
</tr>
<tr>
<td>3</td>
<td>Moderately skilled — Has performed job during training program; limited additional training may be required.</td>
</tr>
<tr>
<td>2</td>
<td>Limited skill — Has performed job during training program; additional training is required to develop skill.</td>
</tr>
<tr>
<td>1</td>
<td>Unskilled — Is familiar with process, but is unable to perform job.</td>
</tr>
</tbody>
</table>

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in “Product Evaluation” and divide by the total number of criteria.)
**ELECTRICAL CIRCUITS**  
**UNIT II**

**PRACTICAL TEST**  
**JOB SHEET #4 — INSTALL A SOLDERLESS TERMINAL**

**STUDENT’S NAME** ________________________________  
**DATE** ________________

**EVALUATOR’S NAME** ________________________________  
**ATTEMPT NO.** ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under “Process Evaluation” must receive a “Yes” for you to receive an overall performance evaluation.

**PROCESS EVALUATION**

(EVALUATOR NOTE: Place a check mark in the “Yes” or “No” blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

<table>
<thead>
<tr>
<th>Step Description</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Checked out proper tools and materials.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Stripped insulation from wire.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Selected the correct terminal.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Crimped terminal to wire using the correct crimper opening.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Checked in /put away tools and materials.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Cleaned the work area.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Used proper tools correctly.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Performed steps in a timely manner (___hrs. ___min. ___sec.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Provided satisfactory responses to questions asked.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**EVALUATOR’S COMMENTS:** ________________________________________________________
JOB SHEET #4 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

<table>
<thead>
<tr>
<th>Item</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wire to terminal connection</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Appearance of terminal end</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

EVALUATOR'S COMMENTS:

PERFORMANCE EVALUATION KEY

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Skilled — Can perform job with no additional training.</td>
</tr>
<tr>
<td>3</td>
<td>Moderately skilled — Has performed job during training program; limited additional training may be required.</td>
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<td>2</td>
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</tbody>
</table>

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)
ELECTRICAL CIRCUITS
UNIT II

PRACTICAL TEST
JOB SHEET #5 — SPLICE A WIRE (SOLDER METHOD)

STUDENT'S NAME ___________________________ DATE ____________

EVALUATOR'S NAME _________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

1. Checked out proper tools and materials. YES NO
2. Stripped back insulation. YES NO
3. Intertwined the wire ends together. YES NO
4. Twisted the strands together. YES NO
5. Soldered the wires. YES NO
6. Taped splice with electrical tape. YES NO
7. Checked in/put away tools and materials. YES NO
8. Cleaned the work area. YES NO
9. Used proper tools correctly. YES NO
10. Performed steps in a timely manner (___hrs. ___min. ___sec.) YES NO
11. Practiced safety rules throughout procedure. YES NO
12. Provided satisfactory responses to questions asked. YES NO

EVALUATOR'S COMMENTS: ____________________________

__________________________________________________________________

__________________________________________________________________
JOB SHEET #5 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

<table>
<thead>
<tr>
<th>Criteria</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount of solder used</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Connection soldered</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Appearance of splice</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

EVALUATOR'S COMMENTS:

PERFORMANCE EVALUATION KEY

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
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</table>

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in “Product Evaluation” and divide by the total number of criteria.)
### ELECTRICAL CIRCUITS
### UNIT II

1. Name ___________________________  Score ________________

### TEST

1. Match the terms on the right with their correct definitions.

   (NOTE: Terms and definitions are continued on the following page.)

   - **a.** A device that opens and closes a circuit
   - **b.** Stranded conductor usually covered with insulating material
   - **c.** Sealed unit containing resistors, diodes, and transistors
   - **d.** Drawing that uses electrical symbols and lines to show electrical circuits
   - **e.** Wire, usually with alligator clips, that is used to provide current or ground to an electrical device
   - **f.** A test instrument used to find current flow
   - **g.** A self-powered light, used to check for open circuits.
   - **h.** A multiple connection point for current or ground which can also be used as a test point
   - **i.** Continuous path along a conductor through which electrical current can flow from a source, through a load, and back to the source
   - **j.** Type of screw, post, pin, or socket at the end of a wire or cable
   - **k.** Refers to the grounded battery terminal or to an electrical circuit or to the north and south pole of a magnet
   - **l.** Any system of wires which are taped together for electrical distribution throughout the vehicle
   - **m.** Uninsulated side of a circuit which is in a vehicle

   1. Cable
   2. Circuit
   3. Continuity light
   4. Crimping tool
   5. Double filament bulb
   6. Gauge
   7. Ground
   8. Integrated circuit
   9. Junction block
   10. Jumper wire
   11. Polarity
   12. Single filament bulb
   13. Solder

   **DE-105**
TEST

___n. Bulb with only one lighting element
___o. Bulb with two lighting elements
___p. A tin lead alloy with a low melting point; used to fuse electrical connections
___q. Determines the diameter and the capacity of a wire or cable
___r. A tool that delivers high temperatures; used to melt solder
___s. A tool used to crimp terminals to wires

2. Calculate the voltage drop across each resistor in the following series circuit.

```
2 Ω
Resistor a

+ 2 AMPS
12 V.

Resistor b
```

a. ____________________________  b. ____________________________

3. Calculate the current going through each resistor in the following parallel circuit.

```
Resistor a

+ 6 AMPS
12 V.

Resistor b
```

a. ____________________________  b. ____________________________
4. Calculate the current going through the resistor that is in series, in the following series-parallel circuit.

![Series-parallel circuit diagram]

Answer

5. Match the basic electrical circuit failures on the right with the correct causes.

- a. Break in an electrical circuit which causes extremely high resistance
- b. Unwanted connection, usually copper to copper, that allows current to bypass all or part of the circuit
- c. Unwanted connection that bypasses all or part of the circuit from the insulated side to the grounded side of the circuit
- d. Failure caused by poor or corroded connections or damaged wires which reduces current flow in the circuit

- 1. Grounded circuit
- 2. High resistance circuit
- 3. Open circuit
- 4. Shorted circuit

6. Select true statements concerning voltage drop by placing an "X" beside each statement that is true.

- a. Voltage drop occurs when electricity flows through a resistance.
- b. Voltage drop can be measured directly by connecting the voltmeter across the component with the circuit turned off.
- c. Voltage drop can be measured by connecting a voltmeter on each end of the component or wire to ground.
- d. Voltage drop adds up when connected in series with the load.

7. Name three types of circuit protection.

a. 

b. 

c. 

8. Complete the following statements concerning selection of cable for rewiring needs by inserting the word that best completes each statement.

a. Cable should be of proper ______ size to handle maximum required electrical loads.

b. Cable should feature ______ and covering materials which provide the longest cable life possible.

9. Select from the following list characteristics of a wiring diagram by placing an "X" beside each characteristic.

   _____a. Wiring diagrams are needed only for beginning mechanics.
   _____b. Lines represent wires.
   _____c. Wires have identification numbers.
   _____d. Troubleshooting suggestions are included on the diagram.
   _____e. Wires are color coded.
   _____f. Components are represented by symbols.
   _____g. Symbols indicate locations of circuits or components in the vehicle.

10. Label the parts of the following circuit identification code by filling in the blanks.

   J 2A 18 BI/Y

   Main Circuit Identification  
   Part of Main Circuit 

   a. ________________
   b. ________________ ________________
11. Match the types of connectors on the right with their correct names.

_____a. Three way connector  1. 

_____b. Roll type  2. 

_____c. Female slide connector  3. 

_____d. Female snap-on  4. 

_____e. Insulated butt connector  5. 

_____f. Slotted-flange bay type  6. 

_____g. Lug type  7. 

_____h. Ring type  8. 

_____i. Male slide connector  9. 

_____j. Male plug connector  10. 

_____k. Slotted hook type  11. 

_____l. Female plug connector  12.
TEST

12. Arrange in order the steps to follow in troubleshooting electrical systems by placing the correct sequence number in the proper blank.

____a. Inspect the system.
____b. Reach a conclusion.
____c. Know the system.
____d. Operate the machine.
____e. Ask the operator.
____f. Test your conclusion.
____g. List the possible cause.

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

13. Read a wiring diagram. (Assignment Sheet #1)

14. Demonstrate the ability to:
   a. Check voltage. (Job Sheet #1)
   b. Check a circuit for an open. (Job Sheet #2)
   c. Install a soldered terminal. (Job Sheet #3)
   d. Install a solderless terminal. (Job Sheet #4)
   e. Splice a wire (solder method). (Job Sheet #5)
## ELECTRICAL CIRCUITS
### UNIT II

## ANSWERS TO TEST

1. a. 15     h. 9     o. 5
   b. 1      i. 2     p. 13
   c. 8      j. 16    q. 6
   d. 18     k. 11    r. 14
   e. 10     l. 19    s. 4
   f. 17     m. 7
   g. 3      n. 12

2. a. 4 volts
   b. 8 volts

3. a. 2 amps
   b. 4 amps

4. 3 amps

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

6. a, c, d

7. a. Fuses
   b. Circuit breaker
   c. Fusible links

8. a. Gauge
   b. Insulating

9. b, c, e, f, g

10. a. Color of wire
     b. Gauge of wire

11. a. 9     e. 7     l. 10
    b. 2      f. 6     j. 11
    c. 5      g. 4     k. 8
    d. 3      h. 1     i. 12

12. a. 3     e. 2
     b. 6      f. 7
     c. 1      g. 5
     d. 4

1:3
13. Evaluated to the satisfaction of the instructor
14. Performance skills evaluated to the satisfaction of the instructor
ELECTRICAL INDICATOR CIRCUITS
UNIT III

UNIT OBJECTIVE

After completion of this unit, the student should be able to test gauges, sending units, and indicator light circuits. Competencies will be demonstrated by completing the job sheets and the unit tests with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to electrical circuits with their correct definitions.
2. Match electrical indicator circuits with their correct functions.
3. Name two electric gauge operation designs.
4. Arrange in order the steps in the operation of magnetic gauges.
5. Name three types of sending units.
6. Distinguish between oil pressure and temperature indicator light circuits.
7. Name two types of charging indicator circuits.
8. Demonstrate the ability to:
   a. Test gauges and sending units (tank unit method). (Job Sheet #1)
   b. Test gauges and sending units (grounded wire method). (Job Sheet #2)
   c. Test oil pressure indicator light. (Job Sheet #3)
   d. Test temperature indicator light. (Job Sheet #4)
ELECTRICAL INDICATOR CIRCUITS
UNIT III

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparency from the transparency master included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information sheet.

F. Discuss information sheet.

(NOTE: Use the transparency to enhance the information as needed.)

G. Provide students with job sheets.

H. Discuss and demonstrate the procedures outlined in the job sheets.

I. Integrate the following activities throughout the teaching of this unit:

1. Give students a wiring diagram and have them trace the indicator circuits.

2. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.

REFERENCES USED IN DEVELOPING THIS UNIT


SUGGESTED SUPPLEMENTAL RESOURCES

A. Text

*Automotive Electronics and Electrical Equipment*, 9th ed.
Order #014831-7
Gregg/McGraw-Hill
P.O. Box 996
Norcross, GA 30091
(404) 449-1837

B. Filmstrip

*Basic Troubleshooting and Repair of Automotive Electrical Components*
Order #B-481
3 cassettes, 3 filmstrips, study guide
Teaching Aids Incorporated
P.O. Box 1798
Costa Mesa, CA 92628-0798
ELECTRICAL INDICATOR CIRCUITS
UNIT III

INFORMATION SHEET

I. Terms and definitions
   A. Gauge — Instrument with a graduated scale
   B. Indicator light — A light in the dash that indicates a problem in the system
   C. Pyrometer — A sensitive voltmeter that measures exhaust temperature
   D. Sending unit (sender) — Variable resistor that controls the current flowing through the gauge which affects needle movement

II. Electrical indicator circuits
   (NOTE: Gauges and indicating lights are used in various combinations.)
   A. Fuel indicator circuit — Gauge and tank unit to indicate the quantity of fuel in the tank
   B. Temperature indicator circuit — Dash panel and engine unit to indicate the temperature of the engine coolant or engine oil
   C. Oil pressure indicator circuit — Dash panel and engine unit to indicate engine oil pressure
   D. Charging indicator circuit — Dash panel unit to indicate alternator charging rate

III. Electric gauge operation design
   A. Variable voltage
      
      Key Switch
      
      Ammeter
      
      Gauge
      
      Operating
      
      Coll
      
      Batter
      
      Starter
      
      Switch
      
      Limiting
      
      Coll
      
      Connector
      
      Partly Full
      
      Position
      
      Float
      
      Empty Position
      
      Sender
      
      Reprinted from MOTOR Auto Engines & Electrical Systems
      © 1970 by permission of The Heartt Corporation.
      
      (NOTE: Current is directed from the ammeter to the key switch, to the gauge, to the sender, and then to ground.)
INFORMATION SHEET

B. Constant voltage

![Circuit Diagram]

(Note: Current flow is the same as in the variable voltage design. The voltage regulator is to regulate the variable (input) voltage from the ammeter, to produce a constant 5.0 volts output to the gauges.)

IV. Operation of the fuel, temperature, and oil pressure magnetic gauges

(Note: The following procedures apply to AC, Auto-Lite and Stewart-Warner variable voltage systems.)

A. Current from the battery passes through the limiting coil to the common connection between the two coils.
INFORMATION SHEET

B. Current can take two paths, one through the operating coil of the gauge and the other through the wire to the sending unit.

C. With low resistance in the sending unit, only a small amount of current flows through the operating coil.

(Note: With more current going through the limiting coil, it becomes magnetically stronger and the needle is pulled to the left.)
INFORMATION SHEET

D. With high resistance in the sending unit, more current will pass through the operating coil.

(NOTE: As the magnetic strength of the operating coil increases, the needle is pulled to the right.)

V. Sending units

A. Fuel

1. When the tank is empty, or the fuel supply is low, the sliding brush has moved to eliminate all resistance in the sending unit.
INFORMATION SHEET

2. When the tank is full, a higher fuel level moves the sliding brush along the rheostat, increasing the resistance.

B. Oil pressure (Transparency 1)

1. When the oil pressure is low, the diaphragm moves the sliding contacts a small distance causing a small amount of resistance.
INFORMATION SHEET

2. When the oil pressure is higher, the diaphragm is flexed more, causing higher resistance.

---

C. Temperature

1. The element in the sending unit has a high resistance value when cold and a low resistance value when hot.
INFORMATION SHEET

2. As the sending unit heats, its lowered resistance allows more current to flow through the operating coil thus pulling the needle to the high or "HOT" side of the scale.

VI. Operation of the oil pressure and temperature indicator light circuits

A. Oil pressure (Transparency 1)

1. The light is wired in series with the ignition switch and the sending unit.

   (NOTE: The sending unit contains a diaphragm and a set of contacts.)

2. When the ignition switch is turned on, current goes through the light and through the closed contacts.

3. When the engine is started, build-up of oil pressure compresses the diaphragm, opening the contacts, thereby breaking the circuit and putting out the light.

B. Temperature

1. A bimetallic sensing switch is connected in series with an incandescent lamp, mounted on the instrument panel and excited by the battery.

2. Under normal conditions the lamp remains off.

   (NOTE: As a test circuit, when the ignition is in "start" position, the red bulb will be lit if it is functioning properly)

3. If the water temperature should reach a point where the engine approaches an overheated condition, the red light will be turned on by the sending unit (temperature switch).
VII. Charging Indicator Circuits

A. Indicator Light

1. Terminal #1 of the voltage regulator is connected with the parallel indicator lamp and resistor to the key switch.

2. With the key switch on, current flows from the battery through the switch, the resistor, and light indicator to #1 terminal and onto junction Y, causing the indicator lamp to burn. (Figure 1)

3. When the alternator starts charging, current flows through the diode trio to junction Y.

4. When the voltage at junction Y equals battery voltage, the indicator lamp will go out. (Figure 2)

B. Ammeter

1. When current is flowing from the charging system into the battery, the pointer will be in the charge direction.

2. When the battery takes over the electrical system's load, current flows in the opposite direction, and the pointer is drawn into the discharge direction.
Electrical Oil Pressure Indicating Systems

Electromagnetic Coil System for Indicating Oil Pressure

Pressure Switch System for Indicating Oil Pressure
ELECTRICAL INDICATOR CIRCUITS
UNIT III

JOB SHEET #1 — TEST GAUGES AND SENDING UNITS
(TANK UNIT METHOD)

A. Tools and materials
   1. Vehicle
   2. Basic hand tool set
   3. Test light or voltmeter
   4. Fuel sending unit
   5. Appropriate service manual

B. Procedure
   (NOTE: The following procedure is in lieu of using a commercial gauge tester.)
   1. Use a spare fuel gauge tank unit known to be correct.
   2. Disconnect the wire at the gauge which leads to the sending unit. This will test whether the gauge (fuel, oil, or temperature) is functioning.
   3. Attach a wire lead from the gauge terminal to the terminal of the spare sending unit. (Figure 1)

FIGURE 1

Reprinted from MOTOR Auto Engines & Electrical Systems
© 1970 by permission of The Hearst Corporation.
JOB SHEET #1

4. Ground the spare sending unit to an unpainted portion of the dash panel and move the float arm.

5. If the gauge operates correctly, the sending unit or wiring is defective.

6. If the gauge does not operate during this test, the gauge or the voltage going to the gauge is defective.

7. If the gauge registers full scale all the time when the key switch is on, grounded wire or sending unit is at fault.
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ELECTRICAL INDICATOR CIRCUITS
UNIT III

JOB SHEET #2 — TEST GAUGES AND SENDING UNITS
(GROUNDED WIRE METHOD)

A. Tools and materials

1. Vehicle
2. Basic hand tool set
3. Test light or voltmeter
4. Appropriate service manual

B. Procedure

(NOTE: The following procedure applies to variable voltage systems.)

1. Turn on key switch.
2. Remove wire connected at sending unit in question (fuel, oil, or temperature).
3. Momentarily ground wire by holding it against a clean, unpainted portion of engine, vehicle body, or frame. (Figure 1)

FIGURE 1

4. Read the gauge pointer which should indicate a full scale reading within 30 seconds.

(NOTE: Some oil pressure gauges will indicate zero instead of a full scale reading.)

5. If the gauge indicates a full scale reading, check
   a. For a bad connection at the sending unit, and repair it.
b. For defective sending unit and replace if needed. (Figure 2)

(NOTE: Both a. and b. could be at fault.)

FIGURE 2

6. If during the test the gauge does not indicate a full scale reading,
   a. Repair faulty voltage at the switch terminal of the gauge.
   b. Replace or repair faulty lead wire between gauge and sending unit.
   c. Replace defective gauge. (Figure 3)

FIGURE 3
ELECTRICAL INDICATOR CIRCUITS
UNIT III

JOB SHEET #3 — TEST OIL PRESSURE INDICATOR LIGHT

A. Tools and materials
   1. Vehicle
   2. Basic hand tool set
   3. Test light or voltmeter
   4. Appropriate service manual

B. Procedure
   1. Watch for oil pressure warning light when the key is turned on.
   2. If it does not light, disconnect the wire from the sending unit, and ground the wire to the frame or cylinder block. (Figure 1)

FIGURE 1

3. If the warning still does not light, check
   a. For voltage in wire coming from bulb to sending unit.
   b. Bulb.
   c. For voltage from key switch to bulb.

4. If the warning light goes on when the wire is grounded, the sending unit should be checked for looseness or poor grounding.
5. If the sending unit is found to be tight and properly grounded, it should be replaced.

6. If the light remains lit when engine is running, check for
   a. Grounded wire between bulb and sending unit.
   b. Bad sending unit. (Figure 2)

**FIGURE 2**

![Diagram of indicator light bulb and oil pressure sending unit](image.png)
ELECTRICAL INDICATOR CIRCUITS
UNIT III

JOB SHEET #4 — TEST TEMPERATURE INDICATOR LIGHT

A. Tools and materials
   1. Vehicle
   2. Test light or voltmeter
   3. Basic hand tool set
   4. Appropriate service manual

B. Procedure
   1. Put key in “start” position to see if red light comes on. If it doesn’t, ground the wire going to sending unit.
   2. Turn key switch back to “start” position, and if the light is lit, replace sending unit.
   3. If light stays off, check for
      a. Voltage of wire going from light to sending unit.
      b. Bad bulb.
      c. Voltage going to the switch side of the bulb.
   4. Repair or replace when necessary.
   5. If the light stays lit all the time, unplug wire going to sending unit.
   6. If the light goes out, replace sending unit.
   7. If the light still stays on, check for a ground in the wire going from the bulb to the sending unit.
ELECTRICAL INDICATOR CIRCUITS
UNIT III

PRACTICAL TEST
JOB SHEET #1 — TEST GAUGES AND SENDING UNITS
(TANK UNIT METHOD)

STUDENT'S NAME ___________________________ DATE __________

EVALUATOR'S NAME ___________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

1. Checked out proper tools and materials. YES NO
2. Disconnected the wire going to the sending unit. 
3. Connected the spare sending unit correctly.
4. Operated the float on the sending unit.
5. Determined which component was at fault.
6. Checked in/put away tools and materials.
7. Cleaned the work area.
8. Used proper tools correctly.
9. Performed steps in a timely manner (hrs. min. sec.) 
11. Provided satisfactory responses to questions asked.

EVALUATOR'S COMMENTS: ____________________________________________

__________________________________________
JOB SHEET #1 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

<table>
<thead>
<tr>
<th></th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test was performed in proper sequence.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Problem was found and corrected.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

EVALUATOR'S COMMENTS: ____________________________

<table>
<thead>
<tr>
<th>PERFORMANCE EVALUATION KEY</th>
</tr>
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<tbody>
<tr>
<td>4 — Skilled — Can perform job with no additional training.</td>
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</tr>
<tr>
<td>1 — Unskilled — Is familiar with process, but is unable to perform job.</td>
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(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)
ELECTRICAL INDICATOR CIRCUITS
UNIT III

PRACTICAL TEST
JOB SHEET #2 — TEST GAUGES AND SENDING UNITS
(GROUNDED WIRE METHOD)

STUDENT'S NAME ________________________________ DATE __________
EVALUATOR'S NAME ______________________________ ATTEMPT NO. _____

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under “Process Evaluation” must receive a “Yes” for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the “Yes” or “No” blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

<table>
<thead>
<tr>
<th></th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Checked out proper tools and materials.</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Turned on key switch.</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Grounded wire going to sending unit.</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Checked connection at sending unit and replaced if needed.</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Checked voltage at the switch terminal.</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Checked lead wire to the sending unit.</td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>Replaced gauge if needed.</td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>Checked in/put away tools and materials.</td>
<td></td>
</tr>
<tr>
<td>9.</td>
<td>Cleaned the work area.</td>
<td></td>
</tr>
<tr>
<td>10.</td>
<td>Used proper tools correctly.</td>
<td></td>
</tr>
<tr>
<td>11.</td>
<td>Performed steps in a timely manner (____hrs. ____min. ____sec.)</td>
<td></td>
</tr>
<tr>
<td>13.</td>
<td>Provided satisfactory responses to questions asked.</td>
<td></td>
</tr>
</tbody>
</table>

EVALUATOR'S COMMENTS: ____________________________________________
JOB SHEET #2 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

EVALUATOR'S COMMENTS: _________________________________

PERFORMANCE EVALUATION KEY

<table>
<thead>
<tr>
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<td>3</td>
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(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)
ELECTRICAL INDICATOR CIRCUITS
UNIT III

PRACTICAL TEST
JOB SHEET #3 — TEST OIL PRESSURE INDICATOR LIGHT

STUDENT'S NAME ___________________________ DATE ____________

EVALUATOR'S NAME ___________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

1. Checked out proper tools and materials. YES NO
2. Turned on key switch. YES NO
3. Grounded sending unit wire. YES NO
4. Checked voltage of sending unit wire. YES NO
5. Checked bulb. YES NO
6. Checked voltage in wire going from switch to wire. YES NO
7. Replaced sending unit if needed. YES NO
8. Looked for grounded wire between bulb and sending unit. YES NO
9. Replaced sending unit if needed. YES NO
10. Checked in/put away tools and materials. YES NO
11. Cleaned the work area. YES NO
12. Used proper tools correctly. YES NO
13. Performed steps in a timely manner (___hrs. ___min. ___sec.) YES NO
14. Practiced safety rules throughout procedure. YES NO
15. Provided satisfactory responses to questions asked. YES NO

EVALUATOR'S COMMENTS: __________________________________________

__________________________________________
JOB SHEET #3 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

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</thead>
</table>

Test was performed in proper sequence.

<table>
<thead>
<tr>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
</table>

Problem was found and corrected.

EVALUATOR’S COMMENTS: ________________________________

______________________________

PERFORMANCE EVALUATION KEY

| 4 — Skilled — Can perform job with no additional training. |
| 3 — Moderately skilled — Has performed job during training program; limited additional training may be required. |
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(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)
ELECTRICAL INDICATOR CIRCUITS
UNIT III

PRACTICAL TEST
JOB SHEET #4 — TEST TEMPERATURE INDICATOR LIGHT

STUDENT'S NAME ___________________________ DATE __________

EVALUATOR'S NAME _________________________ ATTEMPT NO. _____

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under “Process Evaluation” must receive a “Yes” for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the “Yes” or “No” blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

1. Checked out proper tools and materials. YES NO
2. Turned the key switch to “start” position. YES NO
3. Grounded wire going to sending unit. YES NO
4. Turned key switch back to “start” position and replaced sending unit if needed. YES NO
5. Checked voltage of wire going from light to sending unit. YES NO
6. Checked bulb. YES NO
7. Checked voltage going to the switch side of the bulb. YES NO
8. Unplugged wire going to sending unit if necessary. YES NO
9. Replaced sending unit if needed. YES NO
10. Checked for a ground in the wire going from the bulb to the sending unit. YES NO
11. Checked in/put away tools and materials. YES NO
12. Cleaned the work area. YES NO
13. Used proper tools correctly. YES NO
14. Performed steps in a timely manner (___hrs. ___min. ___sec.) YES NO
15. Practiced safety rules throughout procedure. YES NO
16. Provided satisfactory responses to questions asked. YES NO

EVALUATOR’S COMMENTS: ____________________________________________

________________________________________

________________________________________

________________________________________
JOB SHEET #4 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

Test was performed in proper sequence.

Problem was found and corrected.

EVALUATOR'S COMMENTS:

PERFORMANCE EVALUATION KEY

<table>
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<tr>
<th>Score</th>
<th>Description</th>
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ELECTRICAL INDICATOR CIRCUITS
UNIT III

TEST

1. Match the terms on the right with their correct definitions.

   a. Instrument with a graduated scale
   1. Gauge

   b. A sensitive voltmeter that measures exhaust temperature
   2. Indicator light

   c. Variable resistor that controls the current flowing through the gauge which affects needle movement
   3. Pyrometer

   d. A light in the dash that indicates a problem in the system
   4. Sending unit

2. Match the electrical indicator circuits with their correct functions.

   a. Gauge and tank unit to indicate the quantity of fuel in the tank
   1. Charging indicator circuit

   b. Dash panel and engine unit to indicate the temperature of the engine coolant or engine oil
   2. Fuel indicator circuit

   c. Dash panel and engine unit to indicate engine oil pressure
   3. Oil pressure indicator circuit

   d. Dash panel unit to indicate alternator charging rate
   4. Temperature indicator circuit

3. Name two electric gauge operation designs.

   a. 

   b. 

