DEPARTMENT OF COMMERCE

CIRCULAR
OF THE
BUREAU OF STANDARDS

S. W. STRATTON, DIRECTOR

No. 92

OPERATION AND CARE OF VEHICLE-TYPE BATTERIES

[Prepared with the cooperation of the Construction Division
of the Army, War Department]

JUNE 7, 1920

PRICE, 30 CENTS
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PREFACE

Upon the request of Brig. Gen. R. C. Marshall, jr., chief of the Construction Division of the Army, dated September 9, 1918, the Bureau of Standards directed and supervised necessary tests of electric tractors and trucks for use in the Army supply depots. These tests included the investigation of the electrical performance of the batteries for which seven manufacturers submitted equipment. After the original tests on the batteries had been completed, a continuation of the experiments was requested by Col. G. Sevier, General Staff, chief of the engineering and standardization branch. In October, 1918, the standardization committee of the War Department through its subcommittees began the preparation of specifications for tractors, trucks, and batteries, using the data obtained at this bureau as a basis.

The Construction Division of the Army desired a manual of instruction for the care and operation of storage batteries for use in Army depots. The preparation of this manual was undertaken by A. L. Pearson, electrical engineer of that division. The advisory board of the Committee on Education and Special Training of the War Department was consulted in this matter. To meet its needs the plan for this manual was somewhat enlarged.

On July 10, 1919, the chief of the Construction Division of the Army requested that the Bureau of Standards should take over the matter of publishing this manual which it had begun, and that the material which Mr. Pearson had prepared should be revised and added to in order to make the circular of more general use and application. Accordingly, George W. Vinal, associate physicist of the bureau, who had been in immediate charge of the tests and experiments made on these batteries, was assigned to take up the work with Mr. Pearson, and together they have prepared the text of the accompanying circular.

S. W. Stratton,
Director.

January 27, 1920.

OPERATION AND CARE OF VEHICLE-TYPE BATTERIES

CONTENTS

I. INTRODUCTION

The term "battery" is usually applied to a group of connected units called cells. The essential parts of a cell are two dissimilar electrodes immersed in an electrolyte in a suitable jar or container. The electrolyte is a water solution of certain acids, alkalies, or salts which have been found to be adapted to the purpose.

1. DISTINCTIONS BETWEEN PRIMARY AND SECONDARY BATTERIES

Primary batteries convert chemical energy into electrical energy. By so doing, they become exhausted and are discarded, as in the case of dry cells, or are renewed, as in the case of many so-called "wet" batteries. The renewals consist generally of one or both of the electrodes and the material for making the electrolyte. These cells can not be charged by an electric current because some of the reactions which occur in them are irreversible.

Secondary or storage cells, on the other hand, convert chemical energy into electrical energy by reactions which are essentially reversible; that is, they may be charged by an electric current passing through them in the opposite direction to that of their discharge. During this process electrical energy is transformed into chemical energy to be made available at a later time in the form of electrical energy. They are, therefore, called storage batteries or accumulators, as they store energy and so, potentially, electricity; but they do not store electricity as such.

There are also other batteries, some of which are intermediate between primary and secondary batteries. These are generally classed with the primary batteries for practical reasons, although they possess essential characteristics of the secondary batteries.

2. METHODS OF GROUPING CELLS

The positive terminal, or pole, of a cell or battery is the one from which the discharge current flows out into the external circuit. The negative terminal, or pole, is the one through which the discharge current flows from the external circuit back into the battery.

The open-circuit voltage of the storage cell depends entirely upon its chemical composition and in no way upon the number or size of plates. It varies with changes in strength of electrolyte, temperature, and to a small extent upon other factors. The battery voltage (series connection) is that of a single cell multiplied by the number of cells in series.

The capacity of a cell with a given type of plate is proportional to the area of the plate. It is usually expressed in terms of ampere-hours at a given temperature, at a certain rate of discharge in amperes. In all types the higher the discharge rate, the less will be the capacity.

