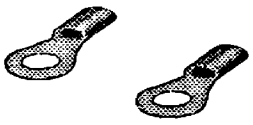
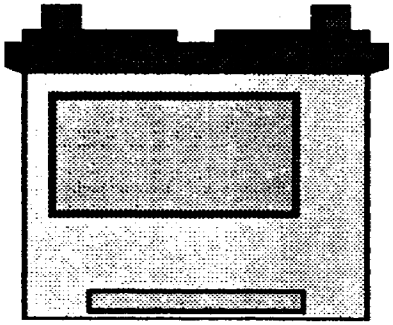
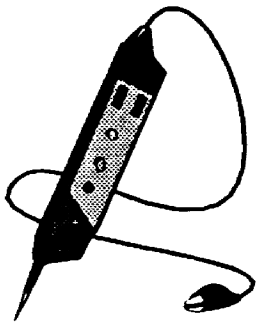
SUBCOURSE **EDITION**
IT 0335 **B**

US ARMY INTELLIGENCE CENTER
INTRODUCTION TO
CELLS AND BATTERIES







THE ARMY INSTITUTE FOR PROFESSIONAL DEVELOPMENT
ARMY CORRESPONDENCE COURSE PROGRAM

AIPD

READINESS/
PROFESSIONALISM

THRU
GROWTH

INTRODUCTION TO CELLS AND BATTERIES

Subcourse Number IT0335

EDITION B

US ARMY INTELLIGENCE CENTER
FORT HUACHUCA, AZ 856134000
2 Credit Hours

SUBCOURSE OVERVIEW

This subcourse is designed to teach you the characteristics of cells and batteries and their effects in simple circuits.

This Subcourse replaces SA 0705

Unless this subcourse is a review, you should complete subcourses IT0332 through IT0334 prior to completing this subcourse.

TERMINAL LEARNING OBJECTIVE

ACTION: You will identify the difference between primary and secondary cells, select the factors that affect voltage rating and current capacity, determine voltage rating and current capacity in series, parallel, and series-parallel circuits, describe common battery test, and identify safety precautions.

CONDITION: You will be given circuits and description of conditions of usage in this subcourse.

STANDARD: To demonstrate competency of this task, you must achieve a minimum of 70% on the subcourse examination.

TABLE OF CONTENTS

LESSON

INTRODUCTION TO CELLS AND BATTERIES

OVERVIEW

LESSON DESCRIPTION:

Upon completion of this lesson, you will be able to recognize the characteristics of cells and batteries and their effects in simple circuits.

TERMINAL LEARNING OBJECTIVE:

ACTION: Identify the difference between primary and secondary cells, select the factors that affect voltage rating and current capacity, determine voltage rating and current capacity in series, parallel, and series-parallel circuits, describe common battery tests, and identify safe precautions.

CONDITION: Given the information provided in this lesson.

STANDARD: To demonstrate competency of this task, you must achieve a minimum of 70 percent on the subcourse examination.

A chemical cell is defined as a device that generates electricity by converting chemical energy to electrical energy.

As chemical energy is converted to electrical energy, by chemical action in a cell, electricity is produced.

A cell consists of ELECTRODES and ELECTROLYTE. When the electrodes are immersed in the electrolyte, the chemical action between them generates electricity.

Electrodes are conductors by which electrons leave or return to a cell. The material an electrode is made of makes it either positive or negative.

Electrolyte is a dilute solution of acid or alkali, and may be either liquid or a moist paste. Electrolyte is the conductor of electrons from electrode to electrode within the cell.

The chemical action in a PRIMARY CELL usually erodes the negative electrode. As this takes place, the composition of the electrolyte is changed and it becomes unusable. A primary cell cannot be recharged. It can be RESTORED by replacing the eroded electrode and the electrolyte.

An example of a primary cell is shown below. The electrodes are made of zinc and copper. The zinc electrode is the negative electrode, or cathode, of the cell. The copper electrode is the positive electrode, or anode of the cell. The electrolyte of the cell is an alkaline solution.

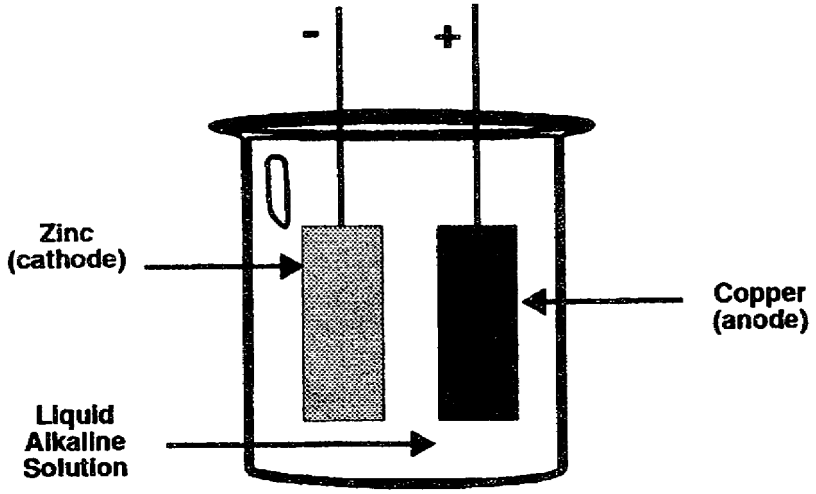


Figure 1-1. Primary Cell.

Another example of a primary cell is shown below. This cell has a positive electrode that is made of carbon and a negative electrode made of zinc. The zinc electrode is also the container for the other pars of the cell. The electrolyte is a moist paste that contains the chemicals necessary to generate electricity as a chemical action takes place between it and the electrodes.