142
4. Arrange in order the steps in the operation of magnetic gauges by placing the correct sequence number in the appropriate blank.

   a. With low resistance in the sending unit, only a small amount of current flows through the operating coil.
   b. Current from the battery passes through the limiting coil to the common connection between the two coils.
   c. With high resistance in the sending unit, more current will pass through the operating coil.
   d. Current can take two paths, one through the operating coil of the gauge and the other through the wire to the sending unit.

5. Name three types of sending units.

   a. ____________________________
   b. ____________________________
   c. ____________________________

6. Distinguish between oil pressure and temperature indicator light circuits by placing an "O" next to the operation of the oil pressure and a "T" next to the operation of the temperature circuits.

   a. When the ignition switch is turned on, current goes through the light and through the closed contacts.
   b. If the water temperature should reach a point where the engine approaches an overheated condition, the red light will be turned on by the sending unit.
   c. When the engine is started, build-up of oil pressure compresses the diaphragm, opening the contacts, thereby breaking the circuit and putting out the light.
   d. Under normal conditions the lamp remains off.
   e. A bimetallic sensing switch is connected in series with an incandescent lamp, mounted on the instrument panel, and excited by the battery.
   f. The light is wired in series with the ignition switch and the sending unit.
TEST

7. Name two types of charging indicator circuits.
   a. ____________________________________________________________
   b. ____________________________________________________________

   (NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

8. Demonstrate the ability to:
   a. Test gauges and sending units (tank unit method). (Job Sheet #1)
   b. Test gauges and sending units (grounded wire method). (Job Sheet #2)
   c. Test oil pressure indicator light. (Job Sheet #3)
   d. Test temperature indicator light. (Job Sheet #4)
ELECTRICAL INDICATOR CIRCUITS
UNIT III

ANSWERS TO TEST

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

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

3.  a.  Variable voltage
    b.  Constant voltage

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

5.  a.  Fuel
    b.  Oil pressure
    c.  Temperature

6.  a.  O   d.  T
    b.  T   e.  T
    c.  O   f.  O

7.  a.  Ammeter
    b.  Indicator light

8.  Performance skills evaluated to the satisfaction of instructor
STORAGE BATTERIES
UNIT IV

UNIT OBJECTIVE

After completion of this unit, the student should be able to troubleshoot and service a battery. Competencies will be demonstrated by completing the job sheets and the unit tests with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to storage batteries with their correct definitions.
2. List three functions of a battery.
3. Identify two types of batteries.
4. Distinguish between the characteristics of batteries.
5. Complete statements concerning the voltage ratings of batteries.
6. Distinguish between ways of rating battery capacity.
7. Complete statements concerning rules for installing batteries.
8. Draw lines showing the installation of battery cables for different volt batteries.
9. Identify types of battery terminal constructions.
10. Select from a list safety rules to be observed during the care and maintenance of batteries.
OBJECTIVE SHEET

11. Demonstrate the ability to:

a. Troubleshoot a battery. (Job Sheet #1)

b. Remove, service, and replace battery. (Job Sheet #2)

c. Measure specific gravity of a conventional battery. (Job Sheet #3)

d. Load test a battery. (Job Sheet #4)

e. Charge test a battery for three minutes. (Job Sheet #5)
STORAGE BATTERIES
UNIT IV

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(Note: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information sheet and handouts.

F. Discuss information sheet and handouts.

(Note: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheets.

H. Discuss and demonstrate the procedures outlined in the job sheets.

I. Integrate the following activities throughout the teaching of this unit:

1. Demonstrate the use of a battery charger.

2. Show film on heavy duty batteries.

3. Cut an old battery in half to demonstrate battery construction.

4. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.

REFERENCES USED IN DEVELOPING THIS UNIT


REFERENCES USED IN DEVELOPING THIS UNIT


SUGGESTED SUPPLEMENTAL RESOURCES

A. Texts

1. Automotive Diagnosis and Tuneup by James A. Johnson
   Gregg/McGraw-Hill
   13955 Manchester Road
   Manchester, MO 63011

2. Delco Remy Service Manual No. 1.2
   AC-Delco, GMC
   400 Renaissance Center
   Detroit, MI 48202

B. Filmstrips

1. Heavy Duty Batteries
   AC-Delco, GMC
   General Motors Building
   Detroit, MI 48202

2. Sift Truck Battery Servicing
   17 Minutes
   3/4" U-matic cassette
   Part No. CEVS 7525
   (NOTE: Order from your nearest Caterpillar dealer)
STORAGE BATTERIES
UNIT IV
INFORMATION SHEET

I. Terms and definitions

A. Battery — Two or more connected cells which convert chemical energy into electrical energy (Transparency 1)

B. Cell — One positive plate group and one negative plate group (Transparency 1)

   (NOTE: Each cell produces approximately 2 volts.)

C. Electrolyte — Solution of water and sulfuric acid

D. Hydrometer — A test instrument for determining the specific gravity of electrolyte

E. Plate group — Similar plates welded to a plate strap (Transparency 1)

F. Specific gravity — Weight of electrolyte compared to an equal volume of water at 60°F

G. Sulfated — Oxidation of positive plate grid wires and formation of lead sulfate crystals which become dense and hard

   (NOTE: A sulfated condition is caused by long storage without recharging. A slow charge may or may not restore the battery.)

II. Functions of a battery

A. Supplies current for cranking the engine

B. Supplies current when the demand exceeds the output of the charging system

C. Stabilizes the voltage in the system during operation

III. Types of batteries

A. Conventional (Transparency 1)

B. Maintenance free (Transparency 2)
INFORMATION SHEET

IV. Characteristics of batteries

A. Conventional
   1. Vent caps are used for each cell.
   2. Electrolyte level has to be checked and water added to each cell.

B. Maintenance free
   1. Lifetime supply of electrolyte
   2. Less gassing and corrosion
   3. Longer shelf life
   4. Some have built-in hydrometer
   5. Withstand more vibration
   6. Resist overcharging

V. Voltage ratings of batteries

A. 6-volt has 3 cells.

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INFORMATION SHEET

B. 12-volt has 6 cells.

Reprinted with permission of Delco Remy Division, GM Corp.

(Note: 6 and 12 volt batteries could be either conventional or maintenance free.)

VI. Ways of rating battery capacity

A. Amp-hour rating — Capacity rated according to quantity of electricity that can be taken from a fully charged battery over a definite period of time.

Example: Battery rated at 100 amp-hour should deliver 5 amps continuously for 20 hours.

B. Cold cranking amps — Number of amps that can be taken from a fully charged battery at 0°F for 30 seconds.

Example: A battery rated at 900 cold cranking amps can produce 900 amps for 30 seconds at 0°F.

VII. Rules for installing batteries

A. Install only fully charged batteries.

B. Do not install a new battery alongside older batteries.

C. Do not install batteries of different capacities.

D. Check polarity of the vehicle before installing the batteries.

(Note: The ground may be to the positive or negative terminal.)
VIII. Installation of battery cables

A. 6-volt batteries

1. 12-volt system

(Note: When connecting positive terminals to positive terminals and negative terminals to negative terminals, amperage will increase, but voltage will stay the same.)
INFORMATION SHEET

2. 24-volt system

(Note: When connecting positive terminals to negative terminals, amperage will stay the same, and voltage will stay the same.)

IX. Types of battery terminal constructions

A. Battery post terminals

B. Bolt-type side terminals

Reprinted with permission of Delco Remy Division, GM Corp.
INFORMATION SHEET

C. Stainless steel stud terminals

X. Safety rules to be observed during the care and maintenance of batteries

A. Wear safety glasses, rubber gloves, and rubber apron when servicing batteries.

B. Electrolyte must not be allowed to come in contact with clothing, skin, eyes, or painted surfaces.

C. Flush immediately with water any area of skin which acid has contacted.

D. Flames or sparks can cause gases given off by battery to explode.
   (NOTE: Gases given off are hydrogen and oxygen.)

E. Avoid shorting or grounding battery terminals during service.

F. Avoid breathing fumes from a battery that is being charged.

G. Leave charger in the "off" position when connecting and disconnecting batteries.
Maintenance-Free Battery

- State-Of-Charge Indicator
- Heat-Sealed Covers
- Stainless Steel Terminals
- Finger Grips
- Liquid/Gas Separator
- Plate Straps and Terminals
- Extrusion-Fusion Intercell Connection
- Epoxy-Anchored Plate Element
- Separator Envelope
- Element On Flat Case Bottom

Hydrometer

Terminals
DE-163

STORAGE BATTERIES
UNIT IV
HANDOUT #1 - COLD CRANKING AMPS FOR
MAINTENANCE-FREE BATTERIES
5.

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90
95

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425
370
475
526

180

75

90
95

370
475
525
400
475

SCI

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Amps
for
Load

(Mn.

SVO'F.

@ -201

( - I rc)

( -21Pc)

tin Amps.) (in Amps.)

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21
21

22F-50
22F-60
24-40
24-50
24-60

22F
22F
24
24
24

12

24F-40 24F
24F-50 24F
24F-60 24F
M24MF 24
C24MF 24

12
12
12

12
12

230
260
200
230

25-60
25R-60
26-40S
26-50S
26-60

25
25R
26
26
26

12
12

310
310

100
100

12
12

180

220

80
70

12

200

70

625
625
370
440
410

26-80S
28R-405
26R-50S
26R-60S
27-50

26
26R
26R
26R

12

27

12

260
180
220
260
220

80
60
70
80
90

525
370
440
525
440

27-60
27F-50
27F-60
27FMF
27MF

27

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12
12
12

290
220
290
270
270

110
90
110
160
160

500
440
580
550
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M27MF

27

31HCT
31-750

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31

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510
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390
410
500

180
250
250
130
150

80

370

125
125

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500
275
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27F
27F
21
27

31-900
34-60

34

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12
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12

41-50
41-60
42-50
45-50
46-5E

41
41

49-4
49.5
49-5E
49-30
49-40

24F
24F
24F
24F
24F

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12

4F,.-50

49-50A
49-60
54-5
55.4

24F
49
24F
22F
22F

12
12
12
12
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55-5
55-5E
55-30
55-40
55-50

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22F
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22F
55
22F
55

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55-60
55-60S
58.4A
50-5

42
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....

12
12

12

370'
450'
250

190
200

250

7,

11.

MAXIMUM
DIMENSIONS
(MM/IN)

APPROX.
WEIGHT
KO/LBS

14.
ELECTROLYTE
REOD.

LITERion

Reserve

21-60
21-72
21R-60
21R-72
22F-40

21R
22F

6.

80
80

125

90

60
75

8. Length
(Ind
flanges)

9.

10. Highl

MCI Top

12.

13.

Wet

Dry

Width

Post)

206/8.1
206/8.1
206/8.1
206/8.1
229/9.0

172/6.8
172/6.8
172/6.8
172/6.8
172/6.8

222/8.8
222/8.8
222/8.8
222/8.8
210/8.3

15.4/34
15.1/33
15.4/34
15.5/35
13.0/29

230/9.1
240/9.5
260/10.4
280/10.2
260/10.2

172/6.8
172/6.8
172/6.8
172/6.8
172/6.8

210/8.3
210/8.3
222/8.8
222/8.8
222/8.8

13.3/29

270/10.6
270/10.6
270/10.6
260/10.2
260/10.2

172/6.8
172/6.8
172/6.8
172/6.8
172/6.8

222/8.8
222/8.8
222/8.8
194/7.6
194/7.6

15.2/33
16.5/36
17.9/39
19.9/44
16.4/36

260/10.2
260/10.2
206/8.1
206/8.1
206/8.1

172/6.8
172/6.8
172/6.8
172/8.8
172/6.8

222/8.8
222/8.8
202/8.0
202/8.0
202/8.0

18.0/40
18.0/40
12.3/27
12.4/27
13.4/29

206/8.1
206/8.1
206/8.1
206/8.1
305/12.0

172/6.8
172/6.8
172/6.8
172/6.8
172/6.8

202/8.0
202/8.0
202/8.0
202/8.0
222/8.8

13.8/30
12.3/27
12.4/27
13.8/30
18.2/40

305/12.0
315/12.4
315,12.4
305/12.0
321/12.8

172/6.8
172.6.8
172.6.8
172/6.8
172/6.8

222/8.8
222/8.8
222/8.8
222/8,8
222/8.8

19.6/43
10.2/40
19.6/43
23.6/52
23.5/62

320/12.5
330/13.0
330/13.0
330/13.0
260/10.3

172/6.8
172/6.A
172/6.8
172/6.8
172/6.8

222/8.8
238/9.4
238/9.4
230/9.4
240/9.4

23.5/52
25.7/57
24.5/54
25.2/55
25.0/55

195

292/11.5
292/11.5
229/9.0
228/8.9
270/10.6

172/6.8
172/6.8
172/6.8
140/5.5
172/6.8

173/6.8
173/6.8
222/8.8
218/8.6
222/8.8

18.3/36
17.7/39
18.0/40
12.3/27
19.0/42

290
395
395
210
230

270/10.6
270/10.6
270/10.6
270/10.6
270/10.6

172/6.8
172/6.8
172/6.8
172/6.8
172/6.8

222/8.8
222/8.8
222/8.8
222/8.8
222/8.8

17.1/38
19.5/43
19.5/43
15.8/35
16.0/35

-

172/6.8
174/6.8
172/6.8
172/6.8
172/6.8

222/8.6
168/6.7
222/8.8
210/8.3
210/8.3

17.1/38
NA
19.5/43
15.6/34
14.3/32

-----------------

315

14.3/31

15.1/33
16.5/36
18.0/40

370
630

290

90

505
400

395
300

70

310

220

270/10.6
381/15.0
270/10.6
240/9.4
240/9.4

90
90

405
405
285
280

300
300
200
225
220

240/9.4
240/9.4
240/9.4
240/9.4
240/9.4

172/6.8
172/6.8
172/0.8
172/6.8
172/6.8

210/8.3
210/8.3
210/8.3
210/8.3
210/8.3

15.6/34
15.6/34
13.8/30
1 (.8/30
14.3/32

212/8.3
240/9.4
225/8.9
260/10.2
260/10.2

154/6.0
172/6.8
154/6.0
172/6.8
172/6.8

218/8.6
210/8.3
212/8.4
222/8.8
222/8.8

NA
15.6/34

180

80

310
250

155
125

200
150

12
12
12
12
12

200
200
130
140
150

210
200
260

75

24

12
12
12
12

180

BO

24

12

250

125

60
65
70

90
80

310
430
405
525
370
500

-

300

--

290
395

1 GO

'1.4/29
.6.8/37
19.5/43


# HANGOUT #1

FREE DOMESTIC BATTERY TEST SPECIFICATIONS

<table>
<thead>
<tr>
<th>Cat No</th>
<th>D.C. Size</th>
<th>12V Volts</th>
<th>Reserve Capacity</th>
<th>Cold cranking current</th>
<th>Max. Length</th>
<th>Approx. Weight</th>
<th>Electrolyte</th>
<th>Reserves</th>
</tr>
</thead>
<tbody>
<tr>
<td>58-5A</td>
<td>24</td>
<td>120</td>
<td>212</td>
<td>125</td>
<td>45</td>
<td>208/10.2</td>
<td>172/6.8</td>
<td>229/8.8</td>
</tr>
</tbody>
</table>

- **Cold cranking current** is typically measured in **amps**.
- **Max. Length** refers to the maximum length of the battery in inches.
- **Approx. Weight** is given in **pounds**.
- **Electrolyte** is a measure of the battery's ability to retain charge.
- **Reserves** indicate how much reserve capacity the battery has.

These specifications are crucial for ensuring that the battery can meet the demands of the vehicle and maintain performance under various conditions.
# FREEDOM BATTERY TEST SPECIFICATIONS

<table>
<thead>
<tr>
<th>Cat No</th>
<th>SAE BCI Size</th>
<th>Amps for 5 sec Test</th>
<th>Cold Cranking Current</th>
<th>Cold Cranking Current SAE Spec</th>
<th>Maximum Dimensions (IN/CM)</th>
<th>Approx Weight K/G</th>
<th>Electrolyte Required Liter(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>87-50</td>
<td>73</td>
<td>12 180 80 830</td>
<td>229/9.0 177/7.0</td>
<td>213/8.4 15.8/35</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>87-60</td>
<td>73</td>
<td>12 210 100 430</td>
<td>229/9.0 177/7.0</td>
<td>213/8.4 17.1/38</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>87A-6</td>
<td>73</td>
<td>12 230 115 465</td>
<td>229/9.0 177/7.0</td>
<td>213/8.4 15.5/33</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>88A-5</td>
<td>74</td>
<td>12 230 125 465 375</td>
<td>229/9.0 177/7.0</td>
<td>213/8.4 15.5/43</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>89-4</td>
<td>74</td>
<td>12 180 80 370 290</td>
<td>229/9.0 177/7.0</td>
<td>213/8.4 17.0/37</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>89-5</td>
<td>74</td>
<td>12 250 125 500 395</td>
<td>229/9.0 177/7.0</td>
<td>213/8.4 19.5/33</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>89-5E</td>
<td>74</td>
<td>12 130 60 275 210</td>
<td>229/9.0 177/7.0</td>
<td>213/8.4 15.8/35</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>89-30</td>
<td>74</td>
<td>12 150 75 300 230</td>
<td>229/9.0 177/7.0</td>
<td>213/8.4 16.0/35</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>89-50</td>
<td>74</td>
<td>12 180 80 370 290</td>
<td>229/9.0 177/7.0</td>
<td>213/8.4 17.0/37</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>89-40</td>
<td>74</td>
<td>12 260 125 505 395</td>
<td>229/9.0 177/7.0</td>
<td>213/8.4 20.5/35</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>89A-5</td>
<td>74</td>
<td>12 270 135 540 440</td>
<td>229/9.0 177/7.0</td>
<td>213/8.4 20.5/45</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>89A-5E</td>
<td>74</td>
<td>12 270 135 540 440</td>
<td>229/9.0 177/7.0</td>
<td>213/8.4 20.5/45</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes:
- **Amps for 5 sec Test**: 120, 180, 210, 230, 240, 260, 270, 300, 350, 400, 450, 500, 550, 600, 650, 700, 750, 800, 850, 900, 950, 1000.
- **Maximum Dimensions (IN/CM)**: 177/7.0, 181/7.1, 185/7.2, 189/7.3, 193/7.4, 197/7.5, 201/7.9, 205/8.1, 209/8.3, 213/8.4.
### FREEDOM BATTERY TEST SPECIFICATIONS

<table>
<thead>
<tr>
<th>Cat No</th>
<th>BCI Group</th>
<th>Voltage</th>
<th>Reserve Capacity (Ah)</th>
<th>Cold Cranking Current</th>
<th>Cold Cranking Current SAE Spec</th>
<th>Maximum Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Length (in) Flange Width (in) Height (in Top Post)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Wet (in) Dry (in)</td>
</tr>
<tr>
<td>1059</td>
<td>24</td>
<td>12</td>
<td>180</td>
<td>115</td>
<td>375</td>
<td>12/10.2 22/22.8 18/944</td>
</tr>
<tr>
<td>1071E</td>
<td>27</td>
<td>12</td>
<td>240</td>
<td>160</td>
<td>490</td>
<td>305/12.0 22/22.8 23/852</td>
</tr>
<tr>
<td>1099</td>
<td>24</td>
<td>12</td>
<td>180</td>
<td>115</td>
<td>375</td>
<td>260/10.2 213/8.4 19/743</td>
</tr>
<tr>
<td>1110</td>
<td>31</td>
<td>12</td>
<td>310</td>
<td>180</td>
<td>625</td>
<td>330/13.0 238/9.4 24/748</td>
</tr>
<tr>
<td>1111</td>
<td>31</td>
<td>12</td>
<td>310</td>
<td>180</td>
<td>625</td>
<td>330/13.0 238/9.4 24/748</td>
</tr>
<tr>
<td>1150</td>
<td>31</td>
<td>12</td>
<td>290</td>
<td>180</td>
<td>580</td>
<td>330/13.0 238/9.4 27/460</td>
</tr>
<tr>
<td>1150</td>
<td>31</td>
<td>12</td>
<td>310</td>
<td>180</td>
<td>625</td>
<td>330/13.0 238/9.4 26/548</td>
</tr>
<tr>
<td>1151</td>
<td>31</td>
<td>12</td>
<td>290</td>
<td>180</td>
<td>580</td>
<td>330/11      238/9.4 27/160</td>
</tr>
<tr>
<td>1151S</td>
<td>31</td>
<td>12</td>
<td>310</td>
<td>180</td>
<td>625</td>
<td>330/13.0 238/9.4 25/856</td>
</tr>
<tr>
<td>1200</td>
<td>31</td>
<td>12</td>
<td>230</td>
<td>130</td>
<td>475</td>
<td>330/13.0 238/9.4 28/657</td>
</tr>
<tr>
<td>1200D</td>
<td>31</td>
<td>12</td>
<td>270</td>
<td>130</td>
<td>550</td>
<td>330/13.0 238/9.4 22/449</td>
</tr>
<tr>
<td>1200E</td>
<td>31</td>
<td>12</td>
<td>230</td>
<td>130</td>
<td>475</td>
<td>330/13.0 238/9.4 28/657</td>
</tr>
<tr>
<td>1201E</td>
<td>31</td>
<td>12</td>
<td>270</td>
<td>130</td>
<td>550</td>
<td>330/13.0 238/9.4 27/500</td>
</tr>
<tr>
<td>1201</td>
<td>31</td>
<td>12</td>
<td>230</td>
<td>130</td>
<td>475</td>
<td>330/13.0 238/9.4 23/451</td>
</tr>
<tr>
<td>1202</td>
<td>31</td>
<td>12</td>
<td>270</td>
<td>130</td>
<td>550</td>
<td>330/13.0 238/9.4 27/450</td>
</tr>
<tr>
<td>1210E</td>
<td>31</td>
<td>12</td>
<td>310</td>
<td>180</td>
<td>625</td>
<td>330/13.0 238/9.4 27/450</td>
</tr>
<tr>
<td>1250E</td>
<td>31</td>
<td>12</td>
<td>290</td>
<td>180</td>
<td>580</td>
<td>330/13.0 238/9.4 27/460</td>
</tr>
<tr>
<td>1251E</td>
<td>31</td>
<td>12</td>
<td>290</td>
<td>180</td>
<td>580</td>
<td>330/13.0 238/9.4 27/460</td>
</tr>
<tr>
<td>2000</td>
<td>31</td>
<td>12</td>
<td>290</td>
<td>180</td>
<td>580</td>
<td>330/13.0 238/9.4 26/863</td>
</tr>
<tr>
<td>2000S</td>
<td>31</td>
<td>12</td>
<td>290</td>
<td>180</td>
<td>580</td>
<td>330/13.0 238/9.4 26/863</td>
</tr>
</tbody>
</table>

*Battery tester cable clamps should be between terminal nuts and lead pads of terminals. If not possible, load value should be 330 amperes for 31-750, 405 amperes for 31-900, 275 amperes for 1110, 1150, 1250E & 1210E, and 240 amperes for 1200 & 1200E.

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## STORAGE BATTERIES
### UNIT IV

### HANDBOUT #2 — COLD CRANKING AMPS FOR CONVENTIONAL BATTERIES

### FILLER-CAP BATTERY TEST SPECIFICATIONS

<table>
<thead>
<tr>
<th>Cat No</th>
<th>BCI Group Size</th>
<th>Amps for Load Test</th>
<th>SAE — BCI</th>
<th>COLD CRANKING CURRENT SAE SPEC 9307</th>
<th>MAXIMUM DIMENSIONS (MM)</th>
<th>APPROX WEIGHT KO LABS</th>
<th>ELECTROLYTE REQUIRED LITERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>353</td>
<td>34</td>
<td>450</td>
<td>160</td>
<td>900</td>
<td>28.8/1.1</td>
<td>18.0/8.6</td>
<td>19.4/8.6</td>
</tr>
<tr>
<td>403</td>
<td>34</td>
<td>240</td>
<td>160</td>
<td>800</td>
<td>28.8/1.1</td>
<td>18.0/8.6</td>
<td>19.4/8.6</td>
</tr>
<tr>
<td>405A</td>
<td>34</td>
<td>240</td>
<td>160</td>
<td>800</td>
<td>28.8/1.1</td>
<td>18.0/8.6</td>
<td>19.4/8.6</td>
</tr>
<tr>
<td>411A</td>
<td>34</td>
<td>240</td>
<td>160</td>
<td>800</td>
<td>28.8/1.1</td>
<td>18.0/8.6</td>
<td>19.4/8.6</td>
</tr>
<tr>
<td>413</td>
<td>34</td>
<td>240</td>
<td>160</td>
<td>800</td>
<td>28.8/1.1</td>
<td>18.0/8.6</td>
<td>19.4/8.6</td>
</tr>
<tr>
<td>413A</td>
<td>34</td>
<td>240</td>
<td>160</td>
<td>800</td>
<td>28.8/1.1</td>
<td>18.0/8.6</td>
<td>19.4/8.6</td>
</tr>
<tr>
<td>417</td>
<td>34</td>
<td>240</td>
<td>160</td>
<td>800</td>
<td>28.8/1.1</td>
<td>18.0/8.6</td>
<td>19.4/8.6</td>
</tr>
<tr>
<td>419</td>
<td>34</td>
<td>240</td>
<td>160</td>
<td>800</td>
<td>28.8/1.1</td>
<td>18.0/8.6</td>
<td>19.4/8.6</td>
</tr>
<tr>
<td>461A</td>
<td>34</td>
<td>240</td>
<td>160</td>
<td>800</td>
<td>28.8/1.1</td>
<td>18.0/8.6</td>
<td>19.4/8.6</td>
</tr>
</tbody>
</table>

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STORAGE BATTERIES
UNIT IV

JCB SHEET #1 — TROUBLESHOOT A BATTERY

A. Tools and materials
   1. Battery
   2. Safety glasses
   3. Rubber gloves
   4. Rubber apron
   5. Job Sheet #2
   6. Job Sheet #3
   7. Job Sheet #4

B. Procedure

   (NOTE: Specific test procedures are required to determine the ability of a battery to
   function properly. For this reason, visual inspection, specific gravity check, and load
   test are sometimes required.)

   1. Visual Inspection
      a. Check for obvious damage such as a cracked or broken case.
      b. If damage is obvious, replace battery.
         (NOTE: Refer to Job Sheet #2.)
      c. If there is no obvious damage, check electrolyte level. If you have a battery,
         proceed to Step 3.
      d. If electrolyte level is above top of plates, proceed to Step 2.
      e. If electrolyte is below top of plates in one or more cells, add water to just
         above the separators. Charge for 15 minutes at 15-25 amps and then pro-
JOB SHEET #1

2. Test specific gravity on conventional batteries.
   (NOTE: Refer to Job Sheet #3.)
   a. Less than 50 points variation between highest and lowest cell, proceed to Step 4.
   b. 50 points or more variation between highest and lowest cell, replace battery.
      (NOTE: Refer to Job Sheet #2.)