The capacity of a battery in ampere-hours is the same as that of a single cell, unless cells are connected in multiple, in which case the capacity will be that of a single cell multiplied by the number of cells in multiple. The capacity of a battery in watt-hours is equal to its capacity in ampere-hours multiplied by the average voltage. Various groupings of cells arranged to produce different combinations of voltage and capacity are shown in Fig. 1. The capacity of batteries for service in tractors and trucks varies from 200 to 300 ampere-hours.

3. TYPES OF STORAGE BATTERIES

There are two general types of storage batteries of practical importance, the lead-acid type and the nickel-iron type. In the lead-acid type, the plates are of lead, immersed in an electrolyte of sulphuric acid, the whole being contained in a jar of glass or of hard-rubber compound. For very large stationary batteries the containers for each cell are usually lead-lined wooden tanks. In the nickel-iron type, the plates are of steel with pockets for the

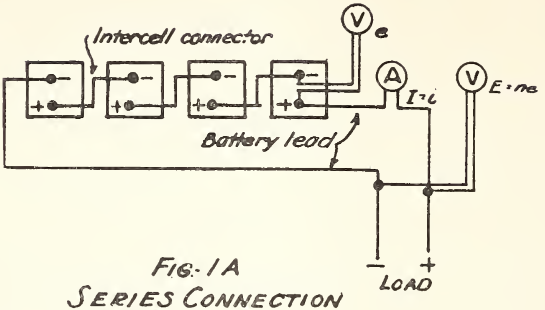


FIG.-1A
SERIES CONNECTION

Total voltage, E, of battery = voltage, e, of a single cell times the number of cells, n. E = ne

Total capacity in amperes, I, = capacity in amperes, i, of a single cell

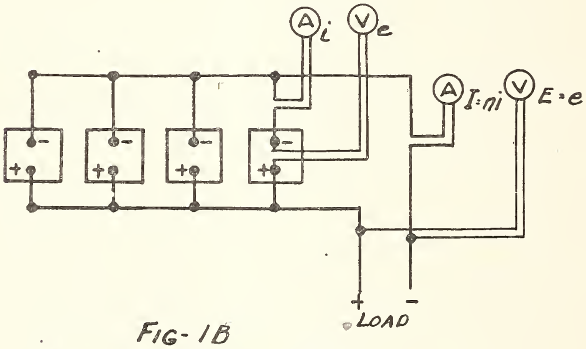


FIG-1B
MULTIPLE CONNECTION

Total voltage, E, of battery = voltage, e, of a single cell. E = e

Total capacity in amperes, I, = capacity in amperes, i, of a single cell times the number of cells, n, I = ni

FIG. 1.—*Diagrams of connections*

The *series system* of connections is used when high voltage and low capacity are required. (Fig. 1A.) The *multiple system* of connections is used when low voltage and high capacity are required. (Fig. 1B.) The *multiple-series* system of connections is used similarly to the series system of connections when it is desired to increase the capacity. (Fig. 1C.) The *series-multiple* system of connections is used similarly to the multiple system of connections when it is desirable to increase the voltage. (Fig. 1D.) This system of connections should rarely, if ever, be used, as all desirable results can be obtained more satisfactorily with the multiple-series system of connections.

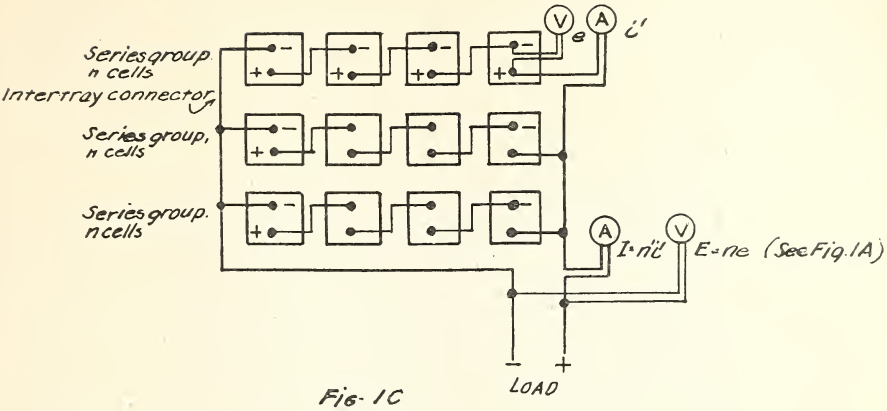


Fig-1C

MULTIPLE-SERIES CONNECTION

Total voltage, E, of battery = voltage, e, of a single cell times the number of cells, n, in one series group