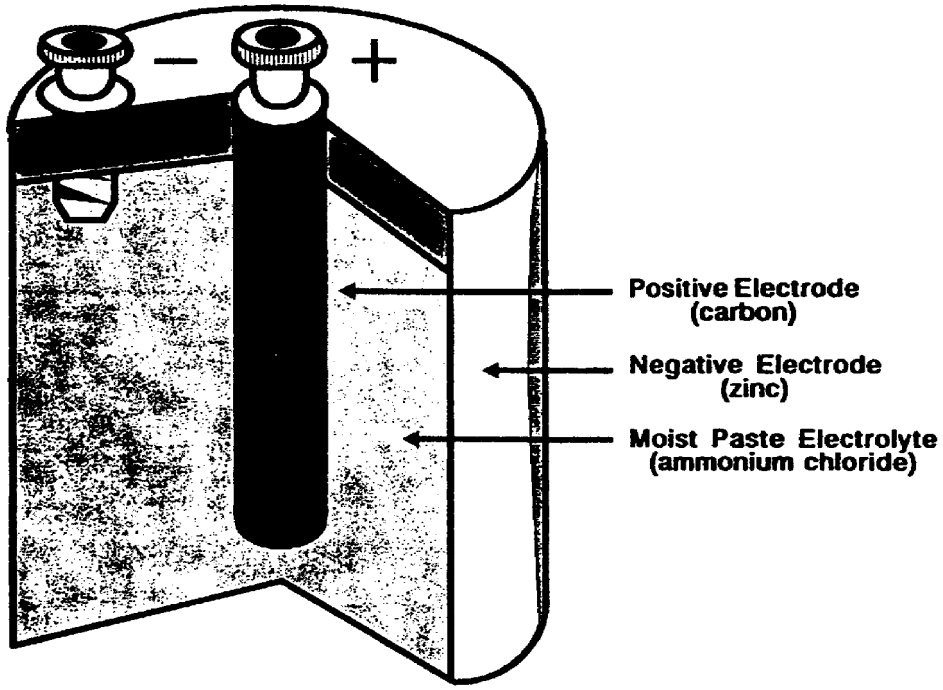


Figure 1-2. Primary Cell.

The chemical action that takes place in a SECONDARY CELL as it generates electricity causes the materials that make up the electrodes to be transferred from one electrode to the other.

A secondary cell can be CHARGED or RECHARGED by forcing a current through it in a direction that is opposite the direction of current flow during discharge.

When a secondary cell is recharged, the materials that were transferred from one electrode to the other change back to the original materials that were used to make the cell.

The chemical action that takes place in a secondary cell affects both the electrode material and the composition of liquid electrolyte, as shown below.

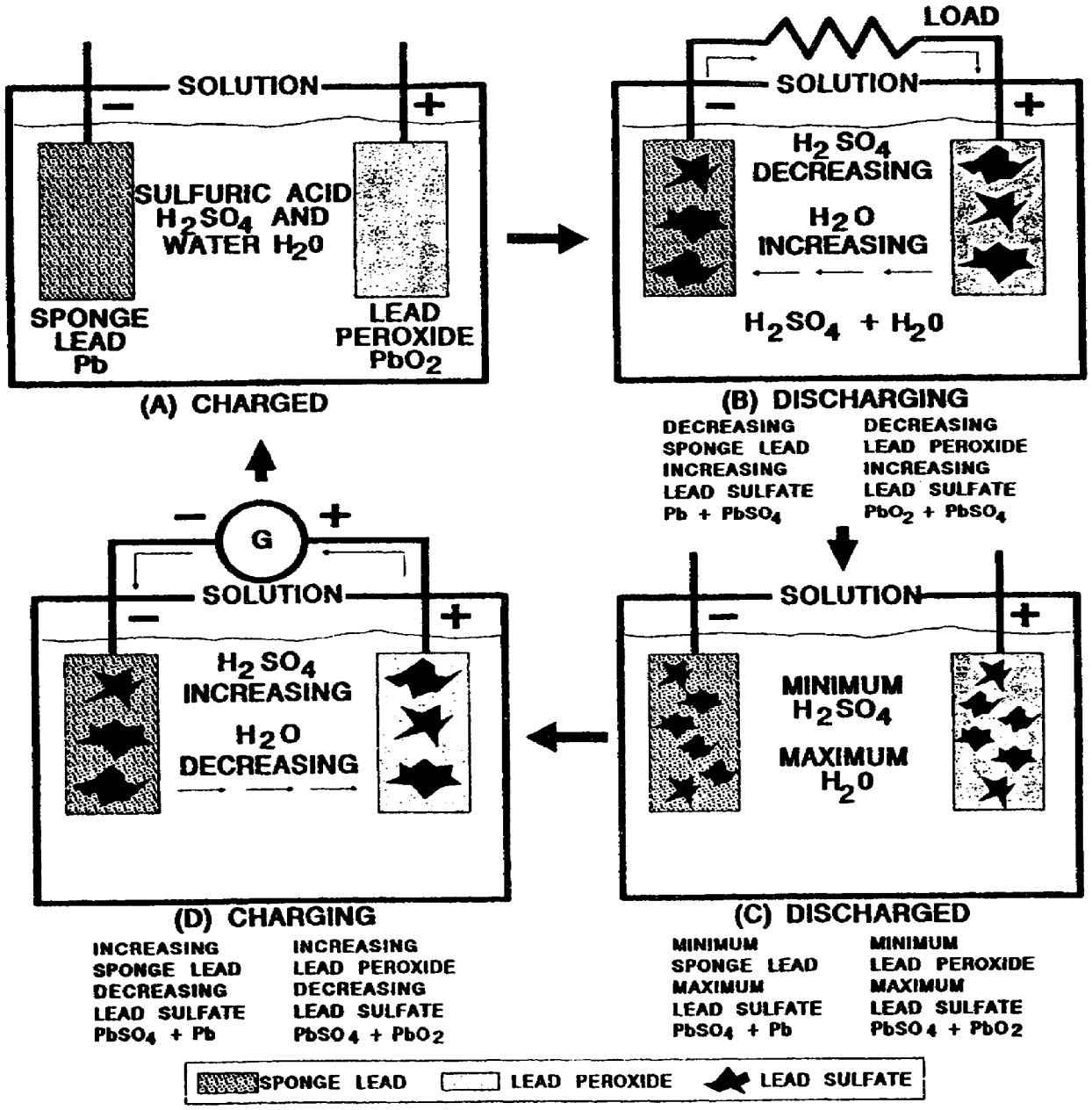


Figure 1-3.