3. Test specific gravity for maintenance-free batteries.
   a. Batteries with built-in hydrometer, go to Step 4.
   b. Batteries with built-in hydrometer, check color of indicator.
      1) Light yellow or white — Replace battery.
      2) Indicator is dark — Charge until indicator turns green, then connect 300 amp load for 15 seconds and proceed to step 4.
         (NOTE: For 300 amp load, refer to Job Sheet #4.)
      3) Green — Proceed to Step 4.

4. Load test the battery.
   a. Obtain specifications for the battery you are testing.
      Manufacturer's specifications:
      ___________ amps ___________ volts
   b. Obtain instructor's initials here ___________ before proceeding to next step.
   c. Connect voltmeter and proper load from specification for 15 seconds.
      (NOTE: Refer to Job Sheet #4.)
   d. If voltage is at or above chart value, return to service.
      (NOTE: Refer to Handouts #1 and 2 for charts.)
   e. If voltage is below chart value, replace battery.
      (NOTE: Maintenance-free batteries without built-in hydrometers must be given a long, slow charge and load tested again.)
STORAGE BATTERIES
UNIT IV

JOB SHEET #2 — REMOVE, SERVICE, AND REPLACE BATTERY

A. Tools and materials
   1. Vehicle
   2. Safety glasses
   3. Rubber apron
   4. Bristle brush
   5. Wire brush
   6. Screwdriver
   7. Battery clamp puller
   8. Combination end wrenches
   9. Battery pliers
   10. Baking soda and water solution (two tablespoons of baking soda to one pint of water)
   11. Battery anti-corrosion paste
   12. Battery post and cable cleaner
   13. Shop towels
   14. Torque wrench
   15. Battery lift strap
   16. Appropriate service manual

B. Procedure

(CAUTION: Remove all jewelry prior to working on any electrical system, and follow all shop safety procedures.)

(NOTE: Observe the location of the positive post so the battery can be installed in the same way.)
JOB SHEET #2

1. Disconnect the battery cables from the battery posts. (Figure 1)
   
   (NOTE: Always disconnect the grounded battery cable first to avoid short circuits. Use care to avoid twisting the battery cable post.)

   FIGURE 1

   Pry Clamp Open

   Pull Cable Off

2. Remove the battery hold-down.

3. Remove the battery from the carrier.
   
   (NOTE: Use a suitable battery lift strap to lift the battery)

4. Inspect the battery carrier for dirt or corrosion.

5. Check battery cables for worn or frayed insulation.
6. Clean battery cable clamps and battery post. (Figure 2)
   (NOTE: Battery posts and inside of battery cable clamps must be clean and bright.)

   FIGURE 2

7. Brush soda water solution on battery, battery post, clamps, and battery hold-down. (Figure 3)
   (NOTE: Keep water and soda from entering the battery through the vent holes in the vent caps.)

   FIGURE 3
8. Wash away residue with clean water. (Figure 4)

(NOTE: Remove all residue that may have lodged around battery, frame, or parts of the vehicle.)

9. Set the battery into place using a lift strap.

(NOTE: Position the battery to allow for correct battery cable attachment.)

10. Install the battery hold-down clamp or strap and tighten securely.

11. Reconnect battery cables to the battery posts. (Figures 5 and 6)

(NOTE: Always reconnect the insulated cable first and the ground cable last. Replace clamp bolts and nuts as needed.)

( CAUTION: Do not hammer or force terminal on post as battery cover breakage may result.)
12. Torque or tighten the battery clamps securely.
   (NOTE: Use care to avoid twisting the cable post.)

13. Spread a coating of battery anti-corrosion paste over the cable clamps and terminals.
STORAGE BATTERIES
UNIT IV

JOB SHEET #3 — MEASURE SPECIFIC GRAVITY
OF A CONVENTIONAL BATTERY

A. Tools and materials
   1. Battery
   2. Hydrometer
   3. Shop towels
   4. Container of clear water
   5. Safety glasses
   6. Rubber gloves
   7. Rubber apron
   8. Appropriate service manual

B. Procedure
   (CAUTION: Follow all shop safety procedures.)
   1. Remove vent caps from battery.
   2. Insert the hydrometer into the first cell.
   3. Squeeze the rubber bulb to draw electrolyte into the hydrometer to suspend the float.
      (NOTE: If the electrolyte level is too low, add water, charge for one hour, and recheck.)
4. Take reading at eye level. (Figure 1)

(NOTE: Make sure the float is not bumping the top of the hydrometer tube or sticking to the side of the tube; write down reading for each cell.)

FIGURE 1

Hold Tube Vertical

Do Not Suck in Too Much Electrolyte

Float Must be Free

Take Reading at Eye Level

5. Squeeze bulb to return electrolyte to cell.

6. Repeat for other cells.
JOB SHEET #3

7. Adjust the readings for temperature.
   a. Add four gravity points (0.004) to the reading for every 10°F above 80°. Subtract four gravity points (0.004) for each 10° below 80°F. (Figure 2)

   ![Temperature Adjustment Chart]

   FIGURE 2

   b. Check specific gravity; it should read from 1.215 to 1.270 (corrected to 80°F electrolyte temperature).

   c. Check the variation in readings between cells; it should be no more than 0.050.

   d. Charge and retest the battery if the readings are not within the above mentioned range.

8. Replace vent caps upon completion of test.

9. Flush any spilled electrolyte with clean water.
STORAGE BATTERIES
UNIT IV

JOB SHEET #4 — LOAD TEST A BATTERY

A. Tools and materials
   1. Battery
   2. Battery capacity tester
   3. Appropriate conductors
   4. Safety glasses
   5. Rubber gloves
   6. Rubber apron
   7. Appropriate service manual

B. Procedure
   (CAUTION: Remove all jewelry prior to working on any electrical system, and follow all shop safety procedures.)
   1. Check service manual to find the recommended load current to test a particular battery.

      Manufacturer's specifications:
      ____________ amps      ____________ volts

      Obtain instructor's initials here ____________ before proceeding to next step.
   2. Connect tester. (Figure 1)

   FIGURE 1
3. Turn the rheostat knob clockwise until the desired load is reached.

4. Apply load equal to three times the ampere-hour rating of battery being tested or 1/2 cold cranking amps.

   (NOTE: Ampere-hour rating should be marked on the outside of battery case. Refer to Handouts #1 and 2 for cold cranking amps.)

5. Read battery voltage at the end of 15 seconds.

   (NOTE: If voltage drops below 1.5 volts per cell in 15 seconds, use the 3-minute charge test.)

6. Loosen rheostat to relieve load at end of 15 seconds.

7. Disconnect tester.
STORAGE BATTERIES
UNIT IV

JOB SHEET #5 — CHARGE TEST A BATTERY FOR THREE MINUTES

A. Tools and materials
   1. Battery
   2. Adjustable, fast-rate battery charger
   3. Battery capacity tester
   4. Appropriate conductors
   5. Safety glasses
   6. Rubber gloves
   7. Rubber apron
   8. Appropriate service manual

B. Procedure

   (CAUTION: Remove all jewelry prior to working on any electrical system, and follow all shop safety procedures.)

   (NOTE: Use charge test only on batteries that fail the capacity test. Do not use this test on maintenance-free batteries.)

   1. Connect tester and charger. (Figure 1)

   FIGURE 1
JOB SHEET #5

2. Turn charger on and adjust the charging rate to 40 amps for 12-volt batteries, 75 amps for 6-volt batteries.

3. Charge battery for 3 minutes.

4. Read individual cell voltages with battery charger still in operation.
   (NOTE: If they vary by more than 0.1 volt, replace battery)

5. Read total battery voltage.
   (NOTE: If it is over 15.5 volts for 12-volt batteries or 7.75 for 6-volt batteries, the battery is unsatisfactory and must be given a long, slow charge and load-tested again. If voltage under load test is less than 9.5 volts (12-volt) or 4.8 volts (6-volt), replace battery)
STORAGE BATTERIES
UNIT IV

PRACTICAL TEST
JOB SHEET #1 — TROUBLESHOOT A BATTERY

STUDENT'S NAME ____________________________ DATE ____________

EVALUATOR’S NAME ____________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under “Process Evaluation” must receive a “Yes” for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the “Yes” or “No” blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

1. Checked out proper tools and materials. YES NO
2. Used safety equipment. ______ ______
3. Visually inspected battery. ______ ______
4. Checked specific gravity. ______ ______
5. Obtained the correct manufacturer's specifications. ______ ______
6. Load tested the battery. ______ ______
7. Checked in/put away tools and materials. ______ ______
8. Cleaned the work area. ______ ______

EVALUATOR’S COMMENTS: ____________________________________________
JOB SHEET #1 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

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<tr>
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<th>4</th>
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<th>1</th>
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</thead>
<tbody>
<tr>
<td>Determined battery condition</td>
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EVALUATOR'S COMMENTS: ____________________________________________________________
__________________________________________________________

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<tr>
<th>PERFORMANCE EVALUATION KEY</th>
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<tbody>
<tr>
<td>4 — Skilled — Can perform job with no additional training.</td>
</tr>
<tr>
<td>3 — Moderately skilled — Has performed job during training program; limited additional training may be required.</td>
</tr>
<tr>
<td>2 — Limited skill — Has performed job during training program; additional training is required to develop skill.</td>
</tr>
<tr>
<td>1 — Unskilled — Is familiar with process, but is unable to perform job.</td>
</tr>
</tbody>
</table>

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)
STORAGE BATTERIES
UNIT IV

PRACTICAL TEST
JOB SHEET #2 — REMOVE, SERVICE, AND REPLACE BATTERY

STUDENT'S NAME ____________________________ DATE ____________

EVALUATOR'S NAME ____________________________ ATTEMPT NO. _____

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

1. Checked out proper tools and materials. YES NO
2. Used safety equipment. YES NO
3. Disconnected battery cables using the proper tools. YES NO
4. Inspected battery carrier. YES NO
5. Checked battery cables. YES NO
6. Cleaned battery, battery clamps, and terminals. YES NO
7. Installed battery, battery hold-down clamps, and reconnected battery terminals. YES NO
8. Checked In/put away tools and materials. YES NO
9. Cleaned the work area. YES NO

EVALUATOR'S COMMENTS: ____________________________________________
JOB SHEET #2 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

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<th>2</th>
<th>1</th>
</tr>
</thead>
</table>

Battery or batteries are installed correctly.

| 4 | 3 | 2 | 1 |

Battery, battery hold-down clamps, and battery terminals are clean and in good working order.

EVALUATOR’S COMMENTS:

———

PERFORMANCE EVALUATION KEY

| 4 — Skilled — Can perform job with no additional training. |
| 3 — Moderately skilled — Has performed job during training program; limited additional training may be required. |
| 2 — Limited skill — Has performed job during training program; additional training is required to develop skill. |
| 1 — Unskilled — Is familiar with process, but is unable to perform job. |

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in “Product Evaluation” and divide by the total number of criteria.)
STORAGE BATTERIES
UNIT IV

PRACTICAL TEST
JOB SHEET #3 — MEASURE SPECIFIC GRAVITY OF A CONVENTIONAL BATTERY

STUDENT'S NAME ___________________________ DATE __________

EVALUATOR'S NAME ___________________________ ATTEMPT NO. _____

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under “Process Evaluation” must receive a “Yes” for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the “Yes” or “No” blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student: YES NO

1. Checked out proper tools and materials. ________ ________
2. Used safety equipment. ________ ________
3. Took specific gravity reading. ________ ________
4. Adjusted the reading for temperature. ________ ________
5. Flushed any spilled electrolyte with clean water. ________ ________
6. Checked in/put away tools and materials. ________ ________
7. Cleaned the work area. ________ ________

EVALUATOR'S COMMENTS: __________________________________________
JOB SHEET #3 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

Accuracy of specific gravity reading

EVALUATOR’S COMMENTS:

PERFORMANCE EVALUATION KEY

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<th>Description</th>
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(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in “Product Evaluation” and divide by the total number of criteria.)
STORAGE BATTERIES
UNIT IV

PRACTICAL TEST
JOB SHEET #4 — LOAD TEST A BATTERY

STUDENT’S NAME _______________________________ DATE ___________

EVALUATOR’S NAME _______________________________ ATTEMPT NO. _______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under “Process Evaluation” must receive a “Yes” for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the “Yes” or “No” blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

1. Checked out proper tools and materials. ____________________________
2. Used safety equipment. ____________________________
3. Obtained battery specifications. ____________________________
4. Connected and operated tester correctly. ____________________________
5. Checked in/out away tools and materials. ____________________________
6. Cleaned the work area. ____________________________

EVALUATOR’S COMMENTS: ____________________________________________
JOB SHEET #4 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a “3” for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

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<td>4</td>
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Evaluation of test results

EVALUATOR'S COMMENTS: ____________________________

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(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)
STORAGE BATTERIES
UNIT IV

PRACTICAL TEST
JOB SHEET #5 — CHARGE TEST A BATTERY FOR THREE MINUTES

STUDENT'S NAME: ___________________________ DATE: ________________
EVALUATOR'S NAME: ________________________ ATTEMPT NO.: ________

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student: YES NO

1. Checked out proper tools and materials.  __________ __________
2. Used safety equipment.  __________ __________
3. Connected tester and charger to battery correctly.  __________ __________
4. Selected the correct amperage on charger.  __________ __________
5. Read total battery voltage to make evaluation of the battery.  __________ __________
6. Checked input away tools and materials.  __________ __________
7. Cleaned the work area.  __________ __________

EVALUATOR'S COMMENTS: ________________________________________
JOB SHEET #5 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria.  

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EVALUATOR'S COMMENTS: ________________________________________________________________
______________________________________________________________

PERFORMANCE EVALUATION KEY

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(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)
1. Match the terms on the right with their correct definitions.

   ______a. Two or more connected cells which convert chemical energy into electrical energy
   1. Battery

   ______b. One positive plate group and one negative plate group
   2. Cell

   ______c. Similar plates welded to a plate strap
   3. Electrolyte

   ______d. Solution of water and sulfuric acid
   4. Hydrometer

   ______e. Weight of electrolyte compared to an equal volume of water at 60°F
   5. Plate group

   ______f. A test instrument for determining the specific gravity of electrolyte
   6. Specific gravity

   ______g. Oxidation of positive plate grid wires and formulation of lead sulfate crystals which become dense and hard
   7. Sulfated

2. List three functions of a battery.

   a. ________________________________________________________________

   b. ________________________________________________________________

   c. ________________________________________________________________
3. Identify the following types of batteries.

4. Distinguish between the characteristics of batteries by placing a “C” next to the characteristics of conventional batteries and an “M” next to the characteristics of maintenance-free batteries.

   a. Lifetime supply of electrolyte
   b. Less gassing and corrosion
   c. Vent caps are used for each cell
   d. Longer shelf life
   e. Built-in hydrometer
   f. Electrolyte level has to be checked and water added to each cell
   g. Withstand more vibration
   h. Resist overcharging

5. Complete the following statements concerning the voltage ratings of batteries by placing the correct number(s) in the blanks. Choose your answers from the following numbers: 3, 6, 9, 12.

   a. 6-volt batteries have ________ cells.
   b. 12-volt batteries have ________ cells.
6. Distinguish between amp hour rating and cold cranking amps by placing an "X" next to the description of cold cranking amps.

   a. Capacity rated according to quantity of electricity that can be taken from a fully charged battery over a definite period of time
   b. Number of amps that can be taken from a fully charged battery at 0°F for 30 seconds

7. Complete the following statements concerning rules for installing batteries by inserting the correct word (on the right) that best completes each statement.

   a. Install only __________ charged batteries. Older
   b. Do not install a new battery alongside __________ batteries. Polarity Different
   c. Do not install batteries of __________ capacities. Fully
   d. Check __________ of the vehicle.

8. Draw lines showing the installation of battery cables.

   a. 6-volt batteries
      1) 12-volt system
         Cable Going To Starter Or Frame

         [Diagram showing connections for 12-volt system]

         2) 24-volt system
         Cable Going To Starter Or Frame

         [Diagram showing connections for 24-volt system]
TEST

b. 12-volt batteries

1) 12-volt system

Cable Going To Starter Or Frame

2) 24-volt system

Cable Going To Starter Or Frame

9. Identify the following types of battery terminal constructions.

a. 

b. 

c. 

192
TEST

10. Select from the following list safety rules to be observed during the care and maintenance of batteries by placing an "X" beside the appropriate rule(s).

   _____a. Electrolyte must not be allowed to come in contact with clothing, skin, eyes, or painted surfaces.

   _____b. Flames or sparks can cause gases given off by battery to explode.

   _____c. Wear safety glasses, rubber gloves, and rubber apron when servicing batteries.

   _____d. Leave charger in the "on" position when connecting and disconnecting batteries.

   _____e. Flush immediately with water any area of skin which acid has contacted.

   _____f. Avoid breathing fumes from a battery that's being charged.

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

11. Demonstrate the ability to:

   a. Troubleshoot a battery. (Job Sheet #1)

   b. Remove, service, and replace battery. (Job Sheet #2)

   c. Measure specific gravity of a conventional battery. (Job Sheet #3)

   d. Load test a battery. (Job Sheet #4)

   e. Charge test a battery for three minutes. (Job Sheet #5)
STORAGE BATTERIES
UNIT IV

ANSWERS TO TEST

1. a. 1  
   b. 2  
   c. 5  
   d. 3  
   e. 6  
   f. 4  
   g. 7  

2. a. Supplies current for cranking the engine  
    b. Supplies current when the demand exceeds the output of the charging systems.  
    c. Stabilizes the voltage in the system during operation.

3. a. Conventional  
      b. Maintenance free

4. a. M  
     b. M  
     c. C  
     d. M  
     e. M  
     f. C  
     g. M  
     h. M

5. a. 3  
     b. 6

6. b

7. a. Fully  
     b. Older  
     c. Different  
     d. Polarity

8. a. 1)  
     2)
ANSWERS TO TEST

b. 1)

2)

9. a. Bolt-type side terminals
   b. Stainless steel stud terminals
   c. Battery post terminals

10. a, b, c, e, f

11. Performance skills evaluated to the satisfaction of the instructor
UNIT OBJECTIVE

After completion of this unit, the student should be able to remove, replace, rebuild, and test a starter, and check voltage drop in a starter circuit. Competencies will be demonstrated by completing the job sheets and the unit tests with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to starting systems and circuits with their correct definitions.
2. List three types of starting systems.
3. List two sources of compressed air for air starting motors.
4. Select from a list components of a gasoline starting system.
5. Select from a list types of starting aids.
6. State the purpose of an electrical starting circuit.
7. Label the major parts in an electrical starting circuit.
8. Match parts of a starting circuit with the functions.
9. Select major parts of a starting motor.
10. Match component parts of a starting motor with their functions.
OBJECTIVE SHEET

11. Complete a statement concerning the conversion of electrical energy into mechanical energy.

12. Select true statements concerning how a starting motor is kept running.

13. Arrange in order the current flow in a starting motor circuit.

14. Identify types of starter field circuits.

15. Match types of starter field circuits with current flow.

16. List four types of starting motor switches.

17. Explain ways starter drives are engaged.

18. Identify types of electromagnetic or lever shift drives.

19. Arrange in order the steps in the operation of a series-parallel switch.

20. Arrange in order the steps in the operation of a transformer-rectifier unit.

21. Demonstrate the ability to:
   a. Remove and replace a starter. (Job Sheet #1)
   b. Disassemble, test, and reassemble a starter. (Job Sheet #2)
   c. Test a starter motor (no-load). (Job Sheet #3)
   d. Rebuild and test a starter solenoid. (Job Sheet #4)
   e. Check voltage drop in a starter circuit. (Job Sheet #5)
STARTING SYSTEMS AND CIRCUITS
UNIT V

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.
   (NOTE: This activity should be completed prior to the teaching of this unit.)
B. Make transparencies from the transparency masters included with this unit.
C. Provide students with objective sheet.
D. Discuss unit and specific objectives.
E. Provide students with information sheet.
F. Discuss information sheet.
   (NOTE: Use the transparencies to enhance the information as needed.)
G. Provide students with job sheets.
H. Discuss and demonstrate the procedures outlined in the job sheets.
I. Integrate the following activities throughout the teaching of this unit:
   1. Demonstrate different designs of starters.
   2. Take a field trip to a starter rebuilding shop.
   4. Have students bring in starters to rebuild.
   5. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.
J. Give test.
K. Evaluate test.
L. Reteach if necessary.
REFERENCES USED IN DEVELOPING THIS UNIT


SUGGESTED SUPPLEMENTAL RESOURCES

A. Texts

Delco Remy Service Manual #1.2
AC-Delco
General Motors Building
Detroit, MI 48202

B. Filmstrips

1. Luce-Neville Starting Motor
Order #A5047
Educational Communications Inc.
Dept. M
761 Fifth Avenue
King of Prussia, PA 19406

2. The Automotive Starting System Explained
Order #B-435
Teaching Aids Incorporated
Post Office Box 1798
Costa Mesa, CA 92628-0798
STARTING SYSTEMS AND CIRCUITS
UNIT V

INFORMATION SHEET

i. Terms and definitions

A. Armature — Main drive of starter motor; converts electrical energy into mechanical energy
B. Brushes — Sliding contacts to feed electrical energy from battery to commutator
C. Camf — Counter electromotive force
D. Commutator — Metal segments attached to ends of wire loops to form contact surface on armature
E. Field winding — Wire wrapped around pole pieces to increase strength of magnetic field when current is passed through windings
F. Inertia — Tendency of a body in motion to remain in motion
G. Motor switch — Any switch that closes the circuit between the battery and starter motor
H. Pinion — Small gear that meshes with a larger gear
I. Pole pieces — Ends of a magnet in the field frame assembly of a starting motor
J. Solenoid — Electromagnetic switch that closes circuit and engages the motor drive pinion with the flywheel
K. Starter switch — Activates the motor switch
   (NOTE: This switch may be either a key or push button.)
L. Voltage drop — The drop, or current used in cables

ii. Types of starting systems

A. Electric motors
B. Gasoline engines
C. Air starters
INFORMATION SHEET

III. Sources of compressed air for air starting motors (Transparency 1)
   A. Separate engine and compressor
   B. Air brake compressor on highway diesel tractors
      (NOTE: The air starting motor produces more torque to turn an engine over than an electric starter motor)

IV. Components of gasoline starting engine
   A. Gasoline engine
   B. Clutch
   C. Gear box
   D. Drive pinion

V. Types of starting aids
   (NOTE: Aids may be used singly or in combination.)
   A. Glow plugs
   B. Starting fluid
   C. Block heater
   D. Oil heater

VI. Purpose of an electrical starting circuit — Converts electrical energy from the battery into mechanical energy at the starting motor to crank the engine.

VII. Major parts in an electrical starting circuit (Transparency 2)
   A. Battery
   B. Starter switch
      (NOTE: The starter switch may be either a key or push button.)
   C. Motor switch
      (NOTE: The motor switch may be either magnetic or solenoid.)
   D. Starting motor
VIII. Function of parts of an electrical starting circuit (Transparency 2)

A. Battery — Supplies energy for the circuit
B. Starter switch — Activates the circuit
C. Motor switch — Closes circuit to motor and engages motor drive with flywheel
D. Starting motor — Drives flywheel to start engine

IX. Major parts of a starting motor (Transparency 3)

A. Motor switch
B. Field frame assembly
C. Armature
D. Drive mechanism

X. Component parts and their functions (Transparency 3)

A. Pole shoe — Forms a magnetic field of force around armature
B. Field winding — Wrapped around pole shoe to strengthen magnetic field when current is passed through the winding
C. Armature — Converts electrical energy into mechanical energy to drive mechanism to crank engine

(Note: The magnetic field around the loop and the field between the pole shoes repel each other causing the loop or armature to turn.)
D. Commutator — Forms contact surface for battery to feed electrical current through armature
E. Brushes — Sliding contacts which feed electrical energy to the commutator
XI. **Conversion of electrical energy into mechanical energy** — Current carrying conductor (armature) formed in a loop and mounted on a shaft; will cause the shaft to rotate when placed inside a magnetic field (field windings)

![Loop of Wire Placed in Field Between Poles]

XII. **How a starting motor is kept running** (Transparency 4)

A. The magnetic field around the armature and the magnetic field between the pole pieces repel each other causing the armature to turn.

B. Metal segments on the ends of the commutator make a one-half turn reversing their connection through sliding contacts (brushes) which causes the current to flow in the opposite direction in the armature windings.

XIII. **Current flow in an electrical starting motor circuit**

A. With the key switch in the start position, current flows from the battery terminal of the starter through the magnetic switch and to ground.
B. The magnetic switch closes allowing current to flow from the battery terminal of the solenoid to the switch terminal of the solenoid.

C. The solenoid closes allowing current to flow from the battery terminal of the solenoid to the motor terminal of the solenoid and at the same time, engages the starter drive with the flywheel. Current then passes through the starter and back to ground.

XIV. Types of starter field circuits (Transparency 5)
A. Series-wound
B. Parallel-wound
C. Series-parallel-wound
D. Compound-wound

XV. Types of starter field circuits and current flow (Transparency 5)
A. Series-wound — Current flows through all the field windings before it flows through the two insulated brushes to the armature
INFORMATION SHEET

B. Parallel-wound — Current flows through one field winding to the brushes, and also through the other field winding to the brushes, placing the field windings in parallel.

C. Series-parallel-wound — One third of the current flows through each pair of field windings to one of the three insulated brushes.

D. Compound-wound — One or more of the poles is shunt wound, connected directly to ground to prevent excessive speeds.

(NOTE: The shunt coil is not affected by the counter voltage (CEMF) induced into the armature windings when passing through the magnetic field of the field coils.)

XVI. Types of starting motor switches

A. Manual
B. Solenoid

(NOTE: Solenoid provides a mechanical means for engaging the pinion with the flywheel.)
C. Magnetic

(NOTE: Magnetic switch does not provide mechanical shifting.)
D. Series-parallel

XVII. Engaging starter drives

A. Inertia of armature acting through drive mechanism
B. Electromagnetic plunger to mechanically shift pinion into mesh

XVIII. Types of electromagnetic or lever shift drives (Transparency 6)

A. Overrunning clutch
B. Sprag clutch drive
C. Positork<sup>®</sup> drive

XIX. Operation of a series-parallel switch

A. Starter switch closes, connecting two 12 volt batteries in series with the starting motor.
B. Solenoid circuit is completed by a set of points mechanically closed by the series-parallel switch plunger and starter turns over. (Transparency 7)
C. Starter switch is released, going into neutral position, permitting operation of electrical equipment by two 12 volt batteries in parallel for normal operation. (Transparency 8)

XX. Operation of a transformer-rectifier unit

A. The operator closes the start switch, forcing 12 V from the batteries marked “A” through the magnetic switch, closing the cranking motor actuating circuit.

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INFORMATION SHEET

B. The current for the solenoid switch and for cranking flows from the positive posts of the "B" batteries to the battery terminal on the solenoid switch, to and over the magnetic switch disk, to insulated terminals, and through the solenoid windings to ground.