Total capacity in amperes, I, of battery - capacity of a single series group, i', times the number of series groups, n'

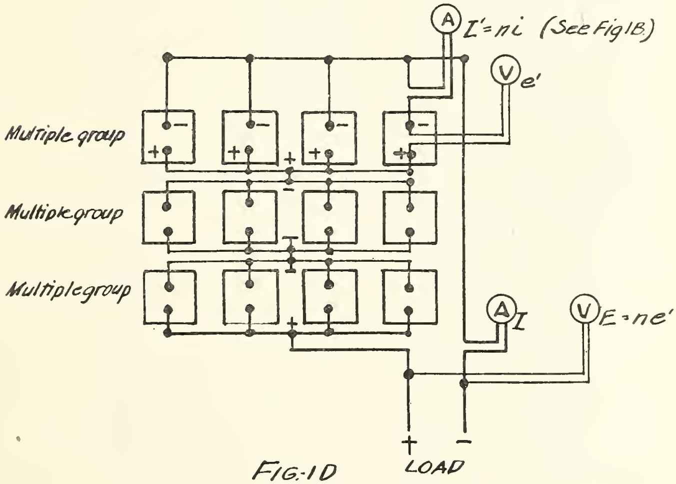


FIG-1D

SERIES-MULTIPLE CONNECTION

Total voltage, E, of battery = voltage, e, of one multiple group times the number of multiple groups

Total capacity in amperes, I, of battery = capacity of one multiple group, I'

FIG. 1.—Continued

active material of nickel and iron oxides immersed in a solution of potassium or sodium hydroxide in water, the whole being contained in a jar of steel.

Specifications for storage batteries for industrial electric tractors and trucks, adopted as standard by the War Department, are given in Appendix A.

II. LEAD-ACID TYPE BATTERIES

1. PLATES

There are two principal types of plates in use, the Planté and the Faure, or pasted plate.

A Planté plate consists of a mass of pure lead, usually with its surface area increased by means of cutting or scoring so that the surface consists of a large number of grooves. The active material is formed electrochemically as a layer of lead peroxide (PbO_2) at the expense of the underlying lead. Such plates are always formed first as positives. Negative plates are formed from positives by reducing the lead peroxide to sponge lead (Pb). The original process of formation consisted of charging the plates alternately in opposite directions, each reversal increasing the capacity of the plate. Temperature, strength of electrolyte, and current density required exact regulation. This process was very wasteful of electrical energy and required a long time. It has been superseded by an accelerated process of forming, which consists of making the plate under formation an anode in an electrolyte of dilute sulphuric acid containing a small amount of some forming agent, such as nitric or some other acid which will attack lead. As in the other process, the temperature, strength of acid, and current density must be right in order to produce successful results.

A Faure, or pasted plate, generally consists of a flat frame or grid of lead-antimony alloy into which the active materials in the form of a paste are pressed. The structure of the grid is such that the active materials are held securely in place. There are many forms of grids, one of which is illustrated in Fig. 2. Another form of grid is shown in Fig. 3, in which the active material is in place. Still another form of pasted plate is the positive of the Ironclad-Exide battery, shown in Fig. 4. This plate consists of a number of vertical units, or pencils, supported in a frame of lead-antimony alloy. Each unit has a central core of irregular section of the same metal. A layer of active material surrounds each core and is retained by a slotted cylindrical casing of hard rubber. The slots are so narrow that the particles of active material can not readily fall out. The pasted type of plate is generally known as a "grid type" and is used exclusively in batteries for vehicles.