The transfer of materials in the cell above causes the sponge lead and lead peroxide to change to lead sulfate. Drawing (D) shows a generator being used to force current through the cell in a direction opposite to the direction of current in drawing (B); therefore, the generator is charging the cell. The electrolyte in drawing (C) is mostly water. (H_2O).

An example of a secondary cell is shown in the drawings below. The positive electrode is made up of the positive plate group and the negative electrode of the negative plate group.

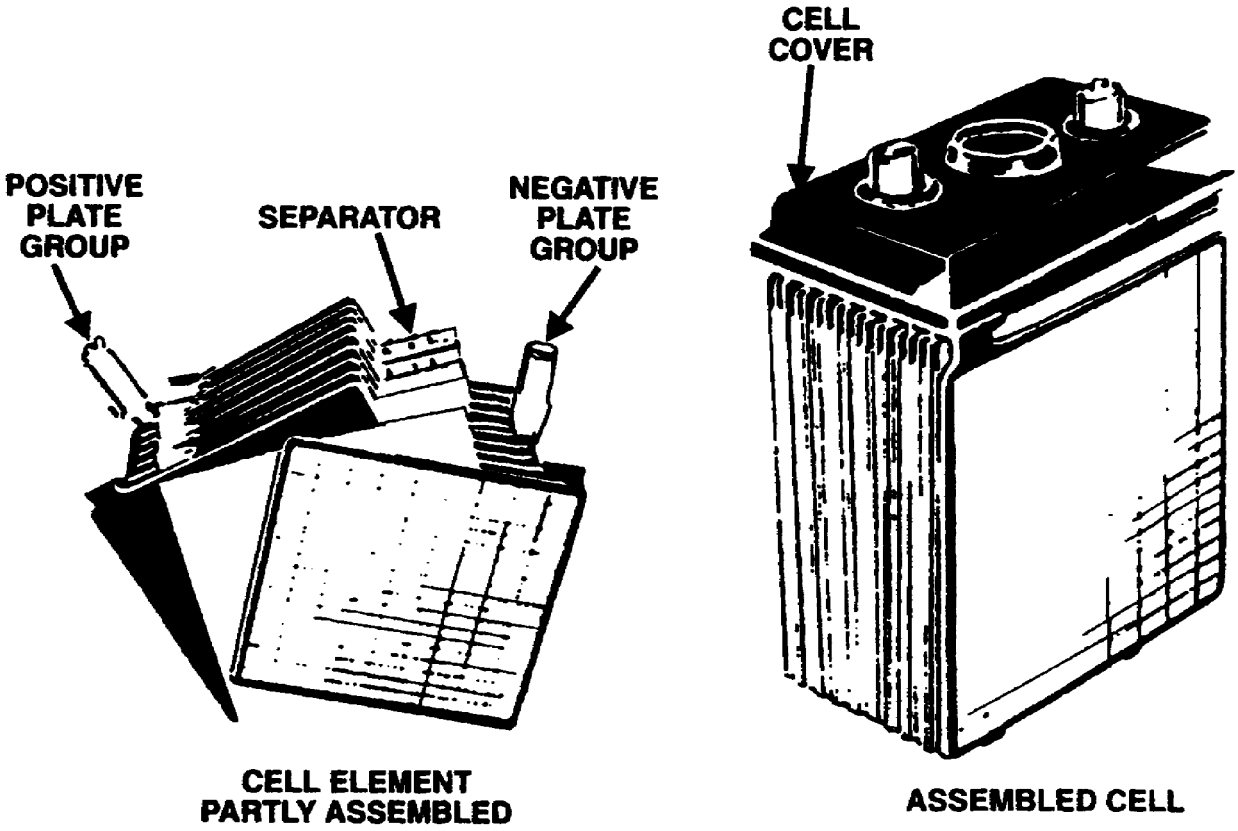


Figure 1-4.

The positive plate group makes up the positive electrode. The negative plate group makes up the negative electrodes. Placing the assembled cell in a container of electrolyte will cause a chemical action that will generate electricity. A secondary cell differs from a primary cell in that a secondary cell can be recharged and a primary cell can only be restored.

The factors that affect the VOLTAGE RATING of a cell are the material the electrodes are made of and the composition of the electrolyte.

The voltage rating of a cell that has a dilute solution of ammonium chloride (sal ammoniac) for its electrolyte, and electrodes made of carbon and zinc, is 1.5 volts.

The factors that affect the CURRENT CAPACITY of a cell are the size of the electrodes, the distance between them in a solution of electrolyte, and the temperature.

The current capacity of a cell is expressed in AMPERE-HOURS. Ampere-hours of a cell is the measurement of current capacity that indicates the amount of current that will flow through a circuit in a certain amount of time.

The ampere-hours, or current capacity of a cell is affected by the size of the electrodes, distance between the electrodes in the electrolyte, and the temperature.

When current flows through a cell, it causes gas bubbles to form and some of them accumulate on the positive electrode. The accumulation of gas bubbles tends to reverse the polarity of the cell, thus increasing the effective resistance of the cell. This reduces the current flow and lowers the voltage available at the cell terminals.

The result of the chemical reaction that causes the accumulation of gas bubbles on the positive electrode of a cell is POLARIZATION.

The impurities in the materials used to make electrodes and electrolyte cause a chemical action to take place in a cell when the circuit is open. This chemical action will discharge a cell when it is not supplying power to a circuit.