C. This action energizes the solenoid and current then flows from the battery terminal of solenoid to the motor terminal, through the starter to ground, and into the negative part of the batteries marked "A." This action connects both sets of batteries in series, creating 24 V for starting.
Air Starting System

Control Valve
Lever Ball Or
Push Button

Air Starting
Reservoir

Safety Valve
150#

Control Valve
Check Valve

Air Pressure
95-120 PSI
From Main
Air System

Hand Valve

Glad Hand

Air Cranking Motor

Courtesy of Mack Trucks, Inc.
Parts in Starting Circuit

- Starter Switches
- Push Button
- Key Switch
- Battery
- Magnetic Switch
- Solenoid (Motor Switch)
- Starting Motor
Parts of a Starting Motor

- Contact Disc
- Heavy-Duty Solenoid Switch
- Plunger
- Return Spring
- Cable
- Linkage Seal
- Shift Lever
- Lever Housing
- Oil Reservoir
- Bronze Bushing
- Sprag Clutch
- Field Coil
- Armature
- O-Ring
- Oil Reservoir
- Bronze Bushing
- Sprag Clutch

© General Motors Corporation
Components of Armature

Loop Of "Live" Wire And Its Magnetic Field

Armature For Starting Motor

Loop Placed In Field Windings

Armature And Brushes
Starter Field Circuits

Four-Pole—Two-Coil Series-Wound Motor

Field Winding
Brush
Current From Battery
Field Winding
Grounds
Commutator
Pole Shoe

Four-Pole—Four-Coil Parallel-Wound Motor

Field Coil
(4 Used)
Parallel Windings
Pole Shoe

Six-Pole—Six-Coil Series-Parallel-Wound Motor

Brush
Pole (6 Used)
Commutator

Compound-Wound Motor

Brush
Shunt Coil
Commutator
Series Coils
Pole Shoe
Types of Electromagnetic or Lever Shift Drives

Overrunning Clutch Drive Engaged

Sprag Clutch Drive

Reprinted with permission of Delco Remy Division, GM Corp.
Series-Parallel Switch — 24 Volts

Output Terminal

Integral Charging System

Starting Switch

Series-Parallel Switch

Circuit Breaker or Fuse

Solenoid Switch (24-Volt)

Cranking Motor (24-Volt)

Ammeter Preferred Location

Ammeter Optional Location

Battery 12-Volt “B”

Battery 12-Volt “A”

Battery 12-Volt “B”

Battery 12-Volt “A”

Reprinted with permission of Delco Remy Division, GM Corp.
Series-Parallel Switch — 12 Volts

Output Terminal

Integral Charging System

Battery 12-Volt “A”

Battery 12-Volt “B”

Battery 12-Volt “B”

Battery 12-Volt “A”

Starting Switch

Series-Parallel Switch

Circuit Breaker or Fuse

Ammeter Optional Location

Solenoid Switch (24-Volt)

Cranking Motor (24-Volt)

Ammeter Preferred Location

Preferred Location

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STARTING SYSTEMS AND CIRCUITS
UNIT V

JOB SHEET #1 — REMOVE AND REPLACE A STARTER

A. Tools and materials

1. Vehicle
2. Basic hand tool set
3. Battery cable pliers
4. Safety glasses
5. Appropriate service manual

B. Procedure

(CAUTION: Remove all jewelry prior to working on any electrical system, and follow all shop safety procedures.)

1. Remove starter.
   a. Disconnect battery ground cable.
   b. Remove the cables and electrical wires from the starter and label. (Figure 1)

   (NOTE: In some cases it may be necessary to remove the starter retaining bolts and allow the starter to be lowered to provide easy removal of the starter wires and cables.)

   FIGURE 1

   Courtesy of Cummins Engine Co., Inc.
c. Remove starter retaining bolts as required. (Figure 2)

(CAUTION: The starting motor mounting capscrews can be metric or standard thread sizes. Be sure to install the same size capscrews which were removed.)

**FIGURE 2**

![Figure 2 Image](image)

Courtesy of Cummins Engine Co., Inc.

d. Remove other starter brackets if used.

e. Remove starter from engine.

(CAUTION: Starter motors are heavy and should be handled carefully during removal to avoid damage to the starter or injury to the worker.)

2. Replace starter

   a. Clean starter and block mounting surfaces.

   b. Position starter in mounting position and start retaining bolts.

   c. Tighten starter retaining bolts securely.

   d. Position starter wires and cables in place and start retaining nuts.
JOB SHEET #1

e. Tighten starter wires and retaining nuts securely. (Figure 3)

   (NOTE: Avoid overtightening and twisting off small retaining nuts.)

   FIGURE 3
   
   Courtesy of Cummins Engine Co., Inc.

f. Replace any brackets that may have been removed and tighten securely.

g. Check all connections.

h. Replace battery ground cable.

i. Start engine two or three times to check starter action.
STARTING SYSTEMS AND CIRCUITS
UNIT V

JOB SHEET #2 — DISASSEMBLE, TEST, AND REASSEMBLE A STARTER

A. Tools and materials
   1. Starter
   2. Basic hand tool set
   3. Suitable armature growler with test light
   4. Two V blocks
   5. Dial indicator
   6. Safety glasses

B. Procedure
   (CAUTION: Remove all jewelry prior to working on any electrical system, and follow all shop safety procedures.)
   1. Disassemble starter.
      a. Clean starter before disassembly.
      b. Mark the commutator end frame, drive housing, and the field-frame assembly with a center punch. (Figure 1)

   FIGURE 1

   (NOTE: These alignment marks will ensure proper commutator, end frame, drive housing, and field frame positions when reassembling.)
c. Remove the bolts that hold the commutator end frame and the field frame together.

(NOTE: Depending on which type starter you have, the bolts may be threaded into the main field frame or may be through bolts that reach through the field frame housing and thread into the shift lever housing.)

d. Remove the dust cover, if applicable, or brush inspection plugs and then remove the screws which connect the field coils to the brush holders. (Figure 2)

FIGURE 2

End Frame & Brush Installation.
Delco-Remy enclosed shift starter

Reprinted from MOTOR Heavy Truck Repair Manual
© 1985 by permission of The Hearst Corporation.

e. Remove the bolts that hold the lever and drive housing to the main field frame.

f. Remove starter end frame.

g. Grasp starter housing and remove the armature and drive assembly from the housing.

h. Remove the armature and drive assembly from the drive housing.

(NOTE: Sometimes the solenoid and shift lever assembly must be removed before the drive assembly and armature can be removed.)

i. Remove starter drive from armature shaft as follows:

(NOTE: On motors using snap ring and retainer as a pinion stop, continue to Steps 1, 2, and 3.)

1) Remove thrust washer.
JOB SHEET #2

2) Tap retainer toward armature to free the snap ring. (Figure 3)

3) Remove snap ring and retainer.
4) Remove starter drive and assist spring. (Figure 4)

j. Remove starter brushes, if required.

2. Test and service starter.
   a. Clean all starter components.
      (NOTE: Clean all parts by wiping with clean cloth. The armature, field coils, and starter drive assembly must not be washed in solvent.)
   b. Arrange all starter components for inspection.
   c. Inspect starter bushing for looseness and replace as required.
d. Inspect starter brushes for wear.
   (NOTE: Brushes worn to half their original length or less should be replaced.)

e. Inspect the starter drive.
   (NOTE: The starter drive pinion gear should turn freely in one direction and lock when turned slowly in the other direction.)

f. Inspect armature commutator.
   (NOTE: If the armature commutator is rough or out-of-round, it should be turned down using suitable equipment.)

g. Test the armature for short circuits. (Figure 5)
   (NOTE: Place the armature on a growler and rotate the armature while holding a hacksaw blade over the armature core. If the blade vibrates, the armature is shorted and will require replacement.)

FIGURE 5

![Diagram of a growler with labels: Steel Blade, Power Switch, Pilot Light.](image-url)

Courtesy of J.I. Case Company.
JOB SHEET #2

h. Check armature for ground. (Figure 6)

(NOTE: Place one lead of a test lamp on the armature core or shaft and the other on the commutator. If the lamp lights, the armature is grounded and will require replacement.)

FIGURE 6

![Test Probe Diagram]

Courtesy of J.I. Case Company.

i. Check armature shaft runout.

(NOTE: Place the armature between two V blocks and position a dial indicator on the armature-shaft center-bearing surface. Rotate the armature 360° to note the runout. If it is higher than .003 of an inch, the shaft must be straightened.)
JOB SHEET #2

j. Check field coil for open circuit. (Figure 7)

(NOTE: Place one lead of the test lamp on the insulated brush and the other on the field connection tab. If the lamp does not light, the field coils are open and will require replacement.)

FIGURE 7

[Diagram of a starter showing Field Connector Tab and Insulated Brush]

k. Check field coil for ground. (Figure 8)

(NOTE: Place one lead of the test lamp on the field connector tab and the other on the grounded brush. If the lamp lights, the field coils are grounded and will require replacement.)

FIGURE 8

[Diagram of a starter showing Field Connector Tab and Grounded Brush]

l. Test, inspect, and replace any parts that are worn or damaged before reassembling starter.
3. Reassemble starter.
   a. Reassemble solenoid in reverse order of disassembly.
   b. Lubricate all bushings, wicks and oil reservoirs with SAE #20 oil.
   c. On motors using snap ring and retainers, reassemble in the following manner.
      1) Install starter drive on armature shaft.
      2) Drive snap ring on shaft. (Figure 9)

      ![Figure 9]

      3) Force snap ring into retainer. (Figure 10)

      ![Figure 10]

      4) Lubricate drive housing bushing with 4 to 5 drops of S.A.E. #20 oil.
      5) Make sure thrust collar is in place against snap ring and retainer.
d. Check pinion clearance.

(NOTE: Shift starter drive into the cranking position and check clearance between starter drive and drive stop. Check with specifications and repair or adjust when needed.)

e. Test starter with a battery and jumper cables to determine starter motor performance.
STARTING SYSTEMS AND CIRCUITS
UNIT V

JOB SHEET #3 — TEST A STARTER MOTOR (NO-LOAD)

A. Tools and materials
   1. Starter
   2. Basic hand tool set
   3. Fully charged battery
   4. Ammeter
   5. Starter technical manual specifications
   6. Voltmeter
   7. Carbonpile resistor
   8. Tachometer
   9. Safety glasses
  10. Appropriate service manual

B. Procedures
   (CAUTION: Remove all jewelry prior to working on any electrical system, and follow all shop safety procedures.)

      a. Remove starter from engine.
      b. Connect starter motor to a fully charged battery. (Figure 1)

   FIGURE 1

Reprinted from MOTOR Heavy Truck Repair Manual ©1985 by permission of The Hearst Corporation.
c. Connect an ammeter between battery and battery terminal of solenoid. (Figure 1)

d. Connect a switch with leads from battery terminal of solenoid to the switch ("W") terminal of the solenoid. (Figure 1)

e. Connect voltmeter to the motor terminal of solenoid and to ground terminal of starter. (Figure 1)

f. Connect carbon pile resistor across the battery. (Figure 1)

g. Place a tachometer on end of armature to measure armature speed. (Figure 1)

h. Start motor by connecting leads to battery terminal.

i. Vary the carbon pile resistor until the specified voltage is shown on the voltmeter.

j. Read the ammeter for the current draw.

k. Read the tachometer for the armature speed.

l. Compare the readings with the technical manual specifications for the starter motor being tested.

2. Interpret no-load test results by checking the problems you find.

   a. Rated current draw and no-load speed indicates a normal starter motor condition.

   b. Low free speed and high current draw indicate:

      1) Too much friction
      2) Shorted armature
      3) Grounded, armature of fields

   c. Failure to operate with high current draw indicates:

      1) A direct ground in the terminal or fields
      2) Frozen bearings

   d. Failure to operate with no current draw indicates:

      1) Open field circuit
      2) Open armature coils
      3) Broken brush springs, worn brushes, or high insulation between commutator bars
JOB SHEET #3

---

f. Low speed and low current draw indicates high internal resistance due to poor connections, dirty commutator, or an open field circuit.

---

f. High free speed and high current draw indicate shorted fields.

Obtain instructor's initials here ____________ before proceeding to Job Sheet #4.

(NOTE: Any of these problems indicate a need to rebuild the starter as outlined in Job Sheet #4.)
A. Tools and materials

1. Solenoid
2. Basic hand tool set
3. Voltmeter
4. Carbonpile resistor
5. Ammeter
6. Safety glasses

B. Procedure

(CAUTION: Remove all jewelry prior to working on any electrical system, and follow all shop safety procedures.)

1. Disassemble and assemble solenoid.
   a. Remove the screws or nut attaching the terminal plate assembly. (Figure 1)
JOB SHEET #4

b. Remove the screw that connects the pull in winding wire to the motor terminal. (Figure 1)

c. Remove contact disk and rod. (Figure 1)

d. Remove nuts on terminal studs and remove studs.

e. Clean and inspect all components.

f. Replace or repair all pitted or worn parts.

g. Reassemble solenoid in reverse order of disassembly.

2. Check solenoid hold-in windings.

a. Make the test connections as shown in Figure 2.

![FIGURE 2]

- Voltmeter
- Switch
- Carbon Pile
- Ammeter
- 12V Battery Supply

Hold-In Winding Test
Courtesy of J.I. Case Company.

b. Close the switch and adjust the carbon pile to decrease the battery voltage to the specified voltage. (Figure 2)

c. Record ammeter reading, turn carbon pile off and open the switch.

d. Compare ammeter reading with the test specifications.

(NOTE: A high reading indicates a shorted winding. A low reading indicates excessive resistance.)
3. Check pull-in winding.
   a. Make test connections as shown in Figure 3.

   ![Figure 3 Diagram]

   FIGURE 3

   Voltmeter
   Switch
   Ammeter
   12V Battery
   Supply
   Carbon Pile

   Pull-In Winding Test
   Courtesy of J.I. Case Company.

   b. Close the switch and adjust the carbon pile to decrease the battery voltage to the specified voltage.

   (CAUTION: To prevent overheating, do not energize the pull-in winding more than 15 seconds.)

   c. Record the ammeter reading, turn the carbon pile off and open the switch.

   d. Compare ammeter reading with the test specification.

   (NOTE: A high reading indicates a shorted winding. A low reading indicates excessive resistance.)
STARTING SYSTEMS AND CIRCUITS
UNIT V

JOB SHEET #5 — CHECK VOLTAGE DROP IN A STARTER CIRCUIT

A. Tools and materials
   1. Engine
   2. Voltmeter
   3. Appropriate service manual

B. Procedure
   (CAUTION: Remove all jewelry prior to working on any electrical system, and follow all shop safety procedures.)
   1. Check insulated cables.
      (NOTE: The following procedures are for a 12 volt negative ground system, using a 40 M.T. starter)
      a. Connect voltmeter positive lead to positive battery terminal. (Figure 1)
      b. Connect negative voltmeter lead to the battery terminal of the solenoid. (Figure 1)
      c. Set voltmeter on lowest scale.
      d. Prevent engine from starting.
      e. Crank engine and read meter.

FIGURE 1

(CAUTION: A cranking motor must never be used for more than 30 seconds at any time and cranking should not be repeated without a pause of two minutes.)
JOB SHEET #5

f. Check voltage drop.

(NOTE: If the voltage drop exceeds 0.4 volts, excessive resistance is indicated.)

2. Check solenoid contacts.

a. Connect positive voltmeter lead to the battery terminal of solenoid. (Figure 2)

FIGURE 2

b. Connect negative voltmeter lead to the motor terminal of solenoid. (Figure 2)

c. Crank engine and read meter.

d. Check voltage drop.

(NOTE: If voltage drop exceeds 0.3 volts, excessive resistance is indicated.)
3. Check ground cable.
   a. Connect voltmeter positive lead to the ground terminal of starter. (Figure 3)
   
   **FIGURE 3**
   
   b. Connect voltmeter negative lead to the negative post of battery. (Figure 3)
   c. Crank engine and read meter.
   d. Check voltage drop.

   (NOTE: If the voltage drop exceeds 0.4 volts, excessive resistance is indicated.)
STARTING SYSTEMS AND CIRCUITS
UNIT V

PRACTICAL TEST
JOB SHEET #1 — REMOVE AND REPLACE A STARTER

STUDENT'S NAME ___________________________ DATE __________

EVALUATOR'S NAME ___________________________ ATTEMPT NO. _____

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

1. Checked out proper tools and materials. YES NO
2. Disconnected battery. YES NO
3. Removed cables and electrical wires and labeled. YES NO
4. Removed starter from engine. YES NO
5. Cleaned starter and block mounting surfaces. YES NO
6. Installed starter and tightened bolts. YES NO
7. Repositioned starter wires and cables in the correct place and tightened nuts securely. YES NO
8. Checked all connections. YES NO
9. Replaced battery cable. YES NO
10. Started engine to check starter action. YES NO
11. Checked in/out away tools and materials. YES NO
12. Cleared the work area. YES NO
13. Used proper tools correctly. YES NO
14. Performed steps in a timely manner (____hrs. ____min. ____sec.) YES NO
15. Practiced safety rules throughout procedure. YES NO
16. Provided satisfactory responses to questions asked. YES NO

EVALUATOR'S COMMENTS: ____________________________________________

________________________________________
JOB SHEET #1 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

<table>
<thead>
<tr>
<th></th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starter operates properly.</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>All connections are clean and tight.</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

EVALUATOR'S COMMENTS: ________________________

PERFORMANCE EVALUATION KEY

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<td>4</td>
<td>Skilled — Can perform job with no additional training.</td>
</tr>
<tr>
<td>3</td>
<td>Moderately skilled — Has performed job during training program; limited additional training may be required.</td>
</tr>
<tr>
<td>2</td>
<td>Limited skill — Has performed job during training program; additional training is required to develop skill.</td>
</tr>
<tr>
<td>1</td>
<td>Unskilled — Is familiar with process, but is unable to perform job.</td>
</tr>
</tbody>
</table>

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in “Product Evaluation” and divide by the total number of criteria.)
STARTING SYSTEMS AND CIRCUITS
UNIT V

PRACTICAL TEST
JOB SHEET #2 — DISASSEMBLE, TEST, AND REASSEMBLE
A STARTER

STUDENT'S NAME ___________________________________________ DATE __________

EVALUATOR'S NAME _________________________________________ ATTEMPT NO. _____

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All Items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

1. Checked out proper tools and materials. YES NO
2. Cleaned starter before disassembly.
3. Marked starter housings.
4. Removed bolts from the commutator end frame.
5. Disconnected the field coil from the brush holders.
6. Removed the lever and drive housing.
7. Removed the armature.
8. Removed starter drive from the armature.
9. Removed starter brushes.
10. Cleaned all starter components.
11. Inspected starter bushing and replaced if required.
12. Inspected brushes and replaced if required.
13. Inspected the starter drive and replaced if required.
15. Tested the armature for short circuits.
17. Checked armature shaft runout.
18. Checked field coil for opens.
19. Checked field coil for grounds.
20. Replaced or repaired any parts that were worn or damaged.
21. Lubricated all bushings, wicks and oil reservoirs.
22. Reassembled starter in the correct order.
23. Checked and adjusted pinion clearance.
24. Tested starter for operation.
25. Checked in/put away tools and materials.
26. Cleaned the work area.
27. Used proper tools correctly.
28. Performed steps in a timely manner (___hrs. ___min. ___sec.)
29. Practiced safety rules throughout procedure.
30. Provided satisfactory responses to questions asked.

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JOB SHEET #2 PRACTICAL TEST

EVALUATOR'S COMMENTS:

________________________________________________________

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

4  3  2  1

Testing procedures and test equipment were used correctly.

4  3  2  1

Starter motor performs properly.

EVALUATOR'S COMMENTS:

________________________________________________________

PERFORMANCE EVALUATION KEY

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(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)
STARTING SYSTEMS AND CIRCUITS
UNIT V

PRACTICAL TEST
JOB SHEET #3 — TEST A STARTER MOTOR (NO-LOAD)

STUDENT'S NAME ___________________________ DATE ___________

EVALUATOR’S NAME _________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under “Process Evaluation” must receive a “Yes” for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the “Yes” or “No” blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

1. Checked out proper tools and materials. YES NO
2. Connected starter to battery. YES NO
3. Connected ammeter. YES NO
4. Connected switch. YES NO
5. Connected voltmeter. YES NO
6. Connected carbon pile resistor. YES NO
7. Used tachometer. YES NO
8. Performed no-load test. YES NO
9. Compared the readings of meters with technical manual. YES NO
10. Came to a conclusion on test results. YES NO
11. Checked in/put away tools and materials. YES NO
12. Cleaned the work area. YES NO
13. Used proper tools correctly. YES NO
14. Performed steps in a timely manner (___hrs. ___min. ___sec.) YES NO
15. Practiced safety rules throughout procedure. YES NO
16. Provided satisfactory responses to questions asked. YES NO

EVALUATOR’S COMMENTS: ________________________________________________

________________________________________________________________________
JOB SHEET #3 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

<table>
<thead>
<tr>
<th></th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
</table>

Made all connections correctly.

<table>
<thead>
<tr>
<th></th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
</table>

Student's evaluation is correct.

EVALUATOR'S COMMENTS: ____________________________

<table>
<thead>
<tr>
<th>PERFORMANCE EVALUATION KEY</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 — Skilled — Can perform job with no additional training.</td>
</tr>
<tr>
<td>3 — Moderately skilled — Has performed job during training program; limited additional training may be required.</td>
</tr>
<tr>
<td>2 — Limited skill — Has performed job during training program; additional training is required to develop skill.</td>
</tr>
<tr>
<td>1 — Unskilled — Is familiar with process, but is unable to perform job.</td>
</tr>
</tbody>
</table>

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)
STARTING SYSTEMS AND CIRCUITS  
UNIT V  

PRACTICAL TEST  
JOB SHEET #4 — REBUILD AND TEST A STARTER SOLENOID  

STUDENT'S NAME ________________________________ DATE ____________  

EVALUATOR'S NAME ________________________________ ATTEMPT NO. ________  

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under “Process Evaluation” must receive a “Yes” for you to receive an overall performance evaluation.  

PROCESS EVALUATION  
(EVALUATOR NOTE: Place a check mark in the “Yes” or “No” blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)  

The student:  

<table>
<thead>
<tr>
<th>Step Description</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Checked out proper tools and materials.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Removed the screws in terminal plate.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Removed the screw from the pull in winding wire.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Removed contact disk and rod.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Removed terminal studs.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Cleaned and inspected and repaired or replaced all components.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Reassembled solenoid.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Checked solenoid held-in winding.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Compared test results with specifications.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Checked input away tools and materials.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Cleaned the work area.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. Used proper tools correctly.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. Performed steps in a timely manner (___hrs. ___min. ___sec.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. Practiced safety rules throughout procedure.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16. Provided satisfactory responses to questions asked.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

EVALUATOR'S COMMENTS: ____________________________________________________________
JOB SHEET #4 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

<table>
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<tr>
<th></th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. All components are clean and installed properly.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>2. Testing procedures and test equipment were used correctly.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>3. Student's evaluation is correct.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

EVALUATOR'S COMMENTS: ____________________________________________________________

<table>
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<th>PERFORMANCE EVALUATION KEY</th>
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<td>4  — Skilled — Can perform job with no additional training.</td>
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<td>3  — Moderately skilled — Has performed job during training program; limited additional training may be required.</td>
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<td>1  — Unskilled — Is familiar with process, but is unable to perform job.</td>
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</table>

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)
STARTING SYSTEMS AND CIRCUITS
UNIT V

PRACTICAL TEST
JOB SHEET #5 — CHECK VOLTAGE DROP IN A STARTER CIRCUIT

STUDENT'S NAME ___________________________ DATE ____________
EVALUATOR'S NAME ___________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under “Process Evaluation” must receive a “Yes” for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the “Yes” or “No” blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

1. Checked out proper tools and materials. YES NO
2. Made voltmeter connection on insulated cables. YES NO
3. Cranked engine and read voltage drop. YES NO
4. Made voltmeter connections for the solenoid contacts. YES NO
5. Cranked engine and read voltage drop. YES NO
6. Made voltmeter connections for ground cables. YES NO
7. Cranked engine and read voltage drop. YES NO
8. Checked in/put away tools and materials. YES NO
9. Cleaned the work area. YES NO
10. Used proper tools correctly. YES NO
11. Performed steps in a timely manner (___hrs. ___min. ___sec.) YES NO
12. Practiced safety rules throughout procedure. YES NO
13. Provided satisfactory responses to questions asked. YES NO

EVALUATOR'S COMMENTS: ________________________________
JOB SHEET #5 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a “3” for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

<table>
<thead>
<tr>
<th>Testing procedures and test equipment were used correctly.</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student’s evaluation of test results is correct.</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

EVALUATOR’S COMMENTS:


PERFORMANCE EVALUATION KEY

| 4   | Skilled — Can perform job with no additional training. |
| 3   | Moderately skilled — Has performed job during training program; limited additional training may be required. |
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STARTING SYSTEMS AND CIRCUITS
UNIT V

NAME ____________________________  SCORE ______________________

TEST

1. Match the terms on the right with their correct definitions.
   a. Ends of a magnet in the field frame assembly of a starting motor
   b. Wire wrapped around pole pieces to increase the strength of the magnetic field when current is passed through the windings
   c. Main drive of starter motor; converts electrical energy into mechanical energy
   d. Metal segments attached to ends of wire loops to form contact surface on armature
   e. Sliding contacts to feed electrical energy from battery to commutator
   f. Small gear that meshes with a larger gear
   g. Electromagnetic switch that closes circuit and engages the motor drive pinion with the flywheel
   h. Any switch that closes the circuit between the battery and starter motor
   i. Tendency of a body in motion to remain in motion
   j. Counter electromotive force
   k. The drop, or current used in cables
   l. Activates the motor switch

2. List three types of starting systems.
   a. __________________________________________
   b. __________________________________________
   c. __________________________________________
3. List two sources of compressed air for air starting motors.
   a. _____________________________________________________________
   b. _____________________________________________________________

4. Select from the following list components of a gasoline starting system by placing an "X" beside each correct component.
   _____a. Motor switch
   _____b. Clutch
   _____c. Drive pinion
   _____d. Oil heater
   _____e. Gear box
   _____f. Gasoline engine

5. Select from the following list types of starting aids by placing an "X" beside each correct type.
   _____a. Oil heater
   _____b. Block heater
   _____c. Clutch
   _____d. Glow plug
   _____e. Starter switch
   _____f. Starting fluid

6. State the purpose of an electrical starting circuit.
   _____________________________________________________________
   _____________________________________________________________
7. Label the major parts in an electrical starting circuit.