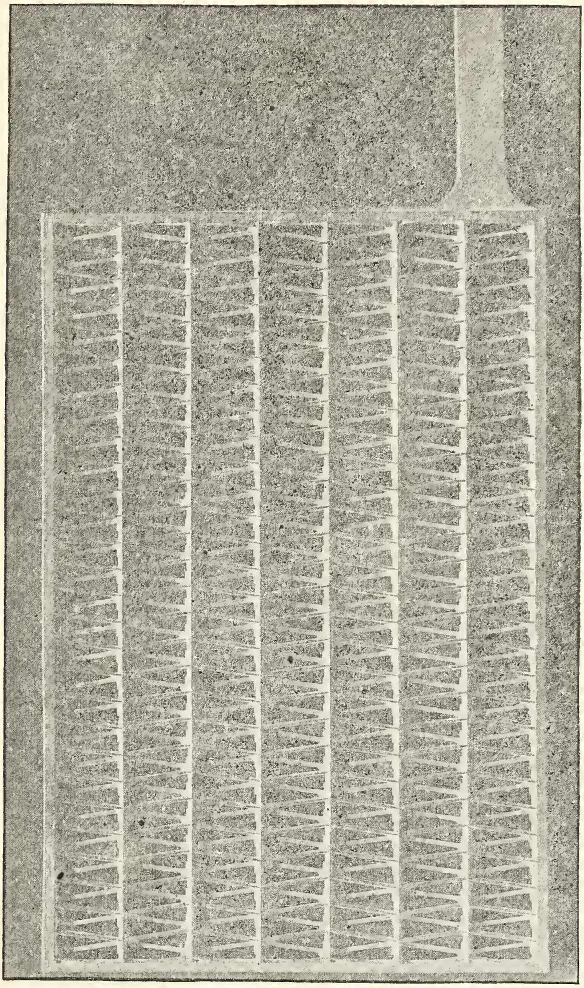


Fig. 2.—*Grid without active material*

Pasted plates of one polarity may be used with Planté plates of opposite polarity. Plates of different design and age, should, however, not be used together in any positive or negative group of a cell on account of local action which will take place between the plates.

Other familiar types of plates are the following: (1) The Manchester positive (Fig. 5) consists of a casting of lead-antimony alloy containing a number of round holes, closely spaced, into which are inserted spiral coils of corrugated lead ribbon. This plate is formed electrochemically, with but slight corrosion of the framework. (2) The Tudor positive (Fig. 6) is cast in cellular form from pure lead. An open type of construction is used, consequently this plate is less subject to warping or buckling than

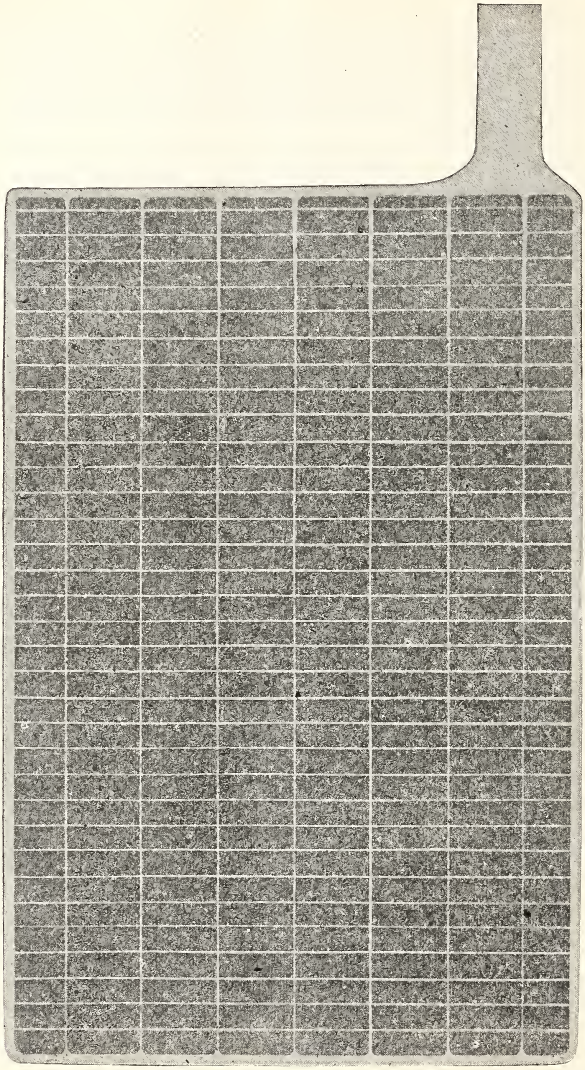


FIG. 3.—*Plate with active material* (*positive*)

other Planté types. The center-web positive is a Planté type, made from a blank of sheet lead, the surface of which is increased by plowing leaves or by spinning with rotating circular disks. The apperance is somewhat similar to the Tudor positive. (3) The box negative (Fig. 7) consists of a grid cast in two halves, the outside of each of which is very thin and perforated. The active material is placed in the small boxes of one half, the other half is then placed on top and the whole riveted together. A more complete description of the many forms of plates which have been used in the past may be found in Wade's Secondary Batteries, page 19, 1903.