The chemical action, of an open-circuit cell, that takes place because of the impurities in the materials used to make electrodes an electrolyte causes LOCAL ACTION which will discharge the cell.

When a lead-acid cell is being discharged, a chemical reaction takes place that causes the sulfuric acid in the electrolyte to combine with the lead plates, which forms lead sulfate.

The formation of lead sulfate coats the electrodes with lead sulfate and decreases the acid content of the electrolyte. The result of this chemical reaction is LEAD SULFATION.

The examples below show how the method of connecting cells to form a battery will determine the terminal voltage.

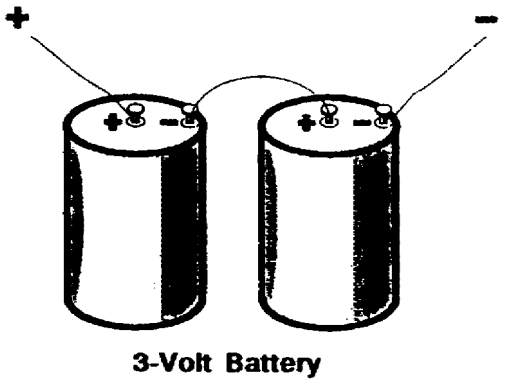


Figure 1-5.

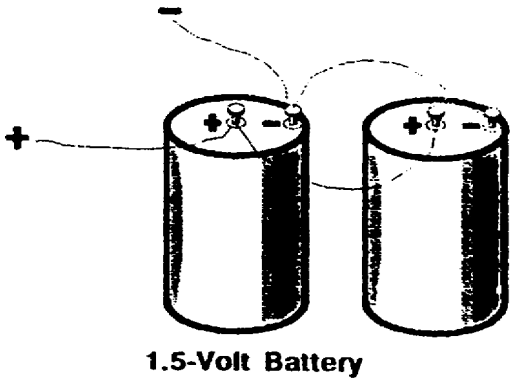


Figure 1-6.

Figure 1-5 shows two 1.5 volt cells connected in series. The terminal voltage of the battery is 3 volts.

Figure 1-6 shows two 1.5 volts cells connected in parallel. The terminal voltage of the battery is 1.5 volts.

The method of connecting cells to form a battery will determine the terminal voltage and current capacity of the battery.

Series connection of cells means that the negative (-) electrode of one cell is connected to the positive (+) electrode of the next cell. When cells are connected using this method, you can determine the terminal voltage of the battery by adding the cell voltages together. The current capacity of a battery of series-connected cells is the same as the current capacity of one cell.

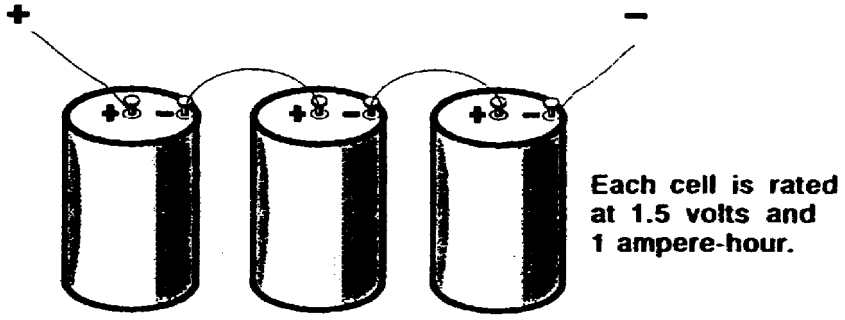
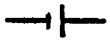
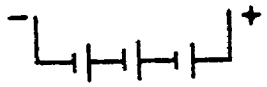


Figure 1-7.

The symbol for cell is  The short line is the negative side of the cell and the long line is the positive side.

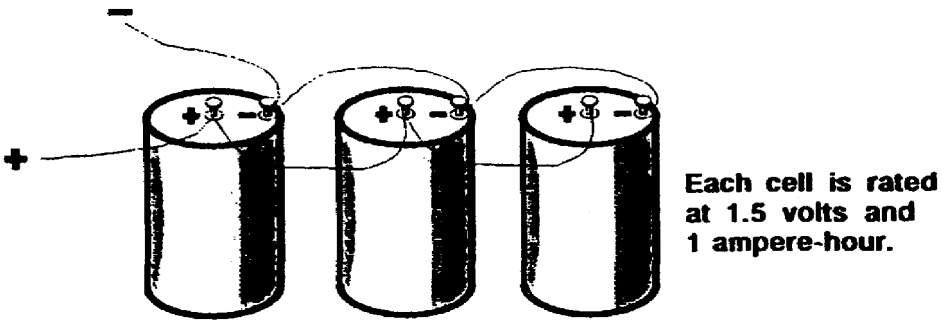
When cells are connected in series to form a battery as shown below, the cell voltages are added together to determine terminal voltage; current capacity is the same as the capacity of one cell.



Each cell of the battery above is rated at 2 volts and 2 ampere-hours, and they am connected in series. The battery has a terminal voltage of 6 volts and a current capacity of 2 ampere-hours.

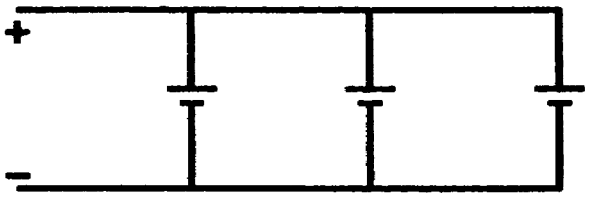
The terminal voltage of a battery that has six (6) cells, each rated at two (2) volts and one (1) ampere-hour, connected in series will be twelve (12) volts and the current capacity will be one (1) ampere-hour.