8. Match parts related to a starting circuit with the correct functions.
   - a. Supplies energy for the circuit
     - 1. Battery
   - b. Activates the circuit
     - 2. Motor switch
   - c. Closes circuit to motor and engages motor drive with flywheel
     - 3. Starting motor
   - d. Drives flywheel to start engine
     - 4. Starter switch

9. Select the major parts of a starting motor by placing an “X” beside the correct part.
   - a. Motor switch
   - b. Shoe pole
   - c. Field frame assembly
   - d. Armature
   - e. Rotor
   - f. Drive mechanism
TEST

10. Match component parts of a starting motor with their correct functions.

____.a. Forms a magnetic field of force around armature
   1. Armature

____.b. Wrapped around pole shoe to strengthen magnetic field when current is passed through the winding
   2. Brushes

____.c. Converts electrical energy into mechanical energy to drive mechanism to crank engine
   3. Commutator

____.d. Forms contact surface for battery to feed electrical current through armature
   4. Field winding

____.e. Sliding contacts which feed electrical energy to the commutator
   5. Pole shoe

11. Complete the following statement concerning the conversion of electrical energy into mechanical energy by filling in the blanks correctly with the following words: Rotate, conductor, magnetic.

   Current carrying __________ formed in a loop and mounted on a shaft, will cause the shaft to __________ when placed inside a __________ field.

12. Select true statements concerning how a starting motor is kept running by placing an "X" beside each statement that is true.

____.a. The magnetic field around the armature and the magnetic field between the pole pieces repel each other causing the armature to turn.

____.b. Metal segments on the ends of the commutator make a one-half turn reversing their connection through sliding contacts which causes the current to flow in the opposite direction in the armature windings.

13. Arrange in order the current flow in an electrical starting motor circuit by placing the correct sequence number beside each step.

____.a. The solenoid closes allowing current to flow from the battery terminal of the solenoid to the motor terminal of the solenoid, and at the same time, engages the starter drive with the flywheel. Current then passes through the starter and back to ground.

____.b. With the key switch in the "start" position, current flows from the battery terminal of the starter through the magnetic switch and to ground.

____.c. The magnetic switch closes, allowing current to flow from the battery terminal of the solenoid to the switch terminal of the solenoid.
TEST

14. Identify four types of starter field circuits.

a. ____________________________
b. ____________________________

c. ____________________________
d. ____________________________

15. Match the types of starter field circuits with the current flow in each type circuit.

_____ a. Current flows through all field windings before it flows through the two insulated brushes to the armature.

_____ b. Current flows through one field winding to the brushes, and also through the other field winding to the brushes, placing the field windings in parallel.

_____ c. One-third of the current flows through each pair of field windings to one of the three insulated brushes.

_____ d. One or more of the poles is shunt wound, connected directly to ground to prevent excessive speeds.

1. Compound-wound
2. Parallel-wound
3. Series-parallel-wound
4. Series-wound
TEST

16. List four types of starting motor switches.
   a. 
   b. 
   c. 
   d. 

17. Explain two ways starter drives are engaged.
   a. 
   b. 

18. Identify three types of electromagnetic or lever shift drives.
   a. 
   b. 
   c. 

![Diagram of electromechanical components]
19. Arrange in order the steps in the operation of a series-parallel switch by placing the correct sequence number beside each step.

_____a. Solenoid circuit is completed by a set of points mechanically closed by the series-parallel switch plunger and starter turns over.

_____b. Starter switch closes, connecting two 12 volt batteries in series with the starting motor.

_____c. Starter switch is released, going into neutral position, permitting operation of electrical equipment by two 12 volt batteries in parallel for normal operation.

20. Arrange in order the steps in the operation of a transformer-rectifier unit by placing the correct sequence number beside each step.

_____a. This action engages the solenoid and current then flows from the battery terminal of solenoid to the motor terminal, through the starter to ground, and into the negative post of the batteries marked A. This action connects both sets of batteries in series, creating 24 V for starting.

_____b. The current for the solenoid switch and for cranking flows from the positive posts of the “B” batteries to the battery terminal on the solenoid switch, to and over the magnetic switch disk, to insulated terminals, and through the solenoid windings to ground.
The operator closes the start switch, forcing 12 V from the batteries marked “A” through the magnetic switch, closing the cranking motor actuating circuit.

21. Demonstrate the ability to:
   a. Remove and replace a starter. (Job Sheet #1)
   b. Disassemble, test, and reassemble a starter. (Job Sheet #2)
   c. Test a starter motor (no-load). (Job Sheet #3)
   d. Rebuild and test a starter solenoid. (Job Sheet #4)
   e. Check voltage drop in a starter circuit. (Job Sheet #5)
1. a. 9  g. 10  
b. 5  h. 7  
c. 1  i. 6  
d. 4  j. 3  
e. 2  k. 12  
f. 8  l. 11  

2. a. Electric motors  
b. Gasoline engines  
c. Air starters  

3. a. Separate engine and compressor  
b. Air from exhaust manifold on highway diesel tractors  

4. b, c, e, f  

5. a, b, d, f  

6. Converts electrical energy from the battery into mechanical energy at the starting motor to crank the engine.  

7. a. Battery  
b. Starter switch  
c. Motor switch  
d. Starting motor  

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

9. a, c, d, f  

10. a. 5  
b. 4  
c. 1  
d. 3  
e. 2  

11. Conductor, rotate, magnetic  

12. a, b
ANSWERS TO TEST

13. a. 3  
   b. 1  
   c. 2  

14. a. Parallel-wound  
    b. Series-wound  
    c. Series-parallel-wound  
    d. Compound-wound

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

    b. Solenoid  
    c. Magnetic  
    d. Series-parallel

17. Explanation should include:  
   a. Inertia of armature acting through drive mechanism  
   b. Electromagnetic plunger to mechanically shift pinion into mesh

18. a. Positork®  
    b. Overrunning clutch  
    c. Sprag clutch drive

19. a. 2  
    b. 1  
    c. 3

20. a. 3  
    b. 2  
    c. 1

21. Performance skills evaluated to satisfaction of instructor
IGNITION CIRCUITS
UNIT VI

UNIT OBJECTIVE

After completion of this unit, the student should be able to remove, service, and replace components of an ignition circuit. Competencies will be demonstrated by completing the job sheets and the unit tests with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to ignition circuits with their correct definitions.
2. Explain the purpose of an ignition circuit.
3. Identify components of an ignition circuit.
4. Match components of an ignition circuit with their correct functions.
5. Distinguish between primary and secondary ignition circuit components.
6. Identify components of a distributor.
7. Arrange in order steps in the operation of an ignition circuit beginning with the battery through one complete cycle.
8. Identify components of a distributor with a built-in governor.
9. Arrange in order steps in the operation of a governed distributor.
10. Distinguish between transistorized and capacitive discharge ignition systems.
OBJECTIVE SHEET

11. Match major components of an electronic ignition system with their functions.

12. Select true statements concerning general precautions for electronic ignition systems.

13. Demonstrate the ability to:
   a. Remove and install a distributor. (Job Sheet #1)
   b. Remove and replace contact points and condenser. (Job Sheet #2)
   c. Adjust dwell on an externally adjustable distributor. (Job Sheet #3)
   d. Check and set ignition timing. (Job Sheet #4)
   e. Remove, service, and replace spark plugs. (Job Sheet #5)
IGNITION CIRCUITS
UNIT VI

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.
   (NOTE: This activity should be completed prior to the teaching of this unit.)
B. Make transparencies from the transparency masters included with this unit.
C. Provide students with objective sheet.
D. Discuss unit and specific objectives.
E. Provide students with information sheet.
F. Discuss information sheet.
   (NOTE: Use the transparencies to enhance the information as needed.)
G. Provide students with job sheets.
H. Discuss and demonstrate the procedures outlined in the job sheets.
I. Integrate the following activities throughout the teaching of this unit:
   1. Discuss the different methods of ignition bypass.
   2. Show electronic parts to students and explain their operation.
   3. Discuss spark plug components.
   4. Discuss ignition cables.
   5. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.
J. Give test.
K. Evaluate test.
L. Reteach if necessary.

REFERENCES USED IN DEVELOPING THIS UNIT

REFERENCES USED IN DEVELOPING THIS UNIT


SUGGESTED SUPPLEMENTAL RESOURCES

A. **Text**

   *Chilton's Guide to Electronic Engine Controls*
   Order #CH-7535
   Teaching Aids Incorporated
   P.O. Box 1798
   Costa Mesa, CA 92628-0798

B. **Filmstrips**

   1. *The Ignition System Explained*
      Order #B-401
      Teaching Aids Incorporated
      P.O. Box 1798
      Costa Mesa, CA 92628-0798

   2. *Electronic Ignition Systems*
      Order #D-E1000
      Teaching Aids Incorporated
      P.O. Box 1798
      Costa Mesa, CA 92628-0798
IGNITION CIRCUITS
UNIT VI

INFORMATION SHEET

I. Terms and definitions

A. Coil polarity — A means of connecting the coil primary windings to the distributor so that current produced at the spark plug will travel from center electrode to ground

Example: Negative-ground systems — The negative primary terminal of coil is connected to distributor. Positive-ground systems — The positive primary terminal is connected to the distributor.

B. Condenser — A unit installed between the breaker points and coil to prevent arcing

(NOTE: A condenser has the ability to absorb and retain surges of electricity.)

C. Dwell — Number of degrees of distributor cam rotation that the ignition points are closed

D. Electronic ignition system — Ignition system using a control unit and magnetic pickup to open and close the primary circuit

E. Electronic module — A switching device that opens and closes the ignition to primary ground circuit

F. Primary ignition circuit — Low voltage circuit which energizes the ignition coil

G. Secondary ignition circuit — High voltage circuit which produces electrical current to jump spark plug gap

H. Spark plug — Provides the gap for the high voltage spark to ignite the fuel/air mixture

I. Timing — Igniting the fuel-air mixture at the exact instant that will enable the engine to develop maximum power

J. Timing marks — Marks used to synchronize ignition circuit so that plugs will fire at precise time

(NOTE: Timing marks are usually located on the vibration damper or flywheel.)
II. Purpose of an ignition circuit — The ignition circuit produces a high voltage spark which ignites the fuel-air mixture in the engine cylinder.

III. Components of an ignition circuit (Transparency 1)

A. Battery
B. Ignition switch
C. Primary resistance unit
D. Ignition coil
E. Contact points
F. Condenser
G. Distributor
H. Breaker cam
I. Spark-advance mechanism

(NOTE: There are two types of spark-advance mechanisms — vacuum and mechanical. Engine vacuum controls timing advance in relation to engine load. Mechanical advance changes engine timing according to engine speed.)

J. Rotor
K. Distributor cap
L. Spark plug
M. Primary ignition wire
N. Secondary ignition cable
O. Ignition bypass circuit

IV. Components of an Ignition circuit and their functions (Transparency 1)

A. Battery — Source of electrical power
B. Ignition switch — Opens and closes the primary circuit between battery and contact points
C. Primary resistance unit — Reduces voltage in the primary circuit to protect the contact points
D. Ignition coil — Transforms low voltage into high voltage necessary to jump the spark plug gap

E. Contact points — Make and break the primary circuit to allow the coil to produce high voltage at the spark plugs

F. Condenser — Device that absorbs surges in the primary circuit when the opening of the ignition points causes an interruption in current flow

G. Distributor — Contains the contact points and condenser; distributes the high voltage current from the coil to the proper cylinder

H. Breaker cam — Opens and closes the contact points

I. Spark-advance mechanism — Regulates the timing of the high voltage circuit for best ignition during all speed and load conditions

J. Rotor — Takes the high voltage current from the coil and directs it to the correct cylinder

K. Distributor cap — Holds the coil and spark plug wires in a sequence and provides a cover for the distributor

L. Spark plug — Provides a spark gap inside the engine cylinder to ignite the fuel-air mixture

M. Primary ignition wire — Carries low voltage from the battery through the ignition coil to the points

N. Secondary ignition cable — Carries high voltage from the secondary side of the coil to the spark plug (heavily insulated wire)

O. Ignition bypass circuit — Primary ignition circuit that bypasses the ignition resistance unit, permitting full battery voltage to the ignition coil during starting only

V. Ignition circuit components

A. Primary — Low voltage circuit (Transparency 2)

1. Battery

2. Ignition switch

3. Resistance unit

4. Primary winding of the coil
INFORMATION SHEET

5. Contact points
6. Condenser
7. Low voltage wire that connects the units

B. Secondary — High voltage circuit (Transparency 3)
1. Secondary winding of the coil
2. Distributor cap
3. Rotor
4. Spark plug
5. High voltage wire that connects the units

VI. Components of a distributor (Transparency 4)
A. Distributor cap
B. Rotor
C. Centrifugal advance mechanism
D. Condenser
E. Vacuum advance unit
F. Breaker plate
G. Distributor cam
H. Contact points
I. Distributor housing
J. Primary lead wire
K. Distributor drive gear

VII. Operation of an ignition circuit
A. With the Ignition switch on and the contact points closed, low voltage current flows from the battery through the primary winding of the coil and through the contact points to ground. (Transparency 5)
B. The flow of low voltage current through the primary windings of the coil causes a magnetic field buildup. (Transparency 6)
C. As the contact points open, current attempts to flow across the point surfaces; the condenser attached to the points absorbs this flow of current. (Transparency 7)

D. Stopping this flow of current causes the magnetic field of the coil to collapse across the secondary coil windings, causing a high voltage surge. (Transparency 8)

E. This high voltage surge is directed from the secondary windings of the coil through the distributor cap and rotor and on to the spark plug to ground. (Transparency 9)

VIII. Components of a distributor with a built-in governor

(NOTE: Except for the built-in maximum speed governor, this distributor is similar to the standard distributor.)

![Diagram of distributor components]

A. Valve shaft
B. Ballast weight
C. Adjusting nut
D. Return spring
E. Cover band

Reprinted with permission of Delco Remy Division, GM Corp.
IX. Operation of a governed distributor (Transparency 10)

A. Vacuum from the intake manifold draws air through the air cleaner, through the distributor and past the carburetor actuator. An overriding feature on the butterfly valve allows the foot pedal to control the butterfly valve position except when the actuator diaphragm pull is sufficient to overcome the opposing spring force.

B. When the distributor shaft revolves fast enough the centrifugal force of the weight pulls against the spring, causing the valve shaft to move transversely in the main shaft, restricting the flow of air.

C. When this restriction occurs, a vacuum is created in the carburetor actuator, causing it to move the butterfly valve in the carburetor, thereby governing the engine speed.

X. Transistorized and capacitive discharge ignition systems

(Note: Both variations are designed to increase primary voltage to coil and reduce voltage to points or eliminate points.)

A. Transistorized ignitions

1. Amplifier is included in circuit between points and ignition coil.

2. Transistors allow very low voltage through the points and very high voltage to the primary windings in coil.

B. Capacitive discharge system

1. System contains special ignition distributor, amplifier, and special coil.

2. System operates to charge a capacitor to a high voltage which, on signal from distributor, is then discharged through the primary windings in coil.

Air Flow and Vacuum Connections Between Carburetor and Delco-Remy Governed Distributor (Typical)

Reprinted from MOTOR Truck and Diesel Repair Manual ©1985 by permission of The Hearst Corporation.
Major components of an electronic ignition system and their functions (Transparency 11)

(NOте: The electronic ignition system functions the same as the conventional ignition system; however, in the electronic system, an electronic control unit and its sensory device, a magnetic pickup, does the job of the ignition points of the conventional system.)

A. Resistor — Maintains constant primary current flow according to engine speed and is bypassed during cranking

B. Control module — Controls the flow of current in the primary windings of the ignition coil and maintains constant dwell

(Cnote: On Ford, Chrysler, and American Motors, this module is a separate unit, mounted firmly to the firewall or fender shield. On G.M. cars, it is self-contained within the distributor.)

C. Magnetic pickup assembly — Sends a small voltage pulse to the control unit to trigger switching transistor to stop current flow in the coil primary windings

D. Armature or reluctor — Rotates with the distributor shaft producing a voltage pulse in the magnetic pickup
XII. General safety precautions for electronic ignition systems

(NOTE: There are numerous variations in procedures, techniques, tools, and parts for servicing all the electronic ignition systems. An appropriate service manual will provide safe, reliable repair procedures.)

A. Always turn the ignition switch off when disconnecting or connecting any electrical connectors or components.

B. Never reverse the battery polarity or disconnect the battery with the engine running.

C. Disconnect the ignition switch feed wire at the distributor when making compression tests.
   (NOTE: This will avoid arcing that may damage components, especially on computer-based ignition systems.)

D. Check all replacement part numbers carefully.
   (CAUTION: Installing the wrong component for a specific application can damage the system.)

E. All manufacturer's instructions must be followed carefully when using test equipment.
   (NOTE: Inaccurate readings and/or damage to ignition system components may result due to the use of improper test equipment.)
Components of an Ignition Circuit

- Spark Advance Mechanism
- Condenser
- Contact Points
- Secondary Ignition Cable
- Breaker Cam
- Rotor
- Primary Resistance Unit
- Ignition Switch
- Primary Ignition Wire
- Distributor
- Spark Plug
- Ignition Coil
- Contact Disk
- Resistor Bypass Circuit Operates Only While Cranking Engine
- Solenoid
- Overrunning Clutch
- Motor Terminal
- Starting Motor
- Battery
- Ignition Bypass Circuit
- Motor Terminal
Primary Circuit

To Starter Motor

Magnetic Switch

Contact Points

Condenser

Battery

Ignition Switch

Resistance Unit

Primary Winding

Low Voltage Wire

Coll
Secondary Circuit

- High Voltage Wire
- Rotor
- Secondary Winding
- Distributor Cap
- Spark Plug
- Coil
- Battery
Components of a Distributor

- Primary Lead
- Contact Points
- Distributor Cam
- Breaker Plate
- Condenser
- Vacuum Advance Unit
- Permanent Lubrication Reservoir
- Centrifugal Advance Mechanism
- Distributor Cap
- Rotor
- Housing
- Drive Gear

Reprinted with permission of Delco Remy Division, GM Corp.
Operation of an Ignition Circuit

Contact Points (Breaker Points) Closed

Primary Winding

Primary Resistance Unit

Ignition Switch On

Ignition Coil
Operation of an Ignition Circuit — B

Contact Points (Breaker Points)
Closed

Magnetic Field Build Up

Primary Winding

Ignition Coil

Ignition Switch On

Wall in Ill Rio
Operation of an Ignition Circuit — C

Contact Points (Breaker Points) Open

Condenser Absorbs Extra Current Momentarily to Prevent Points from Arcing

Ignition Coil

Ignition Switch On

2S6 Ignition Switch On 11.1111, VIM 287
Operation of an Ignition Circuit — D

Contact Points (Breaker Points) Open

High Voltage Surge

Ignition Switch On

Magnetic Field Collapses Across the Secondary Coil Winding
Operation of an Ignition Circuit - E

- Spark Plug
- Rotor
- Ignition Coil
- Secondary Winding
- Distributor Cap
- High Voltage Surge
- Ignition Switch On
- Battery
Operation of a Governed Distributor

- Distributor
- To Carburetor Air Cleaner
- Carburetor
- Centrifugal Valve
- Carburetor Actuator
- Butterfly Valve
- Manifold Vacuum

Reprinted from MOTOR Truck and Diesel Repair Manual ©1985 by permission of The Hearst Corporation.
Major Components of an Electronic Ignition System

- Spark Plug
- Distributor Cap
- Ignition Coil
- Electronic Control Module
- Rotor
- Vacuum Advance
- Magnetic Pick-Up
- Reluctor or Armature
- Ignition Switch
- Battery

Courtesy of Allied Aftermarket, Division of Allied-Signal, Inc.
IGNITION CIRCUITS
UNIT VI

JOB SHEET #1 — REMOVE AND INSTALL A DISTRIBUTOR

A. Tools and materials
   1. Engine
   2. Basic hand tool set
   3. Set of ignition wrenches
   4. Special distributor wrenches as required
   5. Auxiliary starter button
   6. Spark plug socket wrench
   7. Shop towels
   8. Safety glasses
   9. Appropriate service manual

B. Procedure

(CAUTION: Remove all jewelry prior to working on electrical system, and follow all shop safety procedures.)

1. Remove distributor.
   a. Disconnect negative battery cable from battery.
   b. Remove air cleaner if required.
   c. Remove the distributor wire from coil or distributor as required.
   d. Remove the distributor cap and position out of the way.
   e. Mark position of the rotor.

   (NOTE: It is necessary that the position be marked or indicated in some manner for re-installation.)

   f. Remove vacuum hose line from distributor and plug.
JOB SHEET #1

g. Remove distributor clamp screw and hold-down clamp. (Figure 1)

FIGURE 1

h. Pull distributor up slowly and check direction the rotor turns.

(NOTE: The amount the rotor turns and the direction it turns will be necessary for re-installation.)

i. Remove distributor from engine.

(NOTE: If engine is not disturbed while distributor is out, it can be reinstalled without turning engine.)

(CAUTION: Avoid dropping bolts, brackets, or foreign material into opening. Cover with a shop towel.)

j. Service distributor as required.

2. Install distributor.

a. Remove number one cylinder spark plug.

b. Install auxiliary starter button, and crank the engine until compression is felt on number one cylinder.
c. Crank the engine with short movements until the timing marks on the fly-wheel index with the timing marks on the front cover. (Figure 2)

**FIGURE 2**

![Image of engine fly-wheel with timing marks](image.png)

d. Place distributor in opening.

(Note: The rotor must be pointing in the same direction as it was before removal.)

e. Move distributor, if necessary, to engage the oil pump shaft.

(Note: Occasionally the distributor will not fall into place because the oil pump shaft has moved. The rotor should be positioned as close as possible to the beginning location and the engine rotated slightly until it falls into place. Some distributor drives will be driven by oil pump and gear mesh will not be necessary.)

f. Install hold-down clamp and clamp screw.

g. Static time point openings.

(Note: A connection between distributor side of coil and ground with a light or buzzer can be used.)

h. Tighten the hold-down screw slightly.

i. Replace vacuum lines.

j. Replace distributor cap and wires if removed.

k. Replace spark plugs and plug wires.

l. Replace distributor lead wire.

m. Check all connections for correct placement.

n. Start engine and check timing.

p. Check operation of automatic advance.
IGNITION CIRCUITS
UNIT VI

JOB SHEET #2 — REMOVE AND REPLACE CONTACT POINTS AND CONDENSER

A. Tools and materials
   1. Engine
   2. B&sic hand tool set
   3. Ignition wrenches
   4. Feeler gauges, .010-.025
   5. Distributor cam lubricant
   6. Point alignment tools
   7. Timing light
   8. Shop towels
   9. Safety glasses
  10. Appropriate service manual

B. Procedure

   (CAUTION: Remove all jewelry prior to working on electrical system, and follow all shop safety procedures.)

   1. Make sure that ignition switch is in the off position.
   2. Remove distributor cap.
   3. Remove rotor.
   4. Determine condition of contact points and location of wires, screws, and eccentric as used.
JOB SHEET #2

5. Disconnect contact point primary lead wire and condenser wire by loosening screw. (Figure 1)

FIGURE 1

6. Loosen screws holding contact points in place. (Figure 2)

FIGURE 2

7. Remove contact point set.
8. Remove screw holding condenser in place.
9. Remove condenser.
10. Clean breaker plate and distributor cam.
JOB SHEET #2

11. Lubricate distributor cam with a light coat of cam lubricant. (Figure 3)
   (NOTE: On distributors with the centrifugal weights accessible, place a drop of light oil on each weight pivot post.)

   FIGURE 3

12. Place the contact points in distributor and install attaching screws.

13. Replace condenser and attaching screw; tighten securely.

14. Replace the primary lead and condenser wires.
   (NOTE: Position the wires in such a manner to avoid binding or grounding.)

15. Tighten primary lead and condenser wires securely.

16. Check point alignment and adjust as required.

17. Check contact point breaker spring tension.
18. Adjust contact point opening. (Figure 4)

(NOTE: Crank the engine to position the rubbing block of the contact points on the peak of the cam lobe.)

FIGURE 4

19. Adjust contact points to manufacturer's recommendations.

20. Tighten contact point attaching screws securely; recheck contact point opening.

21. Install rotor.

(NOTE: Make sure the rotor is positioned correctly and securely in place.)

22. Install distributor cap.

(NOTE: Make sure the distributor is positioned correctly and securely in place.)

23. Replace distributor in engine, if removed.

25. Set timing to manufacturer's specification. (Figure 5)

FIGURE 5
IGNITION CIRCUITS
UNIT VI

JOB SHEET #3 — ADJUST DWELL ON AN EXTERNALLY ADJUSTABLE DISTRIBUTOR

A. Tools and materials
   1. Engine
   2. Dwell meter
   3. Hex contact point adjusting tool
   4. Safety glasses
   5. Appropriate service manual

B. Procedure

(CAUTION: Remove all jewelry prior to working on electrical system, and follow all shop safety procedures.)

1. Connect dwell meter. (Figure 1)

   (CAUTION: Observe correct hookup procedures, and position wires away from moving engine parts.)

   FIGURE 1

   ![Diagram of distributor side of coil with dwell meter connections]

2. Refer to manufacturer's specifications for desired dwell setting.

3. Start the engine.
JOB SHEET #3

4. Adjust idle speed to manufacturer's specification.
5. Raise distributor cap adjustment window.
6. Insert hex wrench into contact point adjustment screw. (Figure 2)

FIGURE 2

7. Adjust contact point dwell while observing dwell meter reading to comply with manufacturer's specifications.
   (NOTE: Recheck engine idle speed.)
8. Remove hex wrench and recheck dwell reading.
9. Shut off the engine.
10. Remove dwell meter.
11. Push window on distributor cap down securely.
IGNITION CIRCUITS
UNIT VI

JOB SHEET #4 — CHECK AND SET IGNITION TIMING

A. Tools and materials
   1. Engine
   2. Timing light
   3. Combination end wrenches, 7/16"-9/16"
   4. Special distributor wrenches as required
   5. Chalk
   6. Shop towels
   7. Safety glasses
   8. Appropriate service manual

B. Procedure

(CAUTION: Remove all jewelry prior to working on electrical system, and follow all shop safety procedures.)

1. Obtain manufacturer's specifications for ignition timing, dwell, and rpm.
   (NOTE: Rpm and dwell must be set to manufacturer's specifications before timing is set.)

2. Remove vacuum line at the distributor and plug. (Figure 1)

FIGURE 1

REMOVE VACUUM LINE
3. Locate and clean the ignition timing marks on the harmonic balancer; mark with chalk.
4. Locate and clean the timing pointer or plate on the front cover.
5. Connect the timing light according to the instructions for the light being used.
   (NOTE: Do not puncture spark plug cables with pins or clips to make connections.)
6. Position wires away from moving engine parts.
7. Start the engine.
8. Make sure the engine is idling at manufacturer's recommendations.
   (NOTE: The engine must idle correctly to prevent incorrect timing caused by the centrifugal advance.)
9. Direct the timing light toward the timing marks. (Figure 2)
   (NOTE: If the timing is correct, the timing marks will line up at the check point. If the timing is incorrect, proceed as follows.)

FIGURE 2

TIMING
10. Loosen the clamp or lock screw on the distributor.

11. Move the distributor until the timing marks are lined up. (Figure 3)

   FIGURE 3

   MOVE DISTRIBUTOR TO ADJUST TIMING

12. Tighten the clamp or lock screw on the distributor.

13. Recheck timing.


15. Disconnect timing light.

   (NOTE: Remove timing light adapter on spark plug if used.)