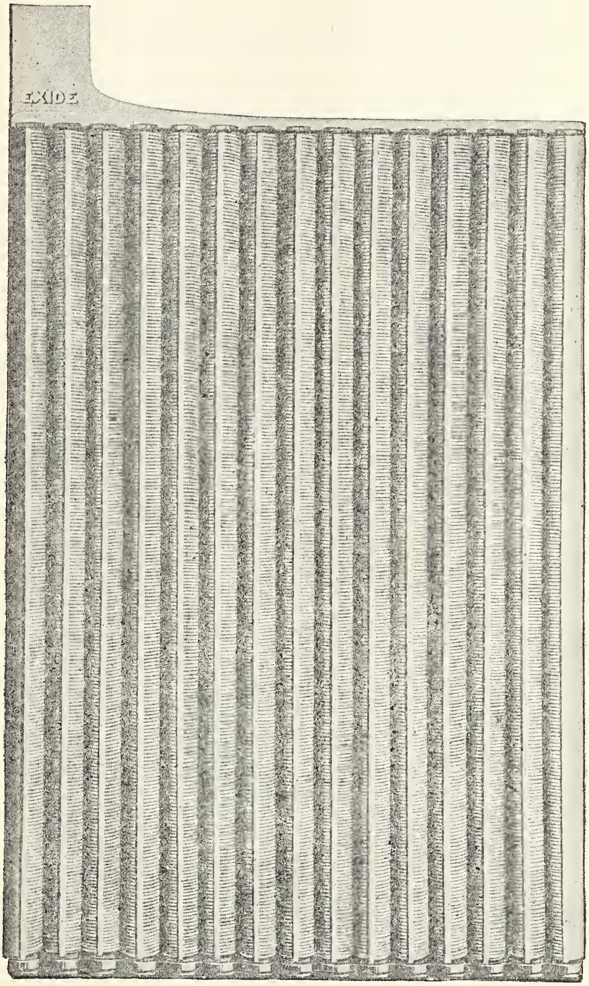


Fig. 4.—*Positive of the Ironclad-Exide cell*

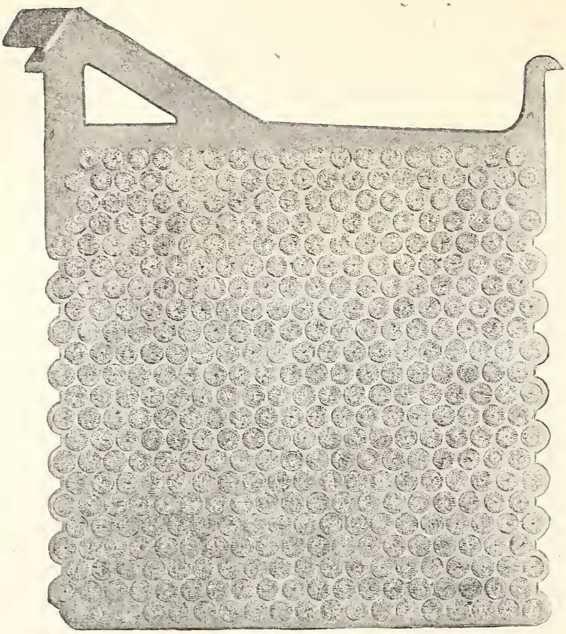


Fig. 5.—*Manchester positive plate*

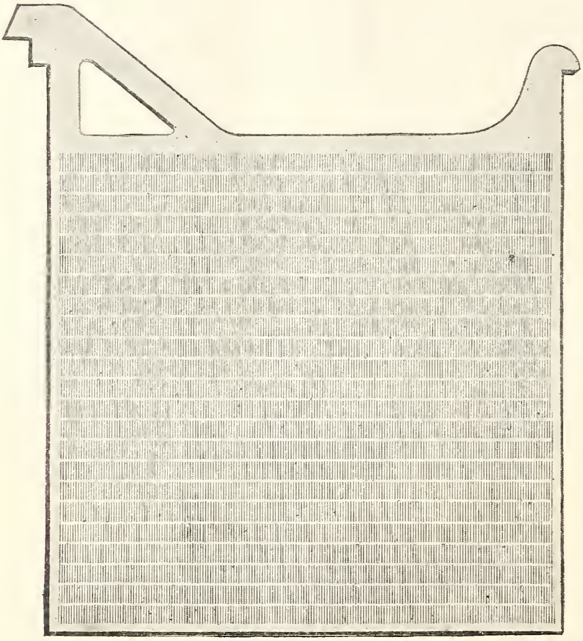


Fig. 6.—*Tudor positive plate*

Plates generally used for vehicle batteries are of a uniform size, 5.75 inches (14.6 cm) in width by 8.625 inches (21.9 cm) in height. Positive plates vary from 0.26 inch (0.65 cm) to 0.13 inch (0.33 cm) in thickness. Negative plates vary from 0.19 inch (0.5 cm) to 0.11 inch (0.3 cm) in thickness. The negative plates are usually made thinner than the positive plates. The elements are assembled with the negative plates always on the outside. Consequently, there is one more negative than positive plate in any cell.

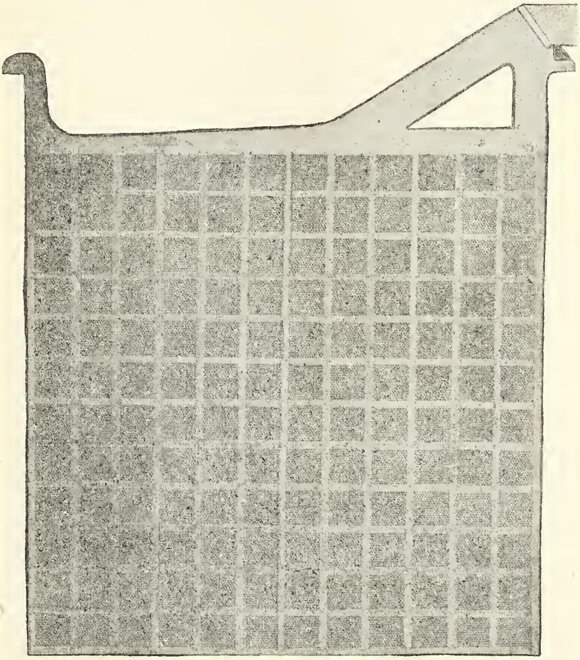


Fig. 7.—*Box negative*

2. SEPARATORS

Plates are generally separated from each other by thin sheets of wood veneer known as separators. The separators are porous to permit electrolytic conduction but prevent metallic conduction, which would short-circuit the cell. The separators are usually corrugated on one side and smooth on the other. The wood must be either naturally free from injurious substances or treated to remove them. The wood separators in tractor batteries are generally kept away from the positive plates by means of thin sheets of perforated hard rubber. In the Ironclad Exide battery the rubber separator is omitted because the positive plate carries its own rubber protection. The smooth side of the wood separator is placed against the negative plate. Various forms of separators are illustrated in Figs. 8 to 11. In addition to the above-described separators, which may be said to represent standard practice for vehicle type batteries, there are other kinds, such as the threaded rubber separator made by one manufacturer and used in his starting and lighting batteries. This separator consists of a sheet of soft-rubber compound containing a great many cotton threads running transversely through the compound. Wood separators are not used in combination with this separator.