Parallel connection of cells means that the negative (-) electrode of one cell is connected to the negative electrode of the next cell, and the positive (+) electrode of one cell is connected to the positive electrode of the next cell. When cells are connected using this method, you can determine the current capacities of the cells together. The terminal voltage of a battery of parallel-connected cells is the same as the terminal voltage of one cell.



The terminal voltage of the battery above is 1.5 volts and the current capacity is 3 ampere-hours.

By using the electrical symbol for cells, the method of connecting cells to form a battery can be shown.



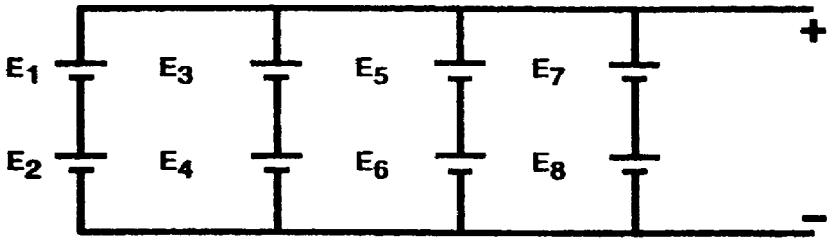
Parallel-connected cell symbols.

If each symbol above represents a cell that is rated at 2 volts and 2 ampere-hours, the battery of cells has a terminal voltage of 2 volts and a current capacity of six (6) ampere-hours.

You can obtain MAXIMUM TERMINAL VOLTAGE by connecting cells in SERIES.

You can obtain MAXIMUM CURRENT CAPACITY by connecting cells in PARALLEL.

The terminal voltage and current capacity of a battery of cells connected in a combination of series-parallel may be determined as shown below.



Each cell is rated at 1.5 volts and 1 ampere-hour.

Cell E_1 is in series with E_2, E_3 is in series with E_4, E_5 in series with E_6, and E_7 with E_8. Cells E_1 and E_2 are in parallel with E_3, and E_4, E_3 and E_4, are in parallel with E_5 and E_6, and E_5 and E_6 in parallel with E_7 and E_8,. The terminal voltage of the combination of E_1, plus E_2 is 3 volts, as is the combination of E_3 plus E_4, E_5 plus E_6, and E_7 plus E_8. The terminal voltage of the battery of cells is 3 volts. The current capacity of the combination of E_1, and E_2 is 1 ampere-hour, as is the combination of E_3 and E_4, E_5, and E_6, E_7 and E_8. The current capacity of the battery is 4 ampere-hours.

If you connected two (2) batteries of cells, each consisting of six (6) series-connected 2 volt---100 ampere-hour cells, in parallel, the terminal voltage of the combination would be 12 volts and the current capacity would be 200 ampere-hours.

The condition of liquid electrolyte solution is determined by measuring SPECIFIC GRAVITY with a HYDROMETER. The specific gravity reading on the scale of a hydrometer indicates the weight of the chemical content of electrolyte solutions.

When the specific gravity reading on a hydrometer scale indicates that the weight of the chemical content of the electrolyte is below a given standard, the cell or battery must be recharged or else have the correct chemical added to adjust the specific gravity.

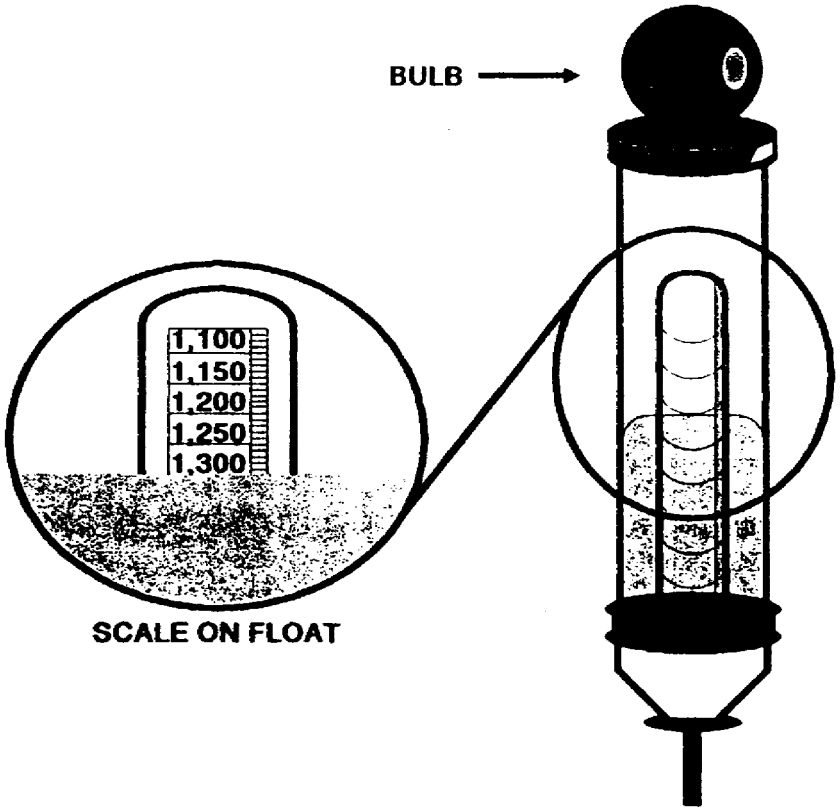


Figure 1-8. Hydrometer.

The INTERNAL CONDITION of battery cells is determined by performing the high-rate discharge test. This test will indicate the terminal voltage of a cell when an external load is placed on it.