16. Replace vacuum line on distributor.
IGNITION CIRCUITS
UNIT VI

JOB SHEET #5 — REMOVE, SERVICE, AND REPLACE SPARK PLUGS

A. Tools and materials
   1. Engine
   2. Spark plug socket, 3/8" drive
   3. Ratchet, 3/8” drive
   4. Extensions, 3”-6”-10” by 3/8” drive
   5. Shop towels
   6. Safety glasses
   7. Appropriate service manual
   8. Torque wrench

B. Procedure
   (CAUTION: Remove all jewelry prior to working on electrical system, and follow all shop safety procedures.)
   1. Remove spark plug wires.
      (NOTE: Pull the wire from the spark plug by grasping the terminal, not by pulling on the wire.)
   2. Loosen the spark plugs.
   3. Clean the area around the spark plug by blowing, wiping, or brushing. (Figure 1)
      (CAUTION: Protect your eyes when using compressed air.)

FIGURE 1

CLEAN AROUND SPARK PLUG
JOB SHEET #5

4. Remove the spark plugs.

(NOTE: Arrange the spark plugs in order as they are removed. The condition of the spark plug can tell a lot about the operation of a particular cylinder. See Figure 2.)

FIGURE 2

5. Wipe the plug hole seat with a clean, dry cloth.

(NOTE: Be careful not to get dirt or filings into the combustion chamber.)

6. Consult the service manual for the proper spark plug.

7. Reset gap on new spark plugs to manufacturer's specifications. (Figure 3)

(NOTE: Use a wire gauge to check the gap. Make sure the electrode surfaces are parallel. Regap every time plugs are serviced.)

(CAUTION: Bend only the ground electrode.)

FIGURE 3
8. Install the plug by hand until tight.

9. Finish the installation with a torque wrench, using torque recommendation in Table 1.

**Table 1**

**SAE-ISO RECOMMENDED INSTALLATION TORQUE**

<table>
<thead>
<tr>
<th>Plug Thread</th>
<th>Cast Iron Heads</th>
<th>Aluminum Heads</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pound Feet</td>
<td>Newton Meters</td>
</tr>
<tr>
<td>10mm Gasket Seat</td>
<td>7-11 lb. ft.</td>
<td>10-15NM</td>
</tr>
<tr>
<td>12mm Gasket Seat</td>
<td>11-19 lb. ft.</td>
<td>15-25NM</td>
</tr>
<tr>
<td>14mm Gasket Seat</td>
<td>26-29 lb. ft.</td>
<td>35-40NM</td>
</tr>
<tr>
<td>14mm Tapered Seat</td>
<td>7-15 lb. ft.</td>
<td>9-20NM</td>
</tr>
<tr>
<td>18mm Gasket Seat</td>
<td>32-38 lb. ft.</td>
<td>43-52NM</td>
</tr>
<tr>
<td>18mm Tapered Seat</td>
<td>15-20 lb. ft.</td>
<td>20-27NM</td>
</tr>
<tr>
<td>7/8&quot;-18</td>
<td>35-43 lb. ft.</td>
<td>47-58NM</td>
</tr>
</tbody>
</table>

**If no torque wrench is available —** tapered seat 14 and 18mm — tighten 1/4" turn (snug) after finger tight. 14 and 18mm gasket seat plugs — tighten 1/2" turn past snug. 10mm gasket seat plugs — tighten 5/8" turn past snug.

Courtesy of Allied Aftermarket, Division of Allied-Signal, Inc.

10. Replace the spark plug wires in the proper order.

   (NOTE: Push the spark plug wires securely into place, and make sure they are in the brackets or holders.)
IGNITION CIRCUITS
UNIT VI

PRACTICAL TEST
JOB SHEET #1 — REMOVE AND INSTALL A DISTRIBUTOR

STUDENT'S NAME ____________________________ DATE __________

EVALUATOR'S NAME ____________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under “Process Evaluation” must receive a “Yes” for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the “Yes” or “No” blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student: YES NO

1. Checked out proper tools and materials. __________ __________
2. Disconnected negative battery cable. __________ __________
3. Removed the distributor wire from coil or distributor. __________ __________
4. Removed distributor cap. __________ __________
5. Removed vacuum hose and plugged. __________ __________
6. Removed clamp screw and hold-down clamp. __________ __________
7. Removed distributor. __________ __________
8. Removed number one spark plug and found top dead center on number one cylinder. __________ __________
9. Installed distributor. __________ __________
10. Installed hold-down clamp and clamp screw. __________ __________
11. Replaced vacuum line. __________ __________
12. Replaced distributor cap and wires. __________ __________
13. Replaced spark plugs and plug wires. __________ __________
14. Checked all connections for correct placement. __________ __________
15. Started engine and checked timing. __________ __________
16. Checked in/put away tools and materials. __________ __________
17. Cleaned the work area. __________ __________
18. Used proper tools correctly. __________ __________
19. Performed steps in a timely manner (____hrs. ____min. ____sec.) __________ __________
20. Practiced safety rules throughout procedure. __________ __________
21. Provided satisfactory responses to questions asked. __________ __________

EVALUATOR'S COMMENTS: __________________________________________

__________________________________________________________________

__________________________________________________________________

312
JOB SHEET #1 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

Steps were performed in proper sequence.

Engine performs correctly.

EVALUATOR'S COMMENTS:

PERFORMANCE EVALUATION KEY

<table>
<thead>
<tr>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skilled — Can perform job with no additional training.</td>
<td>Moderately skilled — Has performed job during training program; limited additional training may be required.</td>
<td>Limited skill — Has performed job during training program; additional training is required to develop skill.</td>
<td>Unskilled — Is familiar with process, but is unable to perform job.</td>
</tr>
</tbody>
</table>

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)
IGNITION CIRCUITS
UNIT VI

PRACTICAL TEST
JOB SHEET #2 — REMOVE AND REPLACE CONTACT POINTS
AND CONDENSER

STUDENT'S NAME ___________________________ DATE ___________

EVALUATOR'S NAME ___________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

**PROCESS EVALUATION**

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student: YES NO

1. Checked out proper tools and materials. _______ _______
2. Checked to see that the ignition switch was off. _______ _______
3. Removed distributor cap. _______ _______
4. Removed rotor. _______ _______
5. Disconnected wires from points and condenser. _______ _______
6. Removed contact point set. _______ _______
7. Removed condenser. _______ _______
8. Installed new points and condenser in distributor. _______ _______
9. Checked point alignment and adjusted as required. _______ _______
10. Adjusted contact points. _______ _______
11. Installed rotor and distributor cap. _______ _______
12. Started engine and checked timing. _______ _______
13. Checked in/out away tools and materials. _______ _______
14. Cleaned the work area. _______ _______
15. Used proper tools correctly. _______ _______
16. Performed steps in a timely manner (____hrs. ____min. ____sec.) _______ _______
17. Practiced safety rules throughout procedure. _______ _______
18. Provided satisfactory responses to questions asked. _______ _______

EVALUATOR'S COMMENTS: ___________________________

______________________________

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JOB SHEET #2 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

<table>
<thead>
<tr>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sequence of steps</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Point alignment</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Performance of engine</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

EVALUATOR'S COMMENTS: ____________________________________________________________

<table>
<thead>
<tr>
<th>PERFORMANCE EVALUATION KEY</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 — Skilled — Can perform job with no additional training.</td>
</tr>
<tr>
<td>3 — Moderately skilled — Has performed job during training program; limited additional training may be required.</td>
</tr>
<tr>
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(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)
IGNITION CIRCUITS
UNIT VI

PRACTICAL TEST
JOB SHEET #3 — ADJUST DWELL ON AN EXTERNALLY
ADJUSTABLE DISTRIBUTOR

STUDENT'S NAME ________________________________ DATE __________
EVALUATOR'S NAME ________________________________ ATTEMPT NO. _____

Instructions: When you are ready to perform this task, ask your Instructor to observe the procedure and complete this form. All items listed under “Process Evaluation” must receive a “Yes” for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the “Yes” or “No” blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:  YES  NO

1. Checked out proper tools and materials.  __________  __________
2. Connected dwell meter.  __________  __________
3. Started engine and adjusted idle.  __________  __________
4. Adjusted point dwell.  __________  __________
5. Killed engine and removed dwell meter.  __________  __________
6. Checked in/put away tools and materials.  __________  __________
7. Cleaned the work area.  __________  __________
8. Used proper tools correctly.  __________  __________
9. Performed steps in a timely manner (____hrs. ____min. ____sec.)  __________  __________
10. Practiced safety rules throughout procedure.  __________  __________
11. Provided satisfactory responses to questions asked.  __________  __________

EVALUATOR'S COMMENTS: __________________________________________
______________________________________________________________________
JOB SHEET #3 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

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<tbody>
<tr>
<td>Sequence of steps</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Dwell setting</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Engine performance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

EVALUATOR'S COMMENTS: _____________________________________________
_________________________________________________________________
_________________________________________________________________
_________________________________________________________________

PERFORMANCE EVALUATION KEY

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<th>Description</th>
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<td>Skilled — Can perform job with no additional training.</td>
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<tr>
<td>3</td>
<td>Moderately skilled — Has performed job during training program; limited</td>
</tr>
<tr>
<td></td>
<td>additional training may be required.</td>
</tr>
<tr>
<td>2</td>
<td>Limited skill — Has performed job during training program; additional</td>
</tr>
<tr>
<td></td>
<td>training is required to develop skill.</td>
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<td>1</td>
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(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)
IGNITION CIRCUITS
UNIT VI

PRACTICAL TEST
JOB SHEET #4 — CHECK AND SET IGNITION TIMING

STUDENT'S NAME ___________________________ DATE __________

EVALUATOR'S NAME ________________________ ATTEMPT NO. _____

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

1. Checked out proper tools and materials. YES NO
2. Obtained manufacturer's specifications. _____ _____
3. Removed vacuum line at the distributor and plugs. _____ _____
4. Marked harmonic balance. _____ _____
5. Connected timing light. _____ _____
6. Started engine and set idle. _____ _____
7. Set timing using timing light. _____ _____
8. Killed engine and disconnected timing light. _____ _____
9. Replaced vacuum line and ran engine. _____ _____
10. Checked in/put away tools and materials. _____ _____
11. Cleaned the work area. _____ _____
12. Used proper tools correctly. _____ _____
13. Performed steps in a timely manner (____hrs. ____min. ____sec.) _____ _____
14. Practiced safety rules throughout procedure. _____ _____
15. Provided satisfactory responses to questions asked. _____ _____

EVALUATOR'S COMMENTS: ____________________________________________

______________________________________________
JOB SHEET #4 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

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<tr>
<th>4</th>
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Sequence of steps

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</table>

Engine timing is set correctly.

---

EVALUATOR'S COMMENTS:

---

PERFORMANCE EVALUATION KEY

| 4 — Skilled — Can perform job with no additional training. |
| 3 — Moderately skilled — Has performed job during training program; limited additional training may be required. |
| 2 — Limited skill — Has performed job during training program; additional training is required to develop skill. |
| 1 — Unskilled — Is familiar with process, but is unable to perform job. |

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)
IGNITION CIRCUITS
UNIT VI

PRACTICAL TEST
JOB SHEET #5 — REMOVE, SERVICE, AND REPLACE SPARK PLUGS

STUDENT'S NAME ___________________________ DATE ____________

EVALUATOR'S NAME ___________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your Instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

1. Checked out proper tools and materials. YES NO
2. Removed plug wires. YES NO
3. Removed spark plugs. YES NO
4. Consulted service manual. YES NO
5. Reset or checked spark plug gap. YES NO
6. Installed spark plugs. YES NO
7. Torqued plug with torque wrench. YES NO
8. Replaced spark plug wires. YES NO
9. Checked in/put away tools and materials. YES NO
10. Cleaned the work area. YES NO
11. Used proper tools correctly. YES NO
12. Performed steps in a timely manner (__hrs. __min. __sec.) YES NO
13. Practiced safety rules throughout procedure. YES NO
14. Provided satisfactory responses to questions asked. YES NO

EVALUATOR'S COMMENTS: __________________________________________

__________________________________________

__________________________________________
JOB SHEET #5 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

<table>
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<tr>
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<tr>
<td>Sequence of steps</td>
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<tr>
<td>Spark plug gap</td>
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<tr>
<td>Engine performance</td>
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EVALUATOR'S COMMENTS:

PERFORMANCE EVALUATION KEY

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
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<tbody>
<tr>
<td>4</td>
<td>Skilled — Can perform job with no additional training.</td>
</tr>
<tr>
<td>3</td>
<td>Moderately skilled — Has performed job during training program; limited additional training may be required.</td>
</tr>
<tr>
<td>2</td>
<td>Limited skill — Has performed job during training program; additional training is required to develop skill.</td>
</tr>
<tr>
<td>1</td>
<td>Unskilled — Is familiar with process, but is unable to perform job.</td>
</tr>
</tbody>
</table>

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)
IGNITION CIRCUITS
UNIT VI

NAME ___________________________  SCORE ___________________________

TEST

1. Match the terms on the right with their correct definitions.

   a. Igniting the fuel-air mixture at the exact instant that will enable the engine to develop maximum power
   b. Marks used to synchronize the ignition circuit so that plugs will fire at the precise time
   c. Low voltage circuit which energizes the ignition coil
   d. High voltage circuit which produces electrical current to jump spark plug gap
   e. Number of degrees of distributor cam rotation that the ignition points are closed
   f. A unit installed between the breaker points and coil to prevent arcing
   g. A means of connecting the coil primary windings to the distributor so that current produced at the spark plug will travel from center electrode to ground
   h. Ignition system using a control unit and magnetic pickup to open and close the primary circuit
   i. A switching device that opens and closes the ignition to primary ground circuit
   j. Provides the gap for the high voltage spark to ignite the fuel/air mixture

   1. Coil polarity
   2. Condenser
   3. Dwell
   4. Electronic ignition system
   5. Electronic module
   6. Primary ignition circuit
   7. Secondary ignition circuit
   8. Spark plug
   9. Timing
   10. Timing marks

2. Explain the purpose of an ignition circuit.

   ______________________________________________________________________
   ______________________________________________________________________
   ______________________________________________________________________

   322
3. Identify the components of an ignition circuit.

a. ________________ b. ________________

c. __________________ d. __________________

e. __________________ f. __________________

f. __________________ g. __________________

h. __________________ i. __________________

i. __________________ j. __________________

k. __________________ l. __________________

l. __________________ m. __________________

m. __________________ n. __________________

n. __________________ o. __________________
4. Match the components of an ignition circuit on the right with their correct functions.

_____a. Source of electrical power
1. Battery

_____b. Opens and closes the primary circuit between battery and contact points
2. Breaker cam

_____c. Reduces voltage in the primary circuit to protect the contact points
3. Condenser

_____d. Transforms low voltage into high voltage necessary to jump the spark plug gap
4. Contact points

_____e. Make and break the primary circuit to allow the coil to produce high voltage at the spark plugs
5. Distributor

_____f. Device that absorbs surges in the primary circuit when the opening of the ignition points causes an interruption in current flow
6. Distributor cap

_____g. Contains the contact points and condenser; distributes the high voltage current from the coil to the proper cylinder
7. Ignition bypass circuit

_____h. Opens and closes the contact points
8. Ignition coil

_____i. Regulates the timing of the high voltage circuit for best ignition during all speed and load conditions
9. Ignition switch

_____j. Takes the high voltage current from the coil and directs it to the correct cylinder
10. Primary ignition wire

_____k. Holds the coil and spark plug wires in a sequence and provides a cover for the distributor
11. Primary resistance unit

_____l. Provides a spark gap inside the engine cylinder to ignite the fuel-air mixture
12. Rotor

_____m. Carries low voltage from the battery through the ignition coil to the points primary side of the ignition coil
13. Secondary ignition cable

_____n. Carries high voltage from the secondary side of the coil to the spark plug
14. Spark-advance mechanism

_____o. Primary ignition circuit that bypasses the ignition resistance unit, permitting full battery voltage to the ignition coil during starting only
15. Spark plug
TEST

5. Distinguish between primary and secondary ignition circuit components by placing a "P" next to primary components and an "S" next to secondary components.

   ____a. Resistance unit
   ____b. Condenser
   ____c. Distributor cap
   ____d. Ignition switch
   ____e. Rotor
   ____f. Secondary winding of the coil
   ____g. High voltage wire that connects the units
   ____h. Low voltage wire that connects the units
   ____i. Contact points
   ____j. Battery
   ____k. Primary winding of the coil
   ____l. Spark plug
6. Identify the components of a distributor.

a. __________________________ b. __________________________
c. __________________________ d. __________________________
e. __________________________ f. __________________________
g. __________________________ h. __________________________
i. __________________________ j. __________________________
k. __________________________

7. Arrange in order the steps in the operation of an ignition circuit beginning with the battery through one complete cycle by placing the correct sequence number beside each step.

_____a. As the contact points open, current attempts to flow across the point surfaces; the condenser attached to the points absorbs this flow of current.

_____b. This high voltage surge is directed from the secondary windings of the coil through the distributor cap and rotor and on to the spark plug to ground.

_____c. The flow of low voltage current through the primary windings of the coil causes a magnetic field buildup.
d. Stopping this flow of current causes the magnetic field of the coil to collapse across the secondary coil windings, causing a high voltage surge.

e. With the ignition switch 'on' and the contact points closed, low voltage current flows from the battery through the primary winding of the coil and through the contact points to ground.

8. Identify the components of a distributor with a built-in governor.

![Distributor Diagram]

- a. 
- b. 
- c. 
- d. 
- e. 

---
9. Arrange in order the steps in the operation of a governed distributor by placing the correct sequence number beside each step.

a. When the distributor shaft revolves fast enough the centrifugal force of the weight pulls against the spring, causing the valve shift to move transversely in the main shaft restricting the flow of air.

b. When this restriction occurs, a vacuum is created in the carburetor actuator, causing it to move the butterfly valve in the carburetor, thereby governing the engine speed.

c. Vacuum from the intake manifold draws air through the air cleaner, through the distributor and past the carburetor actuator. An overriding feature on the butterfly valve allows the foot pedal to control the butterfly valve position except when the actuator diaphragm pull is sufficient to overcome the opposing spring force.

10. Distinguish between transistorized and capacitive discharge ignition systems by placing an "X" next to the descriptions of transistorized ignitions.

a. System contains special ignition distributor, amplifier, and special coil.

b. Transistors allow very low voltage through the points and very high voltage to the primary windings in coil.

c. Amplifier is included in circuit between points and ignition coil.

d. System operates to charge a capacitor to a high voltage which, on signal from distributor, is then discharged through the primary windings in coil.
TEST

11. Match major components of an electronic ignition system on the right with their functions.

   a. Maintains constant primary current flow according to engine speed and is bypassed during cranking
   b. Sends a small voltage pulse to the control unit to trigger switching transistor to stop current flow in the coil primary windings
   c. Rotates with the distributor shaft, producing a voltage pulse in the magnetic pickup
   d. Controls the flow of current in the primary windings of the ignition coil and maintains constant dwell

   1. Armature or reluctor
   2. Control module
   3. Magnetic pickup assembly
   4. Resistor

12. Select true statements concerning general safety precautions for electronic ignition systems by placing an "X" beside each statement that is true.

   a. Always turn the ignition off when disconnecting or connecting any electrical connectors or components.
   b. Reverse the battery polarity or disconnect the battery with the engine running.
   c. Disconnect the ignition switch feed wire at the distributor when making compression tests.
   d. Check all replacement part numbers carefully.
   e. All manufacturer's instructions must be followed carefully when using test equipment.

   (NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

13. Demonstrate the ability to:

   a. Remove and install a distributor. (Job Sheet #1)
   b. Remove and replace contact points and condenser. (Job Sheet #2)
   c. Adjust dwell on an externally adjustable distributor. (Job Sheet #3)
   d. Check and set ignition timing. (Job Sheet #4)
   e. Remove, service, and replace spark plugs. (Job Sheet #5)
IGNITION CIRCUITS
UNIT VI

ANSWERS TO TEST

1. a. 9 f. 2
   b. 10 g. 1
   c. 6 h. 4
   d. 7 i. 5
   e. 3 j. 8

2. Explanation should include — The ignition circuit produces a high voltage spark which ignites the fuel-air mixture in the engine cylinder.

3. a. Battery
   b. Ignition switch
   c. Primary resistance unit
   d. Ignition coil
   e. Contact points
   f. Condenser
   g. Distributor
   h. Breaker cam
   i. Spark-advance mechanism
   j. Rotor
   k. Distributor cap
   l. Spark plug
   m. Primary ignition wire
   n. Secondary ignition wire
   o. Ignition bypass circuit

4. a. 1 f. 3 k. 6
   b. 9 g. 5 l. 15
   c. 11 h. 2 m. 10
   d. 8 i. 14 n. 13
   e. 4 j. 12 o. 7

5. a. P e. S l. P
   b. P f. S j. P
   c. S g. S k. P
   d. P h. P l. S

6. a. Distributor cap
   b. Rotor
   c. Centrifugal advance mechanism
   d. Condenser
   e. Vacuum advance unit
   f. Breaker plate
   g. Distributor cam
   h. Contact points
   i. Distributor housing
   j. Primary lead wire
   k. Distributor drive gear
ANSWERS TO TEST

7. a. 3
   b. 5
   c. 2
   d. 4
   e. 1

8. a. Valve shaft
   b. Ballast weight
   c. Adjusting nut
   d. Return spring
   e. Cover band

9. a. 2
   b. 3
   c. 1

10. b, c

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

12. a, c, d, e

13. Performance skills evaluated to satisfaction of instructor
ALTERNATOR CHARGING CIRCUITS
UNIT VII

UNIT OBJECTIVE

After completion of this unit, the student should be able to test charging circuits and remove, replace, and rebuild an alternator. Competencies will be demonstrated by completing the job sheets and the unit tests with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to alternator charging circuits with their correct definitions.
2. State the purpose of the alternator charging circuit.
3. Match alternator charging circuit components with their correct functions.
4. Identify the major parts of an alternator.
5. Discuss the construction of stator windings.
6. Distinguish between types of alternator circuits.
7. Select from a list characteristics of a brushless alternator.
8. Select true statements concerning the operation of a brushless alternator.
9. Select true statements concerning the operation of a transistorized regulator.
10. Complete statements concerning safety rules for working with alternator charging circuits.
11. Demonstrate the ability to:
   a. Test the Ford alternator charging circuit with external regulator. (Job Sheet #1)
   b. Remove and replace an alternator. (Job Sheet #2)
   c. Disassemble, test, and reassemble an alternator. (Job Sheet #3)
   d. Test a transistorized regulator. (Job Sheet #4)
   e. Test an S.I. series alternator. (Job Sheet #5)
   f. Test charging circuit resistance for GM alternator. (Job Sheet #6)
ALTERNATOR CHARGING CIRCUITS
UNIT VII

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

   (NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information sheet.

F. Discuss information sheet.

   (NOTE: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheets.

H. Discuss and demonstrate the procedures outlined in the job sheets.

I. Integrate the following activities throughout the teaching of this unit:
   1. Demonstrate different types of testing equipment.
   2. Have students identify different models of alternators.
   3. Demonstrate the removal of different types of diodes.
   4. Review safety precautions on electrical systems.
   5. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.
REFERENCES USED IN DEVELOPING THIS UNIT


SUGGESTED SUPPLEMENTAL RESOURCES

A. Text

*Heavy Truck Repair Manual*, Order Code D(3)
Motor Publications
555 West 57th Street
New York, NY 10019

B. Filmstrip

*Leece-Neville 2500 VB Alternator*, Order No. AS041
Educational Communications, Inc.
Department M
761 Fifth Avenue
King of Prussia, PA 19406
ALTERNATOR CHARGING CIRCUITS
UNIT VII

INFORMATION SHEET

I. Terms and definitions

A. Brushless alternator — An alternator that has neither slip rings nor brushes

B. Diode — Device that allows current to flow in one direction and blocks current in opposite direction

C. Grounded circuit — Circuit in which a wire touches ground causing the current to flow to ground instead of through the circuit

D. Heat sink — Dissipates heat from diodes

(Note: High ampere alternators often use finned diodes for better heat removal.)

E. Open circuit — Circuit in which a wire is broken or disconnected

F. Potentiometer — Acts as a voltage divider or voltage adjustment

G. Rectifier bridge — Six diodes mounted in one assembly

H. Rotor — Wire coil wrapped around an iron core and mounted on a rotating shaft

(Note: The rotor assembly does the same job for the alternator as the field coil and pole shoe do for the generator; however, the rotor assembly revolves.)

I. Short circuit — Wire touching another wire and providing a shorter path for current to flow

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INFORMATION SHEET

J. Slip rings — Metal conductors in the form of a ring, fastened to each end of coil and mounted on rotor shaft

(NOTE: Current flows through the regulator, through the insulated brush, through one slip ring into the coil, and out through the other slip ring and the other brush to ground.)

K. Stator — Laminated soft iron ring with three groups of coils

(NOTE: The stator assembly does the same job as the armature in a generator; however, the stator is fixed while the armature turns.)

L. Transistorized regulator — Fully electronic unit composed of resistors, diodes, zener diode, transistors, and thermistor

II. Purpose of the alternator charging circuit — The alternator charging circuit recharges the battery and maintains a supply of electrical current to meet the operating needs of the equipment.

III. Alternator charging circuit components and functions (Transparency 1)

A. Battery

1. Starts the circuit by supplying spark to start engine.
2. Helps out during peak operation when electrical load is too much for alternator.
3. Stabilizes system voltage

B. Alternator

1. Supplies electrical power to accessory circuits
2. Recharges battery

C. Regulator — Limits the alternator voltage to a safe, preset value

D. Ammeter — Measures the rate of current flow

E. Voltmeter — Indicates produced voltage

F. Indicator lights — Indicates problems in system; used in place of a meter
IV. Major parts of an alternator (Transparencies 2 and 3)
   A. Drive end frame
   B. Rotor assembly
   C. Stator assembly
   D. Slip ring end frame
   E. Diodes
   F. Brush assembly
   G. Pulley

V. Construction of stator windings — Windings have three phases which are connected together to form a "Y" or delta connection, with each winding connected to a positive and negative diode. (Transparency 4)

VI. Types of alternator circuits
   (NOTE: The regulator places a resistance in the field circuit which reduces current flow to the alternator rotor.)
   A. External regulator — Field current is regulated before it gets to the rotor, and the field is grounded in the alternator. When the field is grounded in the alternator, it is called a "B" circuit.
   B. Internal regulator — Field current is regulated after it goes through the rotor, and the field is grounded through the regulator. When the field is grounded in the regulator, it is called an "A" circuit.