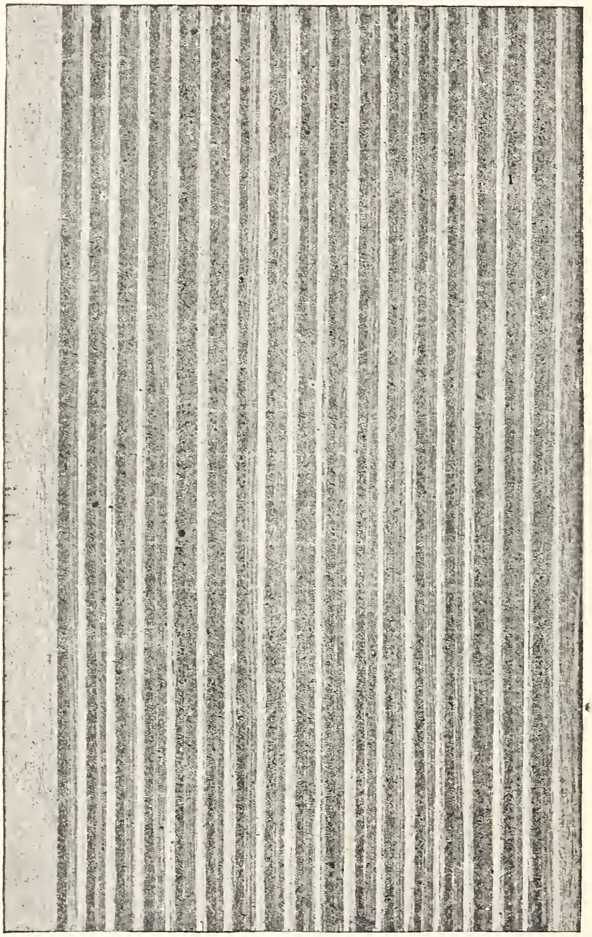


Fig. 8.—*Wood separator with corrugation on one side only*

3. JARS

Jars, or containers, of portable cells are of hard-rubber compound. The bottoms of the jars contain ribs or bridges upon which the plates rest and which form pockets or spaces into which the sediment, gradually thrown off from the plates in service, settles. This space is ordinarily of ample size to hold the sediment deposited during the life of the wood separator. If the separators are worn out the cell must be dismantled for their replacement. At this time the jars may be cleaned.

The cover of the cell is of material similar to the jar and has openings through which the terminal posts project. The terminal post of each group usually is provided with a flange upon which the cover rests. There are various devices in use for the prevention of leakage of electrolyte around the posts where they pass through the cover. In one form several rings are cast around the post, and the sealing compound, by flowing into the grooves thus formed, makes the joint tight. In another form the post is threaded, and a nut (called a sealing nut) is used to force a soft-rubber gasket around the post against the inside of the cover, thus making the joint tight.

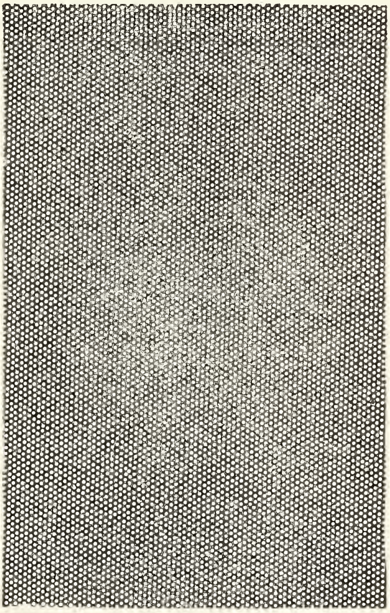


Fig. 9.—*Perforated hard rubber separator*

4. CONNECTORS

Each group of positive and negative plates is welded, or burned, as commonly expressed, to a connecting strap of lead or lead alloy. There are several types of straps, but the pillar-post type is considered to be the best. This has the post cast integral. A typical form is illustrated by Fig. 12, which also shows one form of sealing nut.