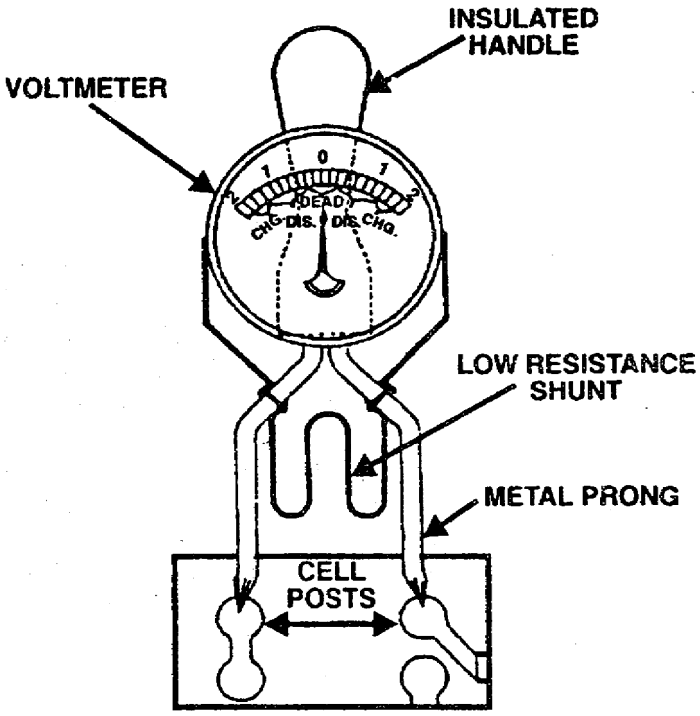


Figure 1-9. High-Rate Discharge Tester.

The voltage reading on the item of test equipment illustrated above can be used to determine the internal condition of battery cells.

The INTERNAL CONDITION of battery cells can be determined by using a HIGH-RATE DISCHARGE TESTER.

Another method of determining the condition of a cell or battery of cells is by measuring OPEN-CIRCUIT VOLTAGE. This test should be made with a PRECISION VOLTMETER.

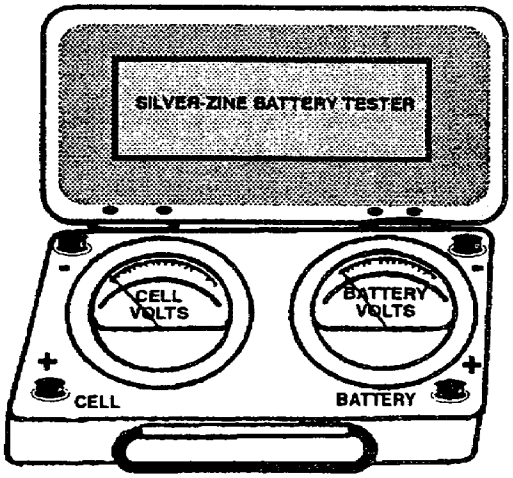


Figure 1-10. Silver-Zinc Battery Tester.

Highly accurate open-circuit voltage readings are taken to determine the condition of cells or batteries.

As you work around batteries and battery compartments, you will be handling acid and alkaline solutions. You will also be exposed to gaseous fumes. For these reasons, you must be extremely cautious and observe many safety precautions.

There are several safety precautions to be observed when handling batteries. You should be extremely careful to KEEP OPEN FLAMES and SPARKS AWAY from batteries. This means absolutely NO SMOKING. You should make NO REPAIRS, CONNECTIONS, or DISCONNECTIONS to a battery while it is BEING CHARGED. When mixing electrolyte, ALWAYS POUR ACID VERY SLOWLY INTO the WATER. Never pour water into acid, as the rapid generation of heat that results will cause the electrolyte to splatter. You must remember that electrolyte contains acids or alkalines which will burn your skin and destroy your clothing. You should remember that the gases produced by the chemical actions of a battery are very explosive. For this reason, you should NEVER OPEN BATTERIES EXCEPT IN WELL-VENTILATED SPACES. If possible, the TEMPERATURE of battery compartments and storage rooms SHOULD BE BELOW 95 DEGREES FAHRENHEIT as well as being WELL VENTILATED. If TOOLS are required to remove or replace batteries, they should have INSULATED HANDLES. You should NEVER DISCONNECT a BATTERY that is SUPPLYING POWER to a circuit; also, NEVER CONNECT a BATTERY to a CLOSED CIRCUIT.

LESSON

PRACTICE EXERCISE

1. The generation of electricity by converting chemical energy to electrical energy takes place in a _____ .

2. Electricity is generated or produced by _____ in a chemical cell.

3. A chemical cell is defined as a device that _____by chemical action.

4. Write the electrical definition of a chemical cell in the space below:

   _____

   _____

5. The chemical action that takes place between _____ and _____ in a cell generates electricity.

6. The positive and negative conductors of a cell are the _____.

7. The dilute solution of acid or alkali is the _____ of a cell.

8. The negative electrode is usually eroded in a _____ cell because of the _____ action that takes place.

9. By replacing the eroded electrode and the electrolyte, a primary cell can be _____ .

10. From the example below, fill in the blanks.

    a. The anode is made of _____ .

    b. The anode is the _____ electrode.

    c. The cathode is made of _____ .

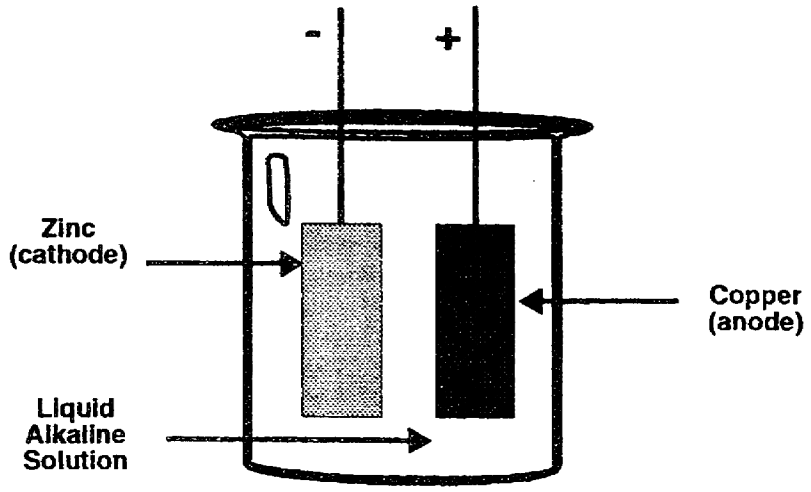
    d. The cathode is the _____ electrode.

    e. The electrodes are immersed in a liquid _____ solution.

    f. The liquid alkaline solution is the _____ of the cell.

    g. The chemical action between the electrodes and electrolyte _____ electricity.

    h. A primary cell can be _____ by replacing the electrodes and the electrolyte.