VII. Characteristics of a brushless alternator (Transparency 5)
   A. High mileage unit
   B. Used on both gasoline and diesel engines
   C. Regulator compartment can be vented for increased capability
   D. Uses large bearings at both ends
   E. Has extra large grease reservoirs
   F. Has extra large lip seal to keep grease in and dirt out
   G. Regulator compartment is air tight
   H. Designed to operate between engine overhauls without attention
VIII. Operation of a brushless alternator
A. To generate voltage in the stator windings, it is only necessary for the rotor to cause alternating north and south magnetic lines to cut across the stator windings.
B. The field coil is mounted to the end frame.
C. The rotor is mounted on bearings and fits between the stator and field coil.
D. The field coil produces a north pole at the right hand side of the coil.
E. Magnetic lines cross the air gap between the field coil and rotor to make all the right hand rotor poles all north poles.
F. The non-magnetic lines of force cannot go through the non-magnetic ring directly; instead they pass through the air gap into the left hand south magnetic poles of the rotor; the magnetic lines then cross the air gap between the rotor and field coil and then into the field coil to complete the magnetic path.
G. The non-magnetic ring has diverted the magnetic field into the stator windings, and as the rotor turns, AC voltage is generated in the stator windings.

IX. Operation of a transistorized regulator
A. Allows battery current to excite the alternator field coils
B. Controls charging voltage at safe values during operation by regulating the field current

X. Safety rules for working with alternator charging circuits
A. Never attempt to polarize the circuit.
B. Be sure the battery is in good operating condition before making any tests or adjustments.
C. Never operate the alternator in an open circuit, except when instructed in the technical manual.
D. Never short or ground the alternator terminals.
E. Do not disconnect the voltage regulator while the alternator is running.
F. Disconnect the negative battery cable first when removing the alternator or battery.
G. Do not use acid-core solder on the alternator terminals; use only a rosin-core solder.
H. Never immerse the circuit components in cleaning solution.
Alternator Charging Circuit Components

Alternator With Internal Voltage Regulator

Alternator With External Mounted Voltage Regulator

Courtesy of Deutz-Allis Corporation.
Parts of an Alternator

- Heat Sink
- Diodes
- Slip Ring End Frame
- Stator Assembly
- Brush Assembly
- Pulley
- Rotor Assembly
- Drive End Frame
Parts of an Alternator
(Continued)

REAR BEARING
REAR HOUSING SPRINGS
BRUSHES
DIODE PLATES
PRINTED-CIRCUIT BOARD
WASHER
STATOR
TERMINAL INSULATORS
BRUSH RETAINER
INSULATOR
BEARING SPACERS
ROTOR
SLIP-RING
BEARING RETAINER
FRONT HOUSING
FAN SPACER
FAN
PULLEY
NUT

Courtesy of Ford Motor Company.
Stator Winding Construction

Delta-Connected Stator Windings

"Y"-Connected Stator Windings
Brushless Alternator Construction

- 24-Volt Output Terminal
- T-R Rectifier Bridge
- Extra-Large Grease Reservoir
- Stationary Field Coil (Brushless Construction)
- Steel Bushing with Locking Thread
- Lip Seals
- Labyrinth Seal
- Heavy-duty Ball Bearings
- Extra-Large Grease Reservoir
- Transformer
- Transformer Rectifier for 24-Volt Starting
- Integrated Circuit Regulator
- Heavy-Duty Roller Bearing with Lip Seal
- Steel Mounting Bushings
- Adjustable Bushing
ALTERNATOR CHARGING CIRCUITS
UNIT VII

JOB SHEET #1 — TEST THE FORD ALTERNATOR CHARGING CIRCUIT
WITH EXTERNAL REGULATOR

A. Tools and materials

1. Vehicle
2. Basic hand tool set
3. Voltmeter
4. Ammeter
5. Variable resistor
6. Jumper wire
7. Safety glasses

B. Procedure

(CAUTION: Remove all jewelry prior to working on electrical system, and follow all shop safety procedures.)

(NOTE: There are many methods of testing the alternator systems. The method outlined in this job sheet is simplified and adaptable to most light-duty alternators.)

1. Test the battery.
   (NOTE: For valid tests, the battery must be at least half charged and in good condition.)
2. Check and adjust belt tension.
3. Test alternator output.

(NOTE: The following diagnostic procedures are for a charging system that is not charging.)

a. Make test instruments connections as shown in Figure 1.

b. Disconnect the field from the regulator by removing the regulator gang plug.
JOB SHEET #1

c. Connect the field to the battery output terminal with jumper lead. (Figure 2)

(NOTE: This "feeds" the field directly, bypassing the regulator and wiring.)

FIGURE 2

Reprinted from MOTOR Truck and Diesel Repair Manual ©1985 by permission of The Hearst Corporation.

d. Start and operate the engine at idle speed.

e. Adjust rheostat and engine speed until a speed of 2,000 rpm and a voltmeter reading of 15 volts is obtained.

(NOTE: These specifications may vary slightly from model to model; consult the appropriate service manual for accurate specifications.)

(CAUTION: Never allow voltmeter to read over 16 volts; damage to the charging system could occur.)

f. Read ammeter.

(NOTE: If the alternator starts to charge and is within 10 amps of rated output, the regulator or wiring is at fault. If the alternator does not charge, it is defective.)

g. Reduce engine speed and turn off carbon pile rheostat after current output test is completed.

h. Turn off ignition switch.
4. Test wiring.

a. Hook voltmeter to the wire connecting to the "A" terminal of the regulator and observe voltmeter reading. (Figure 3)

(NOTE: Remove gang plug from regulator.)

FIGURE 3

(b. Turn on ignition switch, and check voltage of the wire leading from the ignition switch to the regulator.

1) Test systems that have an ammeter by connecting voltmeter to the wire leading to the "S" terminal of the regulator. (Figure 4)

(NOTE: If there is no voltage, repair or replace wire.)

FIGURE 4
JOB SHEET #1

2) Test systems that have an indicator light by hooking voltmeter to the wire connecting to the "I" terminal of the regulator. (Figure 4)

(NOTE: If there is no voltage, repair or replace wire.)

c. Turn ignition switch off.

d. Test the wire connecting the "S" terminal of the alternator to the "S" terminal of the regulator. (Figure 5)

(NOTE: This procedure is for systems with an indicator light.)

1) Connect voltmeter to the wire leading to the "S" terminal of the alternator. (Figure 5)

FIGURE 5

2) Connect jumper lead to "A" and "S" terminals of the regulator. (Figure 5)

(NOTE: If there is no voltage, repair or replace wire.)
e. Test wire connecting the “F” terminal of the alternator to the “F” terminal of the regulator.

1) Hook voltmeter to wire leading to the “F” terminal of the alternator. (Figure 6)

FIGURE 6

2) Use jumper lead to connect the “A” and “F” terminals of the regulator.

(NOTE: If there is no voltage, repair or replace wire.)

f. Reconnect all regulator and alternator connections.

5. Test regulator.

a. Turn on ignition switch.

b. Check for good grounding of voltage regulator.

(NOTE: If the ground of the regulator is in question, connect jumper wire from the base of the regulator to the frame of the alternator.)

c. Connect voltmeter to the field of the alternator.

(NOTE: If there is no voltage and all the above tests were satisfactory, the voltage regulator is at fault.)
ALTERNATOR CHARGING CIRCUITS
UNIT VII

JOB SHEET #2 — REMOVE AND REPLACE AN ALTERNATOR

A. Tools and materials
   1. Vehicle
   2. Basic hand tool set
   3. Battery cable clamp removal tool
   4. Shop towels
   5. Safety glasses
   6. Appropriate service manual

B. Procedure
   (CAUTION: Remove all jewelry prior to working on electrical system, and follow all shop safety procedures.)
   1. Remove alternator.
      a. Remove battery ground.
      b. Remove wire leads.
         (NOTE: Alternator leads should be tagged for replacement.)
      c. Loosen the adjusting screw locknut. (Figure 1)
      d. Loosen retaining nut. (Figure 1)
      e. Loosen mounting bolts. (Figure 1)
      f. Remove alternator belt.

FIGURE 1

Courtesy of Cummins Engine Co., Inc.
JOB SHEET #2

9. Remove the adjusting link mounting bolt and the adjusting link. (Figure 2)

h. Remove the alternator mounting capscrew, nut, washer, and the alternator. (Figure 2)

FIGURE 2

1. Adjusting Link Mounting Bolt
2. Adjusting Link

2. Install alternator.
   a. Install the alternator, capscrew, washer, and nut to the mounting bracket.
      (NOTE: Do not tighten the capscrew and nut until the alternator belt is installed and adjusted.)
   b. Install the adjusting link and mounting capscrew.
   c. Install and adjust the alternator belt, using correct belt tension gauge.
   d. Install wire leads and tighten securely.
   e. Install battery ground cable.

3. Start engine and check operation of alternator.
ALTERNATOR CHARGING CIRCUITS
UNIT VII

JOB SHEET #3 — DISASSEMBLE, TEST, AND REASSEMBLE AN ALTERNATOR

A. Tools and materials
   1. Alternator
   2. Basic hand tool set
   3. Alternator pulley removal tools
   4. Alternator diode removal equipment
   5. Alternator testing equipment
   6. Torque wrench
   7. Shop towels
   8. Safety glasses
   9. Appropriate service manual

B. Procedure
   (CAUTION: Remove all jewelry prior to working on electrical system, and follow all shop safety procedures.)
   1. Disassemble alternator.
      a. Scribe the alternator before disassembly. (Figure 1)

FIGURE 1

Remove Thru Bolts
Scribe Alternator

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b. Remove through bolts holding the end frames together.

c. Pry at bolt locations to separate the drive end frame from the slip ring end frame. (Figure 2)

(NOTE: Be sure stator stays with slip ring end of frame.)

FIGURE 2

d. Remove the slip ring end frame and stator (as an assembly) from drive end frame and rotor assembly.

e. Remove the three stator lead attaching nuts.

f. Separate stator from slip ring end frame.

g. Remove screws, brushes, and brushholder assembly.

h. Remove heat sink from end frame.

i. Remove pulley retaining nut. (Figure 3)

FIGURE 3

REMOVE PULLEY RETAINING NUT
JOB SHEET #3

j. Remove pulley and fan using pullers as required.
k. Remove rotor and spacers from end frame assembly.
l. Remove drive frame bearing retainer and bearing from drive end frame.

2. Test alternator components.
   a. Wash all metal parts except stator, diodes, and rotor assemblies.
   b. Replace bearings as required.
   c. Inspect rotor slip rings.
      (NOTE: The slip rings should be clean and free of scratches.)
   d. Service as required.
   e. Inspect brushes for wear.
   f. Replace brushes as required.
   g. Test the rotor for grounds. (Figure 4)
      1) Hold one test probe of the ohmmeter against the rotor shaft.
      2) Hold the other against either of the slip rings. (Figure 4)
      (NOTE: If the field coil is not grounded, the ohmmeter will not move
      from its infinite position.)

FIGURE 4

Ohmmeter
Checking Rotor for Grounds, Shorts and Opens

Reprinted with permission of Delco Remy Division, GM Corp.
**JOB SHEET #3**

h. Test rotor for an open or short circuit by holding one probe against each slip ring. (Figure 4)

(NOTE: If there is no open or short circuit, the ohmmeter should indicate the resistance specified in the service manual.)

i. Test the stator for grounds.

1) Connect one test probe of the ohmmeter to the stator frame.

2) Connect the other test probe to any stator lead. (Figure 5)

![Figure 5: Checking Stator Windings](Check For Opens)

(Note: The ohmmeter will show an infinity reading when the stator winding is not grounded.)

j. Test the stator for open circuit.

(Note: This test will not work on a delta wound stator.)

1) Connect test probes of an ohmmeter between A and B stator leads. (Figure 5)
JOB SHEET #3

2) Connect test probes between A and C stator leads. (Figure 5)

3) Connect tests probes between B and C stator leads. (Figure 5)

(NOTE: If the ohmmeter falls to show continuity, there is an open winding)

k. Test diodes for shorts or opens.

(NOTE: If a test lamp is used instead of an ohmmeter, voltage should be 12 volts or less)

1) Connect one of the ohmmeter leads to the heat sink or diode body. (Figure 6)

2) Connect the other ohmmeter lead to the diode lead or flat metal connector. (Figure 6)

FIGURE 6

Capacitor
Brush Holder
Regulator

Insulated Heat Sink
Grounded Heat Sink

Connect To Flat Metal And Not Threaded Stud

Ohmmeter

Rep. printed with permission of Delco: Remy Division, GM Corp.
JOB SHEET #3

3) Observe the ohmmeter reading.

(NOTE: If both readings are low, the diode is shor ted. If both are high, the diode has an open. If one reading is high and the other is low, the diode is good.)

4) Check the other diodes in the same manner.

5) Replace any defective diodes.

(NOTE: Use special tools manufactured for this purpose.)

I. Test diode trio for resistance reaction.

(NOTE: A diode trio is used in conjunction with an integrated voltage regulator.)

1) Connect the negative ohmmeter probe to the long lead.

2) Connect the positive probe to each short lead. (Figure 7)

(NOTE: You should obtain at each short lead a low-resistance reaction.)

FIGURE 7

![Ohmmeter Single Connector Three Connectors](image-url)
3) Reverse the ohmmeter probes. (Figure 7)
   (NOTE: You should obtain a high reading.)

3. Reassemble alternator.
   a. Assemble heat sink to end frame.
b. Install brush holder and brushes into slip ring end frame. (Figure 8)

(NOTE: Insert a pin or wire through the hole to hold the brushes in the holder.)

FIGURE 8

BRUSHES IN POSITION

---

c. Install stator assembly in slip ring end frame, and locate diode connectors over the relay, diode, and stator leads.

d. Install and tighten terminal nuts securely.

e. Install bearing in drive end frame.

f. Install rotor in drive end frame.

g. Install fan, spacer, pulley, and retaining nut.

h. Tighten nut to manufacturer's specifications.

i. Assemble slip ring, end frame, and stator assembly to drive end frame and rotor assembly.

(NOTE: Align end frames by referring to scribe marks put on during disassembly.)
JOB SHEET #3

j. Install through bolts in the end frame assembly.
k. Tighten bolts securely.
l. Remove wire holding brushes in place.
m. Check alternator operation.
ALTERNATOR CHARGING CIRCUITS
UNIT VII

JOB SHEET #4 — TEST A TRANSISTORIZED REGULATOR

A. Tools and materials
   1. Vehicle
   2. Basic hand tool set
   3. Voltmeter
   4. Carbon pile resistor
   5. Ammeter
   6. Jumper wire
   7. Safety glasses
   8. Appropriate service manual

B. Procedure
   (CAUTION: Remove all jewelry prior to working on electrical system, and follow all shop safety procedures.)
   (NOTE: For a particular test procedure, always follow the equipment technical manual.)
   1. Test regulator voltage.
      (NOTE: This test can be performed either on or off the machine. Use an alternator that is known to be in good repair.)
      a. Set up the test circuit. (Figure 1)

      FIGURE 1
      ![Diagram of test circuit](image)

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JOB SHEET #4

b. Connect a voltmeter to the alternator ground and output terminals. (Figure 1)
   (NOTE: Be sure to use a voltmeter with an accuracy within 0.1 volts.)

c. Start the engine; momentarily connect jumper wire to excite the field, and apply a load of about 10 amperes — use lights, motors, carbon pile resistors, etc.

d. Operate the circuit for about 15 minutes to stabilize the temperature of the regulators.

e. Measure and record the temperature about one inch from the regulator case.

f. Compare the voltmeter reading with the voltage specifications listed in the machine service manual.

g. Adjust the reading for the temperature recorded above.

2. Adjust transistorized regulator.

   a. Use adjusting screw to change the operating voltage for different conditions.
      (NOTE: This may not be used on some transistorized regulators.)

   b. Since most transistorized regulators are sealed units, repair by replacing if they are found faulty.
ALTERNATOR CHARGING CIRCUITS
UNIT VII

JOB SHEET #5 — TEST AN S.I. SERIES ALTERNATOR

A. Tools and materials
   1. Vehicle
   2. Voltmeter
   3. Ammeter 0-75 amp rating or higher
   4. Carbon pile
   5. Screwdriver
   6. Clean shop towels
   7. Basic shop tools
   8. Appropriate service manual

B. Procedure

(CAUTION: Remove all jewelry prior to working on electrical system, and follow all shop safety procedures.)

1. Test the battery.

   (NOTE: For valid tests, the battery must be at least half charged and in good condition.)

2. Check alternator drive belt tension, and adjust as necessary.

3. Check all charging system wiring for defects and all terminal connections for cleanliness and tightness.

   (NOTE: If all the above steps are satisfactory, check the alternator with the following procedure.)

4. Disconnect battery ground cable.
5. Make test instrument connections for the type of alternator to be tested, as shown in Figure 1.

**FIGURE 1**

![Diagram of test connections for 10-SI, 27-SI, and 25-SI alternators.](image)

Reprinted with permission of Delco Remy Division, GM Corp.

(NOTE: The hex bolt on the output terminal on the 25-SI alternator is electrically insulated.)
6. Operate engine at moderate speed, and adjust the carbon pile rheostat as required to obtain maximum current output.

   (NOTE: If ammeter reading is within 10 amps of rated output, the alternator and regulator are not defective. If ammeter reading is not within 10 amps of rated output, bypass regulator to see if the alternator or regulator is at fault.)

7. Bypass regulators on 10-SI and 27-SI alternators. (Figure 2)

   (NOTE: Ground the field winding by inserting a screwdriver into the test hole.)

**FIGURE 2**

![Insert Screwdriver
Ground Tab To
End Frame

End Frame Hole

Tab

(CAUTION: Tab is within ¾ inch [19.05 mm] of the casting surface. Do not force screwdriver deeper into the end frame; severe damage to the alternator could result.)
   a. Remove field coil leads from the regulator.
   b. Ground one field lead and connect the other field lead to battery voltage.

9. Operate engine at moderate speed, and adjust carbon pile rheostat to obtain maximum current output.
   (NOTE: If current output is within 10 percent of rated output, replace the voltage regulator. If current output is not within 10 percent of rated output, remove alternator and bench test field windings, rectifier, and stator.)

10. Turn engine off and disconnect all test instruments.
ALTERNATOR CHARGING CIRCUITS
UNIT VII

JOB SHEET #6 — TEST CHARGING CIRCUIT RESISTANCE
FOR GM ALTERNATOR

A. Tools and materials

1. Vehicle
2. Basic tool set
3. Voltmeter
4. Ammeter
5. Jumper wire
6. Safety glasses
7. Appropriate service manual

B. Procedure

(CAUTION: Remove all jewelry prior to working on electrical system, and follow all shop procedures.)

(NOTE: This job sheet is adaptable to the Ford charging circuit covered in Job Sheet #1.)

1. Test wiring for 10 D.N. alternators.
   
a. Test wire going to #3 terminal of the regulator by connecting voltmeter.

   (NOTE: High resistance in this line will cause the alternator voltage to be high.)

   1) Connect a voltmeter as indicated by V1. (Figure 1 or Figure 2)

   (NOTE: Circuit #1 is for indicator light charging systems, and circuit #2 is for charging systems using an ammeter.)
2) Energize the field relay.
   a) Connect a jumper wire from the #3 terminal to the # terminal. (Figure 1)
      (NOTE: This will energize the field for circuit #1.)

      ![Figure 1](image)

      Reprinted with permission of General Motors Corporation.

   b) Turn on the ignition switch. (Figure 2)
      (NOTE: This will energize the field for circuit #2.)

      ![Figure 2](image)

      Reprinted with permission of General Motors Corporation.

   b. Observe voltmeter reading.
      (NOTE: The voltage drop should not exceed .3 volts.)
2. Test voltage drop between the alternator output terminal and the battery.
   a. Connect an ammeter in series with the battery terminal of the alternator. (Figure 1, 2, or 3)
   (NOTE: Figure 3 or circuit 3 features GM's SI series alternators.)

   ![Figure 3](image_url)

   Reprinted with permission of General Motors Corporation.
   b. Start the engine.
   c. Turn on enough lights and accessories to obtain a 20 ampere charge rate.
   d. Connect a voltmeter as indicated by V2 and V3. (Figures 1, 2, and 3)
   e. Observe voltmeter readings.
   (NOTE: The combined total of V2 and V3 should not exceed .8 volts.)

3. Test voltage drop in the ground circuit. (Figures 1, 2, and 3)
   a. Shut off engine, but leave lights and accessories on.
   b. Connect a voltmeter as indicated by V4. (Figure 1, 2, or 3)
   c. Observe voltmeter reading.
   (NOTE: V4 should not exceed .1 volt.)

4. Turn off lights and accessories and disconnect voltmeter.
ALTERNATOR CHARGING CIRCUITS
UNIT VII

PRACTICAL TEST
JOB SHEET #1 — TEST THE FORD ALTERNATOR CHARGING CIRCUIT WITH EXTERNAL REGULATOR

STUDENT'S NAME ___________________________ DATE ____________

EVALUATOR'S NAME _________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under “Process Evaluation” must receive a “Yes” for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the “Yes” or “No” blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

1. Checked out proper tools and materials. YES NO
2. Tested the battery. _____ _____
3. Checked and adjusted belt tension. _____ _____
4. Tested alternator output. _____ _____
5. Tested wiring leading to the “A” terminal of the regulator. _____ _____
6. Tested wire connecting ignition switch to the regulator. _____ _____
7. Tested wire connecting the “S” terminal of the alternator to the “S” terminal of the regulator. _____ _____
8. Tested wire connecting the “F” terminal of the regulator to the “F” terminal of the alternator. _____ _____
9. Tested regulator. _____ _____
10. Checked in/out away tools and materials. _____ _____
11. Cleaned the work area. _____ _____
12. Used proper tools correctly. _____ _____
13. Performed steps in a timely manner (___hrs. ___min. ___sec.) _____ _____
14. Practiced safety rules throughout procedure. _____ _____
15. Provided satisfactory responses to questions asked. _____ _____

EVALUATOR'S COMMENTS: ________________________________________________________________

______________________________________________________
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JOB SHEET #1 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

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<tr>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
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</table>

Student performed all steps in proper sequence.

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Student's evaluation of charging system is valid.

EVALUATOR'S COMMENTS:


PERFORMANCE EVALUATION KEY

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<tbody>
<tr>
<td>4</td>
<td>Skilled — Can perform job with no additional training.</td>
</tr>
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<td>3</td>
<td>Moderately skilled — Has performed job during training program; limited additional training may be required.</td>
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<td>2</td>
<td>Limited skill — Has performed job during training program; additional training is required to develop skill.</td>
</tr>
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<td>1</td>
<td>Unskilled — Is familiar with process, but is unable to perform job.</td>
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</table>

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in “Product Evaluation" and divide by the total number of criteria.)
ALTERNATOR CHARGING CIRCUITS
UNIT VII

PRACTICAL TEST
JOB SHEET #2 — REMOVE AND REPLACE AN ALTERNATOR

STUDENT’S NAME ____________________________ DATE ____________

EVALUATOR’S NAME ____________________________ ATTEMPT NO. _____

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under “Process Evaluation” must receive a “Yes” for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the “Yes” or “No” blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:  

1. Checked out proper tools and materials.  YES NO
2. Removed battery ground.  YES NO
3. Removed wire leads.  YES NO
4. Removed alternator.  YES NO
5. Installed alternator.  YES NO
6. Installed and adjusted alternator belt.  YES NO
7. Installed wire leads and tightened securely.  YES NO
8. Installed battery ground cable.  YES NO
9. Checked operation of alternator.  YES NO
10. Checked in/out tools and materials.  YES NO
11. Cleaned the work area.  YES NO
12. Used proper tools correctly.  YES NO
13. Performed steps in a timely manner (hrs. min. sec.)  YES NO
14. Practiced safety rules throughout procedure.  YES NO
15. Provided satisfactory responses to questions asked.  YES NO

EVALUATOR’S COMMENTS: ____________________________________________
JOB SHEET #2 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a “3” for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

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<td>4</td>
<td>3</td>
<td>2</td>
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</tbody>
</table>

Student performed all steps in proper sequence.

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<td>4</td>
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</table>

Alternator operates properly.

EVALUATOR'S COMMENTS: __________________________

PERFORMANCE EVALUATION KEY

<p>| | | | | |</p>
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(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in “Product Evaluation” and divide by the total number of criteria.)
ALTERNATOR CHARGING CIRCUITS
UNIT VII

PRACTICAL TEST
JOB SHEET #3 — DISASSEMBLE, TEST, AND REASSEMBLE AN ALTERNATOR

STUDENT'S NAME ______________________________ DATE __________
EVALUATOR'S NAME ____________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

1. Checked out proper tools and materials. ____________________________ YES NO
2. Scribed the alternator. ____________________________ YES NO
3. Separated the drive and frame from the slip ring frame. ____________________________ YES NO
4. Removed the stator. ____________________________ YES NO
5. Removed the brushes and brushholder. ____________________________ YES NO
6. Removed heat sink. ____________________________ YES NO
7. Removed pulley and fan. ____________________________ YES NO
8. Removed rotor. ____________________________ YES NO
9. Tested rotor. ____________________________ YES NO
10. Tested the stator. ____________________________ YES NO
11. Tested diodes. ____________________________ YES NO
12. Tested diode trio. ____________________________ YES NO
13. Reassembled alternator. ____________________________ YES NO
14. Checked alternator operation. ____________________________ YES NO
15. Checked in/output tools and materials. ____________________________ YES NO
16. Cleaned the work area. ____________________________ YES NO
17. Used proper tools correctly. ____________________________ YES NO
18. Performed steps in a timely manner (___hrs. ___min. ___sec.) ____________________________ YES NO
19. Practiced safety rules throughout procedure. ____________________________ YES NO
20. Provided satisfactory responses to questions asked. ____________________________ YES NO

EVALUATOR'S COMMENTS: ____________________________________________

__________________________________________
JOB SHEET #3 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

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<th>4</th>
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<tbody>
<tr>
<td>Student performed steps in proper sequence.</td>
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<tr>
<td>4</td>
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<td>2</td>
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<tr>
<td>Student's evaluation of alternator components is valid.</td>
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<tr>
<td>4</td>
<td>3</td>
<td>2</td>
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</tr>
<tr>
<td>Alternator operates properly.</td>
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</table>

EVALUATOR'S COMMENTS: ________________________________

PERFORMANCE EVALUATION KEY

| 4 — Skilled — Can perform job with no additional training. |
| 3 — Moderately skilled — Has performed job during training program; limited additional training may be required. |
| 2 — Limited skill — Has performed job during training program; additional training is required to develop skill. |
| 1 — Unskilled — Is familiar with process, but is unable to perform job. |

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)
# ALTERNATOR CHARGING CIRCUITS
## UNIT VII

## PRACTICAL TEST
### JOB SHEET #4 — TEST A TRANSISTORIZED REGULATOR

<table>
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<th>STUDENT'S NAME</th>
<th>DATE</th>
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<tbody>
<tr>
<td>EVALUATOR'S NAME</td>
<td>ATTEMPT NO.</td>
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</table>

**Instructions:** When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under “Process Evaluation” must receive a “Yes” for you to receive an overall performance evaluation.

## PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the “Yes” or “No” blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

<table>
<thead>
<tr>
<th>Step</th>
<th>YES</th>
<th>NO</th>
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<tbody>
<tr>
<td>1. Checked out proper tools and materials.</td>
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<tr>
<td>2. Made all test instrument connections.</td>
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<tr>
<td>3. Started and loaded alternator 10 amperes.</td>
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<tr>
<td>4. Measured and recorded temperature of regulator.</td>
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<tr>
<td>6. Adjusted voltage regulator.</td>
<td></td>
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<tr>
<td>7. Replaced regulator.</td>
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<tr>
<td>8. Checked in/put away tools and materials.</td>
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<tr>
<td>9. Cleaned the work area.</td>
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<tr>
<td>10. Used proper tools correctly.</td>
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<tr>
<td>11. Performed steps in a timely manner (___hrs. ___min. ___sec.)</td>
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<tr>
<td>13. Provided satisfactory responses to questions asked.</td>
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**EVALUATOR'S COMMENTS:**

__________________________________________________________________

__________________________________________________________________

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Job Sheet #4 Practical Test

Product Evaluation

(Evaluator Note: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

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<td>1. Student performed steps in proper sequence.</td>
<td></td>
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</tr>
<tr>
<td>2. Regulator operates correctly.</td>
<td></td>
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</tbody>
</table>

Evaluator's Comments: ______________________________________________________

Performance Evaluation Key

<table>
<thead>
<tr>
<th></th>
<th>Skilled — Can perform job with no additional training.</th>
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<tbody>
<tr>
<td>4</td>
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<td>3</td>
<td>Moderately skilled — Has performed job during training program; limited additional training may be required.</td>
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<td>2</td>
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<tr>
<td>1</td>
<td>Unskilled — Is familiar with process, but is unable to perform job.</td>
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</tbody>
</table>

(Evaluator Note: If an average score is needed to coincide with a competency profile, total the designated points in “Product Evaluation” and divide by the total number of criteria.)
ALTERNATOR CHARGING CIRCUITS
UNIT VII

PRACTICAL TEST
JOB SHEET #5 — TEST AN S.I. SERIES ALTERNATOR

STUDENT'S NAME: _________________________________ DATE __________

EVALUATOR'S NAME: _______________________________ ATTEMPT NO. ___

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under “Process Evaluation” must receive a “Yes” for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the “Yes” or “No” blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

1. Checked out proper tools and materials. YES NO
2. Tested the battery. YES NO
3. Checked alternator belt. YES NO
4. Checked wiring. YES NO
5. Disconnected battery ground. YES NO
6. Made test instrument connections. YES NO
7. Operated engine and tested alternator output. YES NO
8. Bypassed voltage regulator. YES NO
9. Turned off engine and disconnected test instruments. YES NO
10. Checked input/put away tools and materials. YES NO
11. Cleaned the work area. YES NO
12. Used proper tools correctly. YES NO
13. Performed steps in a timely manner (___hrs. ___min. ___sec.) YES NO
14. Practiced safety rules throughout procedure. YES NO
15. Provided satisfactory responses to questions asked. YES NO

EVALUATOR'S COMMENTS: _____________________________________________

_________________________________________
JOB SHEET #5 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

<table>
<thead>
<tr>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
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</table>

Student performed steps in proper sequence.

<table>
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<tr>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
</table>

Student's evaluation of the charging system is valid.

<table>
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<tr>
<th>4</th>
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<th>2</th>
<th>1</th>
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</table>

Alternator operates properly.

EVALUATOR'S COMMENTS:

PERFORMANCE EVALUATION KEY

<table>
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(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)
ALTERNATOR CHARGING CIRCUITS
UNIT VII

PRACTICAL TEST
JOB SHEET #6 — TEST CHARGING CIRCUIT RESISTANCE FOR GM ALTERNATOR

STUDENT'S NAME ____________________________ DATE ___________

EVALUATOR'S NAME ___________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

1. Checked out proper tools and materials. YES NO
2. Tested wire going to the #3 terminal of the regulator. ______ ______
3. Tested wire going to the alternator output terminal. ______ ______
4. Tested voltage drop in the ground circuit. ______ ______
5. Turned off lights to accessories and disconnected voltmeter. ______ ______
6. Checked in/put away tools and materials. ______ ______
7. Cleaned the work area. ______ ______
8. Used proper tools correctly. ______ ______
9. Performed steps in a timely manner (___hrs. ___min. ___sec.) ______ ______
10. Practiced safety rules throughout procedure. ______ ______
11. Provided satisfactory responses to questions asked. ______ ______

EVALUATOR'S COMMENTS: ________________________________________
______________________________

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JOB SHEET #6 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

<table>
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<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Student performed steps in proper sequence.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Student's evaluation of wiring is adequate.</td>
<td></td>
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</table>

EVALUATOR'S COMMENTS:

PERFORMANCE EVALUATION KEY

<p>| | | | | |</p>
<table>
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ALTERNATOR CHARGING CIRCUITS
UNIT VII

NAME_________________________________________  SCORE______________________

TEST

1. Match the terms on the right with their correct definitions.

   1. Brushless alternator
   2. Diode
   3. Grounded circuit
   4. Heat sink
   5. Open circuit
   6. Potentiometer
   7. Rectifier bridge
   8. Rotor
   9. Short circuit
  10. Slip rings
  11. Stator
  12. Transistorized regulator

   ___a. Wire coil wrapped around an iron core and mounted on a rotating shaft
   ___b. Laminated soft iron ring with three groups of coils
   ___c. Device that allows current to flow in one direction and blocks current in opposite direction
   ___d. Metal conductors in the form of a ring, fastened to each end of coil and mounted on rotor shaft
   ___e. Wire touching another wire and providing a shorter path for current to flow
   ___f. Circuit in which a wire is broken or disconnected
   ___g. Circuit in which a wire touches ground causing the current to flow to ground instead of through the circuit
   ___h. Fully electronic unit composed of resistors, diodes, zener diodes, transistors, and thermistor
   ___i. Dissipates heat from diodes
   ___j. An alternator that has neither slip rings nor brushes
   ___k. Acts as a voltage divider or voltage adjustment
   ___l. Six diodes mounted in one assembly

2. State the purpose of the alternator charging circuit.

   ____________________________________________________________
   ____________________________________________________________
3. Match of alternator charging circuit components on the right with their correct functions.

   a. Starts the circuit by supplying spark to start engine, helps out during peak operation when electrical load is too much for alternator, and stabilizes system voltage
   b. Measures the rate of current flow
   c. Supplies electrical power to accessory circuits and recharges battery
   d. Indicates produced voltage
   e. Limits the alternator voltage to a safe, preset value
   f. Indicates problems in system; used in place of a meter

4. Identify the major parts of an alternator.
   a. 
   b. 
   c. 
   d. 
   e. 
   f. 
   g. 

5. Discuss the construction of stator windings.
TEST

6. Distinguish between types of alternator circuits by placing an “E” next to the description of an external regulator.

_____a. Field current is regulated before it gets to the rotor, and the field is grounded in the alternator. When the field is grounded in the alternator, it is called a “B” circuit.

_____b. Field current is regulated after it goes through the rotor, and the field is grounded through the regulator. When the field is grounded in the regulator, it is called an “A” circuit.

7. Select from the following list characteristics of a brushless alternator by placing an “X” beside each correct characteristic.

_____a. Is a low mileage unit

_____b. Is used on diesel engines only

_____c. Regulator compartment is non-vented

_____d. Uses large bushings at both ends

_____e. Has extra large grease reservoirs

_____f. Has extra small lip seal to keep grease in, and dirt out

_____g. Regulator compartment is air tight

_____h. Designed to operate between engine overhauls without attention

8. Select true statements concerning operation of a brushless alternator by placing an “X” beside each statement that is true.

_____a. To generate voltage in the stator windings, it is only necessary for the rotor to cause alternating north and south magnetic lines to cut across the stator windings.

_____b. The field coil is mounted to the end frame.

_____c. The rotor is mounted on bearings and fits between the stator and field coil.
TEST

_____ d. The field coil produces a north pole at the right hand side of the coil.

_____ e. Magnetic lines cross the air gap between the field coil and rotor to make all the right hand rotor poles all north poles.

_____ f. The non-magnetic lines of force cannot go through the non-magnetic ring directly; instead they pass through the air gap into the left hand, south magnetic poles of the rotor; the magnetic lines then cross the air gap between the rotor and field coil and then into the field coil to complete the magnetic path.

_____ g. The non-magnetic ring has diverted the magnetic field into the stator windings, and as the rotor turns, AC voltage is generated in the stator windings.

9. Select true statements concerning operation of a transistorized regulator by placing an "X" beside each statement that is true.

_____ a. Allows battery current to excite the alternator field coils

_____ b. Controls charging voltage at safe values during operation by requesting the field current

10. Complete the following statements concerning safety rules for working with alternator charging circuits by inserting the word(s) that best completes each statement.

a. Never attempt to ____________ the circuit.

b. Be sure the battery is in good operating condition before making any tests or ____________

c. Never operate the alternator in an ____________ circuit, except when instructed in the technical manual.

d. Never ____________ or ground the alternator terminals.

e. Do not disconnect the voltage regulator while the alternator is ____________.

f. Disconnect the ____________ battery cable first when removing the alternator or battery.

g. Do not use acid-core solder on the alternator terminals; use only a ____________ core solder.

h. Never immerse the circuit components in ____________ solution.
(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

11. Demonstrate the ability to:
   a. Test the Ford alternator charging circuit with external regulator. (Job Sheet #1)
   b. Remove and replace an alternator. (Job Sheet #2)
   c. Disassemble, test, and reassemble an alternator. (Job Sheet #3)
   d. Test a transistorized regulator. (Job Sheet #4)
   e. Test an S.I. series alternator. (Job Sheet #5)
   f. Test charging circuit resistance for G.M. alternators. (Job Sheet #6)
ALTERNATOR CHARGING CIRCUITS
UNIT VII

ANSWERS TO TEST

1. a. 8   e. 9   i. 4
   b. 11  f. 5   j. 1
   c. 2   g. 3   k. 6
   d. 10  h. 12  l. 7

2. The alternator charging circuit recharges the battery and maintains a supply of electrical current to meet the operating needs of the equipment.

3. a. 3   d. 6
   b. 2   e. 5
   c. 1   f. 4

4. a. Drive end frame
   b. Rotor assembly
   c. Stator assembly
   d. Slip ring end frame
   e. Diodes
   f. Brush assembly
   g. Pulley

5. Windings have three phases which are connected together to form a “Y” or delta connection, with each winding connected to a positive and negative diode.

6. a

7. e, g, h

8. a, b, c, d, e, f, g

9. a, b

10. a. Polarize
    b. Adjustments
    c. Open
    d. Short
    e. Running
    f. Negative
    g. Rosin
    h. Cleaning

11. Performance skills evaluated to the satisfaction of the instructor.
EMERGENCY SHUT-DOWN CIRCUITS
UNIT VIII

UNIT OBJECTIVE

After completion of this unit, the student should be able to troubleshoot a shut-down and alarm circuit. Competencies will be demonstrated by completing the job sheet and the unit tests with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to emergency shut-down circuits with their correct definitions.
2. Select true statements concerning characteristics of a coolant temperature switch-gauge.
3. Select true statements concerning characteristics of an oil pressure switch-gauge.
4. Arrange in order steps in the operation of the magnetic switch.
5. Select true statements concerning shut-off solenoids.
6. Complete statements concerning characteristics of the overspeed contactor switch.
7. Select true statements concerning the oil pressure contactor switch.
8. Complete statements concerning the operation of an alarm system.
9. Demonstrate the ability to troubleshoot a shut-down and alarm circuit. (Job Sheet #1)
SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information sheet.

F. Discuss information sheet.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheet.

H. Discuss and demonstrate the procedures outlined in the job sheet.

I. Integrate the following activities throughout the teaching of this unit:

1. Discuss safety procedures pertaining to emergency shut-down circuits.

2. Take a field trip to at least 3 different truck stops to see different types of shut-down circuits.

   (NOTE: Shut-down circuits can also be found anywhere that emergency generators are located, such as, in hospitals, in shopping centers, on combines, and on irrigation systems.)

3. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.
REFERENCES USED IN DEVELOPING THIS UNIT

A. *Swichgage*® Diagnostic General Catalog 1987-88. Tulsa, OK: Frank W. Murphy Manufacturer.


SUGGESTED SUPPLEMENTAL RESOURCES

Filmstrip

*Alarm Switches and Shutoffs* (93 slides)
Order #JEG02702
Caterpillar Tractor Co.
Literature Orders Section
1335 S.W. Washington
Peoria, IL 61602
EMERGENCY SHUT-DOWN CIRCUITS
UNIT VIII

INFORMATION SHEET

I. Terms and definitions
   A. Flow control switch — Senses coolant flow through system and warns operator of immediate shut-down.
   B. Magnetic switch — Same as a solenoid but does not have an activating device.
   C. Murphy switch — An automatic shut-down switch for coolant, oil, and fuel systems.
   D. Normally closed switch (NC) — A switch that is activated by an electrical signal to shut down a device or an engine.
   E. Normally open switch (NO) — A switch that is activated either manually or electrically and returns to the open position when released.
   F. Overspeed governor — Protects engine from excessive rpm (NOTE: This is also known as an overspeed trip.)
   G. Solenoid — An electric coil with a moveable iron core; when current flows through the coil, it forms a magnet, and the iron core moves to activate a device.
   H. Switch — Electrical or mechanical device that opens or closes a circuit.
   I. Temperature sending unit — Monitors engine coolant temperature.

II. Characteristics of a coolant temperature switch-gauge (Transparencies 1 and 3)
   A. A combination coolant temperature gauge and safety switch.
   B. Connected directly into engine cooling system by a heat bulb and capillary tube.

Courtesy of Frank W. Murphy Manufacturers, Tulsa, Oklahoma.
INFORMATION SHEET

C. The contacts in the switch-gauge react according to their design.

1. One wire, contact pointer type — The pointer contacts the high coolant temperature adjustment screw grounding the switch gauge.

![Diagram of one wire, contact pointer type](image)

(Courtesy of Frank W. Murphy Manufacturer, Tulsa, Oklahoma)

2. Three wire, micro switch type — The contacts open to de-energize the circuit.

![Diagram of three wire, micro switch type](image)

(Courtesy of Frank W. Murphy Manufacturer, Tulsa, Oklahoma)

D. The gauges are adjusted at the factory to shut off the engine when the coolant temperature reaches 205-210°F.

(NOTE: This setting can be changed by using the 1/16” hex head wrench or small screwdriver and turning the adjustment screw.)

III. Characteristics of an oil pressure switch gauge (Transparencies 1 and 2)

A. A combination oil pressure gauge and safety switch

B. Connected by a tube directly to the engine oil gallery pressure

![Diagram of oil pressure switch gauge](image)

(Courtesy of Frank W. Murphy Manufacturer, Tulsa, Oklahoma)
INFORMATION SHEET

C. The contacts in the switch-gauge react according to their design.

1. One wire, contact pointer type — The pointer contacts the low oil pressure adjustment screw, grounding the switch-gauge.

   One wire, contact pointer type diagram

   Skl. Model
   
   Low
   Red
   Case
   Grnd.

   Courtesy of Frank W. Murphy Manufacturer, Tulsa, Oklahoma.

2. Three wire, micro switch type — The contacts open to de-energize the circuit.

   Three wire, micro switch type diagram

   EO Model
   
   NC Red
   Com. White
   NO Black

   Courtesy of Frank W. Murphy Manufacturer, Tulsa, Oklahoma.

D. Adjusted at the factory to shut down the engine when oil pressure drops below 10 to 12 psi

   (NOTE: This setting can be changed by using a 1/16″ hex head wrench or small screwdriver to turn adjusting screw.)

IV. Operation of the magnetic switch

A. Wired into the circuit of the safety controls; supplies current to open fuel shut-off solenoid.

   Operation of the magnetic switch diagram

   Courtesy of Deutz-Allis Corporation.
B. Whenever the pointer of any safety-gauge makes contact and completes a circuit, it will momentarily energize the coil in the magnetic switch, releasing the armature and opening the circuit to the fuel shutoff solenoid, stopping the engine.

C. When the problem has been corrected, the reset button must be pressed in before the engine can be started.

V. Shut-off solenoids

A. Energized by any of the following:
   1. Water temperature contactor switch or switch-gauge
   2. Oil pressure contactor switch or switch-gauge
   3. Overspeed contactor switch
   4. Manual control switch

B. Work by overriding the governor and moving the fuel rack to the shut-off position

C. Shut off fuel supply

D. Shut off air supply.

VI. Characteristics of the overspeed contactor switch (Transparency 3)

A. It is mounted to the tachometer drive.

B. When the engine overspeeds, the contact points close and send a signal to the shut-off solenoid.

C. If the overspeed contactor switch is activated, it will have to be reset.
INFORMATION SHEET

VII. Oil pressure contactor switch (Transparencies 3 and 4)
   A. Is an electric switch
   B. Signals the shut-off solenoid
   C. On automatic start-stop systems, a double set of contacts opens to disconnect the starter solenoid.

VIII. Operation of an alarm system (Transparency 5)
   A. Uses a light in the dash to warn driver of system failure
   B. Uses a horn to warn driver of system failure
   C. Has to be reset after engine has been stopped
Types of Switch Gauges

Oil Pressure

Water Temperature

Micro Switch Type

High Water Temperature Safety Switch

Low Oil Pressure Safety Switch

Tape Black Wire

Tape White Wire

Red

Red

Black

To Battery Source

Ammeter

Safety Control Off On Switch

Bypass Switch

Charging Circuit

Warning Horn

Warning Horn Relay

Fuel Injection Pump Shut Off Solenoid

Switch Gauges Used With Bypass Switch

Courtesy of Deutz-Allis Corporation.
Types of Switch Gauges
(Continued)

High Water Temperature Safety Switch
Low Oil Pressure Safety Switch

Ammeter
Charging Circuit
Optional Switch
Magnetic Switch
Fuse - 5 Amp
Reset Button
Fuel Injection Pump Shut Off Solenoid
Warning Horn

Current Type Safety Shutdown Switch-Gauges Oil
The Pointer Contact Type With Magnetic Switch

Pointer Contact Type

Oil Pressure

Water Temperature

Oil Pressure

Water Temperature

Courtesy of Deutz-Allis Corporation.
Automatic Shut-Down Device

- Oil Pressure Switch
- Fuel Pressure Switch
- Water Temp. Switch
- Overspeed Governor Switch
- Shut-Down Solenoid

© General Motors Corporation
Typical Shut-Down Switches
(Continued)

[Diagram of Oil Pressure Switch with labels: Terminal (2), Adjusting Screw, Locknut, Bracket, Spring, Plunger, Contact Points, Pressure Chamber, Diaphragm, Drilled Passage]

[Diagram of Low Water Temperature Switch with labels: Terminal, Switch Actuating Lever, Spring, Contact Wheel, Plunger, Switch Block, Switch Button, Adjusting Screw, Spring, Support]
Alarm Systems

**NOTES**

1. IGN. RESISTOR 'R', OR RESISTOR IGN. WIRE MUST BE BETWEEN NC TERMINAL OF MAGNETIC SWITCH & IGNITION COIL.
2. A, B, & C, REPRESENT ALTERNATE METHODS OF ENGINE SHUTDOWN FOR DIESEL OR SPARK IGNITION ENGINES. SELECT APPROPRIATE CIRCUIT & WIRE ACCORDINGLY.
3. D, INDICATES WIRING TO VEHICLE HORN FOR WARNING, RATHER THAN SHUTDOWN.
4. INDICATES CUSTOMER WIRING:

---

**Wiring diagram showing choice of circuits to provide alarm only by panel mounted indicator (large flashing red light or mini-siren) or vehicle horn, shutdown for diesel or gasoline engine. To restart after shutdown merely turn ignition key off and on.**

Courtesy of Frank W. Murphy Manufacturer, Tulsa, Oklahoma.
EMERGENCY SHUT-DOWN CIRCUITS
UNIT VIII

JOB SHEET #1 — TROUBLESHOOT A SHUT-DOWN AND ALARM CIRCUIT

A. Tools and materials

1. Vehicle
2. Basic hand tool set
3. Circuit tester
4. Clean shop towels
5. Jumper wire with alligator clips
6. Appropriate service manual

B. Procedure

(CAUTION: Remove all jewelry before working on any electrical circuit, and follow all shop safety procedures.)

(NOTE: The following covers Murphy's 20 series Switchgages® and #117 magnetic switch. The wiring and the type of magnetic switch will differ for various applications. Refer to the service manual.)

1. Turn on optional switch and check for voltage at the “B” terminal on the magnetic switch. (Figure 1)

   (NOTE: If there is no voltage, replace fuse or repair wiring.)

   FIGURE 1

   Courtesy of Deutz-Allis Corporation.
2. Ground the "S" terminal of the magnetic switch.

3. Test voltage at the "C" terminal of magnetic switch. (Figure 2)
   (NOTE: If there is voltage at the "C" terminal, repair or replace magnetic switch.)

4. Disconnect wires from the "S" terminal of the magnetic switch and start engine.

5. Connect the switch-gauges to the "S" terminal of the magnetic switch one at a time. (Figure 3)
   (NOTE: If engine stops, repair or replace the circuit or gauge that is at fault.)

6. Test voltage at the fuel shut off solenoid.
   (NOTE: If there is no voltage, replace or repair wiring or magnetic switch. If there is voltage and solenoid is not working, check ground circuit; if it is okay, replace solenoid.)
JOB SHEET #1

7. Test voltage in the wire going from the optional switch to the horn relay.
   (NOTE: If there is no voltage, repair or replace circuit.)

8. Disconnect the wire going from the "C" terminal of the magnetic switch to the horn relay. (Figure 4)
   (NOTE: If the horn does not operate, check voltage in wire going from the relay to the horn. If voltage is not present, replace horn relay)

![FIGURE 4](image)

9. Test horn by connecting voltage to the insulated terminal.
   (NOTE: If horn doesn't operate and the ground circuit is good, replace or repair horn.)
EMERGENCY SHUT-DOWN CIRCUITS
UNIT VIII

PRACTICAL TEST
JOB SHEET #1 — TROUBLESHOOT A SHUT-DOWN AND ALARM CIRCUIT

STUDENT'S NAME ___________________________ DATE ___________

EVALUATOR'S NAME ___________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

<table>
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The student:

<table>
<thead>
<tr>
<th></th>
<th>YES</th>
<th>NO</th>
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<tbody>
<tr>
<td>1. Checked out proper tools and materials.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Checked for voltage at the “B” terminal.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Tested for voltage at the “C” terminal.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Checked switch-gauges and wiring.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Tested fuel shut-off solenoid.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Tested horn relay.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Tested horn.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Checked in/put away tools and materials.</td>
<td></td>
<td></td>
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<tr>
<td>9. Cleaned the work area.</td>
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<td>10. Used proper tools correctly.</td>
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<td>11. Performed steps in a timely manner (__hrs. __min. __sec.)</td>
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<td>13. Provided satisfactory responses to questions asked.</td>
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EVALUATOR'S COMMENTS: ____________________________________________
JOB SHEET #1 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a “3” for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

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<td>4</td>
<td>3</td>
<td>2</td>
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Problem in the circuit is found and repaired.

EVALUATOR’S COMMENTS:

PERFORMANCE EVALUATION KEY

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<td>4 — Skilled — Can perform job with no additional training.</td>
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<td>3 — Moderately skilled — Has performed job during training program; limited additional training may be required.</td>
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<td>2 — Limited skill — Has performed job during training program; additional training is required to develop skill.</td>
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<tr>
<td>1 — Unskilled — Is familiar with process, but is unable to perform job.</td>
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(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in “Product Evaluation” and divide by the total number of criteria.)
EMERGENCY SHUT-DOWN CIRCUITS
UNIT VIII

1. Match the terms on the right with their correct definitions.

   a. Electrical or mechanical device that opens or closes a circuit
   b. Same as a solenoid but does not have any activating device
   c. An electric coil with a moveable iron core; when current flows through the coil, it forms a magnet, and the iron core moves to activate a device
   d. Monitors engine coolant temperature
   e. A switch that is activated either manually or electrically and returns to the open position when released
   f. A switch that is activated by an electrical signal to shut down a device or an engine
   g. Senses coolant flow through system and warns operator of immediate shut-down
   h. Protects engine from excessive rpm
   i. An automatic shut-down switch for coolant, oil, and fuel systems

2. Select true statements concerning characteristics of a coolant temperature switch-gauge by placing an “X” beside each statement that is true.

   a. A combination coolant temperature gauge and safety switch
   b. On the one wire, contact pointer gauge, when the pointer contacts the high coolant temperature adjustment screw, it opens the switch-gauge.
   c. On the three wire, micro switch, the contacts close to de-energize the circuit.
   d. The gauges are adjusted at the factory to shut off the engine when the coolant temperature reaches 205 - 210°F.
TEST

3. Select true statements concerning characteristics of an oil pressure switch-gauge by placing an "X" beside each statement that is true.

   ____a. A combination oil pressure gauge and safety switch
   ____b. Connected by a tube directly to the engine air breather
   ____c. The contacts in the switch-gauge are all the same
   ____d. Adjusted at the factory to shut down the engine when the oil pressure rises above 10 to 12 psi

4. Arrange in order the steps in the operation of the magnetic switch.

   ____a. Whenever the pointer of any safety-gauge makes contact and completes a circuit, it will momentarily energize the coil in the magnetic switch, releasing the armature and opening the circuit to the fuel shutoff solenoid, stopping the engine.
   ____b. Wired into the circuit of the safety controls; supplies current to open fuel shut-off solenoid
   ____c. When the problem has been corrected, the reset button must be pressed in before the engine can be started.

5. Select true statements concerning shut-off solenoids by placing an "X" beside each statement that is true.

   (NOTE: A statement is true only if all parts of the statement are true.)

   ____a. Energized by any of the following:
      1) Water temperature contactor switch or switch-gauge
      2) Oil pressure contactor switch or switch-gauge
      3) Overspeed contactor switch
      4) Manual control switch
   ____b. Work by overriding the governor and moving the control switch to the shut-off position
   ____c. Shut off fuel supply

6. Complete the following statements concerning characteristics of the overspeed contactor switch by inserting the word that best completes each statement.

   a. It is mounted to the ____________ drive
   b. When the engine overspeeds, the contact points ____________ and send a signal to the shut-off solenoid.
   c. If the overspeed contactor switch is not activated, it will have to be ____________.
TEST

7. Select true statements concerning the oil pressure contactor switch by placing an "X" beside each statement that is true.

_____a. Is an electric switch
_____b. Signals the shut-off solenoid
_____c. On automatic start-stop systems, a double set of contacts closes to disconnect the starter solenoid.

8. Complete the following statements concerning the operation of an alarm system.

a. Uses a light in dash to warn driver of __________________________

b. Uses a __________ to warn driver of system failure

c. Has to be reset after __________________________

(NOTE: If the following activity has not been accomplished prior to the test, ask your instructor when it should be completed.)

9. Demonstrate the ability to troubleshoot a shut-down and alarm circuit. (Job Sheet #1)
EMERGENCY SHUT-DOWN CIRCUITS
UNIT VII

ANSWERS TO TEST

1. a. 8 f. 4
   b. 2 g. 1
   c. 7 h. 6
   d. 9 i. 3
   e. 5

2. a, d

3. a

4. a. 2
   b. 1
   c. 3

5. a, c

6. a. Tachometer
   b. Open
   c. Reset

7. a, b

8. a. System failure
   b. Horn
   c. Engine has been stopped

9. Performance skills evaluated to the satisfaction of the instructor