11. From the example below, fill in the blanks.

    a. The anode is the _____ electrode.

    b. The cathode is the _____ electrode.

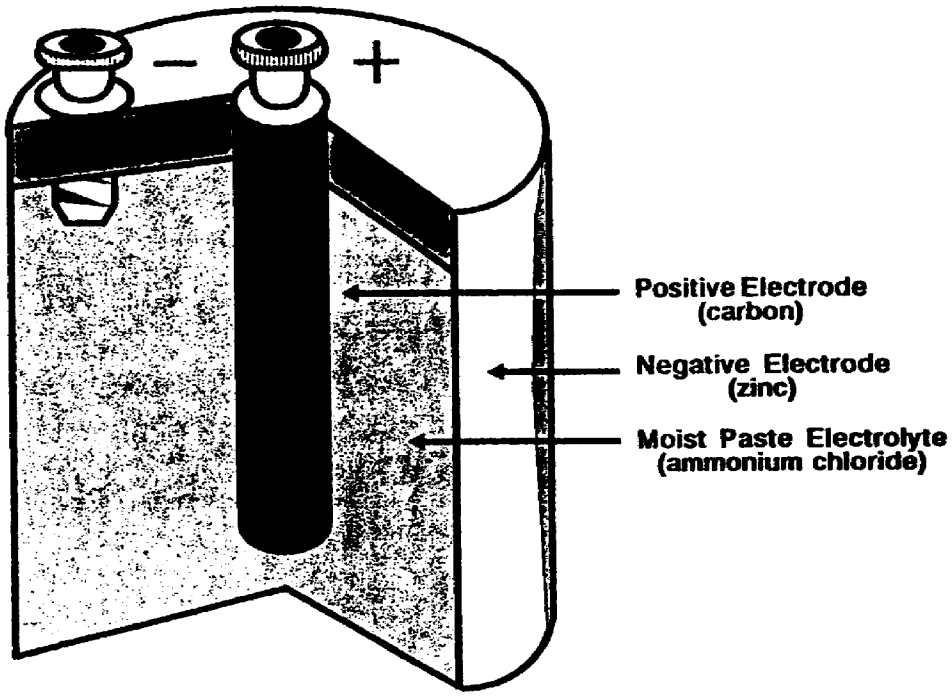
    c. The electrolyte is a moist _____of

    _____

    d. The chemical action in the cell generates _____ .

    e. The chemical action causes the _____ electrode to erode.

    f. The electrode and electrolyte must be replaced to _____ a primary cell.



12. As a secondary cell discharges, the chemical action causes the materials to be _____ from one of the _____ to the other.

13. By forcing a current through a secondary cell in the opposite direction to that of discharge,
the cell can be _____ ,

14. Recharging a secondary cell causes the _____ _____ to change back to the original materials. A secondary
cell is recharged by forcing a _____ through the cell in the
_____ direction to that of discharge.

15. Select, from the statements below, the characteristics of primary and secondary cells. Write "primary" in the space beside the characteristics of a primary cell, and “secondary” in the space beside the characteristics of a secondary cell.

_____ a. Recharged by forcing a current through it in a direction that is opposite to that of discharge.

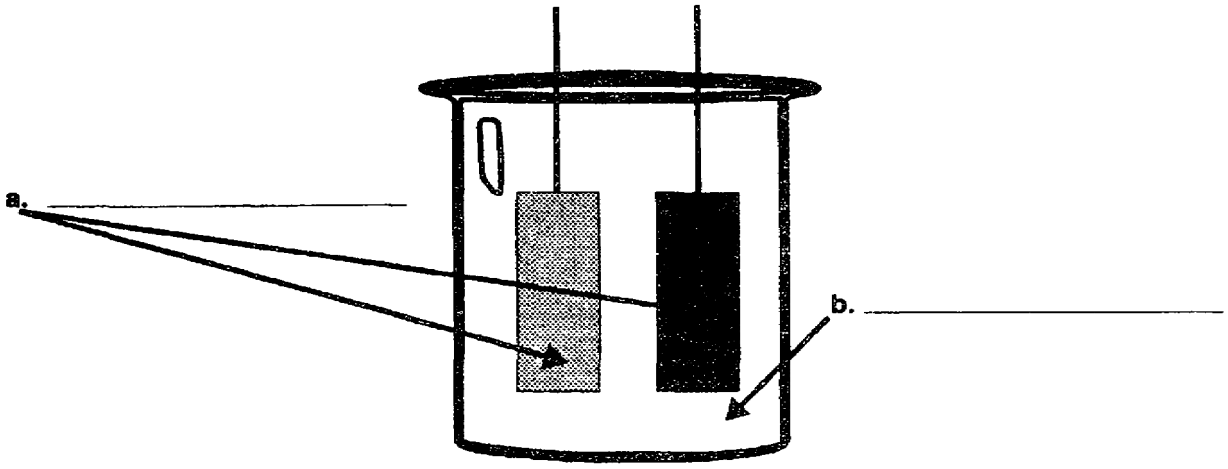
_____ b. Chemical action usually erodes the negative electrode.

_____ c. Materials are transferred from one electrode to the other during discharge.

_____ d. Electrolyte may be a moist paste.

_____ e. Restored by replacing the eroded electrodes and the electrolyte.

16. Label the parts of the cell drawn below.



17. Electrode material and electrolyte composition affect the _____ _____ of a cell.

18. The voltage rating of a cell is affected by the composition of the _____ and
materials the _____ are made of.

19. Select, from the list below, the factors that affect the voltage rating of a cell. Circle the letter beside your choice.

    a. The composition of the electrolyte.

    b. The resistance of the entire circuit in which the cell is to be used.

    c. The size of the electrodes and the distance between them in the solution of electrolyte.

    d. The material the electrodes are made of.

20. The size of the electrodes, the distance between them in the electrolyte, and the temperature affect the _____ of the cell.

21. A cell that has a current capacity of two ampere-hours will supply a circuit with _____ amperes of current flow for one _____ ,or _____ ampere for two _____ .

22. Select from the list below, the factors that affect the current capacity of a cell. Circle the letter beside your choices.

    a. temperature

    b. composition

    c. size of the electrodes

    d. distance between the electrodes

    e. material of the electrodes

    f. resistance of the circuit

23. Select, from the statements below, the description of each of the following terms: a. polarization, b. local action, and c. lead sulfation. Write the correct term in the space below each statement.

    a. The result of the chemical reaction that takes place when current flows through a cell, causing gas bubbles to accumulate on the positive electrode.

    _____

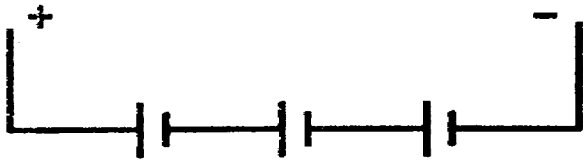
    b. The result of the chemical reaction that takes place during discharge of a lead-acid cell.

    c. The chemical action that takes place in a cell when the circuit is open, caused by the impurities in the materials used to make electrodes and electrolyte.

24. Write the electrical definition of a battery in the space below:

_____ .

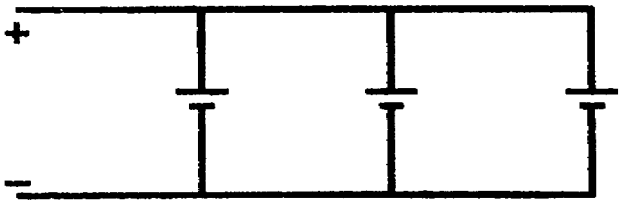
25. Determine the terminal voltage and the current capacity of each of the batteries of cells drawn below. Each cell is rated at 1.5 volts and 5 ampere-hours.



Series-connected cells.

a. Terminal voltage is _____ volts.

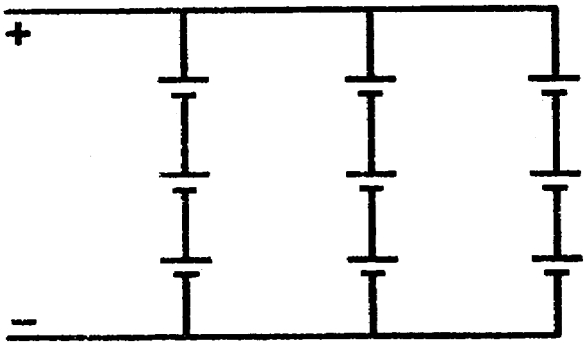
b. Current capacity is _____ampere-hours.



Parallel-connected cells.

c. Terminal voltage is _____ volts.

d. Current capacity is _____ampere-hours.



Series-Parallel-connected cells.

e. Terminal voltage is _____ volts.

f. Current capacity is _____ ampere-hours.

26. Match the cell and battery test equipment listed below to the description of the test that can
be made with each item. Write the letter that is beside each item of test equipment in the space provided beside the test that can be made with the equipment.

a. high-rate discharge tester — ( ) 1. Gives highly accurate open-circuit cell and battery voltage readings.

b. Silver-Zinc — ( ) 2. Indicates the internal condition battery tester of battery cells.

c. Hydrometer — ( ) 3. Measures the specific gravity of electrolyte.

27. Complete the statements listed below about safety precautions to be observed when handling batteries. Write the correct response in the blanks.

a. Be extremely careful to keep _____ _____ and sparks away from batteries while they are being _____ .

b. Do not make repairs, connections, or disconnections to a
_____
while it is being _____ .

c. When mixing electrolyte, always pour the _____ very slowly into the
_____ .

d. Never open batteries except in well-_____
spaces.

e. The temperature of battery compartments and storage spaces should be kept below _____ _____F., if possible, and the spaces should
be well-ventilated.

f. Tools with insulated _____ should be used to replace or
remove batteries.

g. Never connect or disconnect a battery to a closed
_____ .

LESSON

PRACTICE EXERCISE

ANSWER KEY AND FEEDBACK

Item	Correct Answer and Feedback
1.	chemical cell
2.	chemical action
3.	generates electricity
4.	a device that generates electricity by chemical action
5.	electrodes, electrolyte
6.	electrodes
7.	electrolyte
8.	primary, chemical
9.	restored
10.	a. copper b. positive c. zinc d. negative e. alkaline f. electrolyte g. generates h. restored
11.	a. positive b. negative c. paste, ammonium, chloride d. electricity e. negative f. restore
12.	transferred, electrodes

13. recharged

14. transferred materials, current, opposite

15. a. secondary
    b. primary
    c. secondary
    d. primary
    e. primary

16. a. electrodes
    b. electrolyte

17. voltage rating

18. electrolyte, electrodes

19. a and d are correct

20. current capacity

21. 2, hour
    1, hours

22. a, c, and d are correct

23. a. polarization
    b. lead sulfation
    c. local action

24. two or more cells connected together

25. a. 4.5
    b. 5
    c. 1.5
    d. 15
    e. 4.5
    f. 15

26. 1. b
    2. a
    3. c

27.

a. open flames charged
b. battery charged
c. acid water
d. ventilated
e. 95 degrees
f. handles
g. circuit