Connections between individual cells of a tray or case are known as intercell connectors. Similarly connections between individual

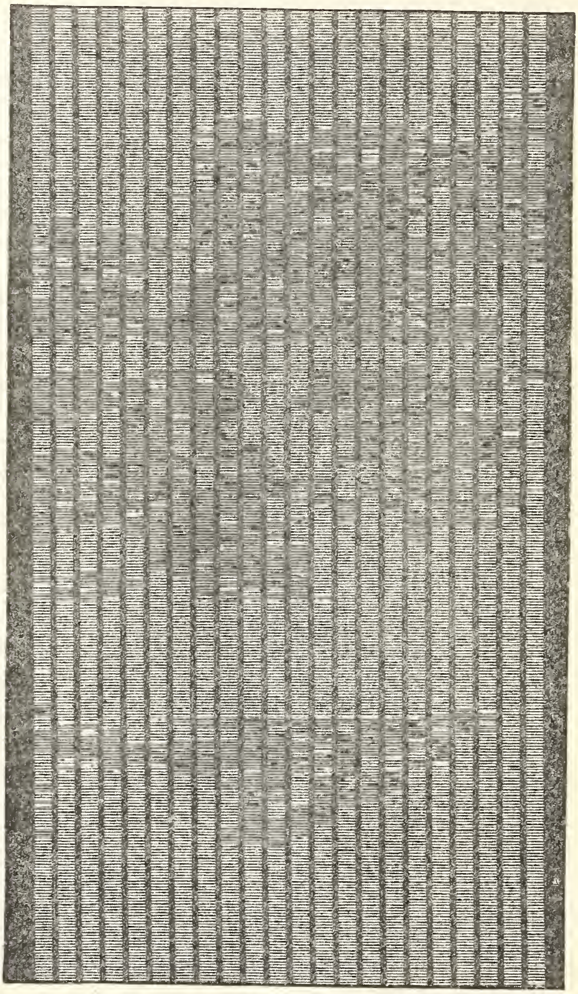


Fig. 10.—*Slotted hard rubber separator*

trays or cases are known as intertray connectors. These may be either burned to the posts of the cells or bolted. Burned-on connectors are to be preferred, as a better joint is insured by the welding. With a bolted connection the acid may creep in between the contact surfaces and cause corrosion which will tend to destroy the joint electrically. An approved form consists of a copper

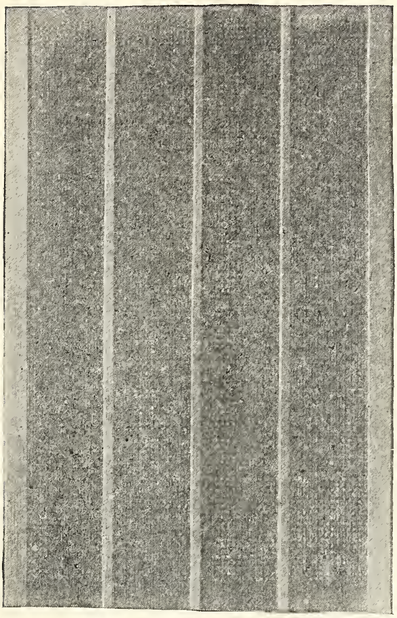


FIG. 11.—*Perforated hard rubber separator with soft rubber ribs*

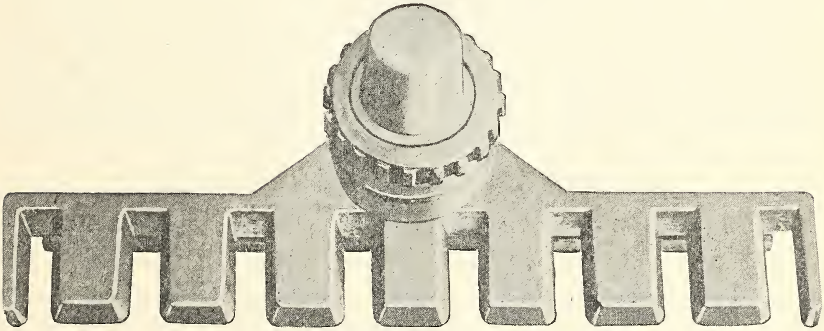


FIG. 12.—*Connecting strap, pillar-post type*

strap heavily lead plated. This form combines flexibility with high conductivity. A loop allows of expansion and movement of the cells without danger of cracking the covers under excessive strains. Solid lead intercell connectors are frequently used.

Intertray connectors usually consist of flexible, rubber-covered copper cables with terminals for burning or bolting to cell posts and such special terminals as may be required for connections between trays.

Fig. 13 illustrates the general details of a cell of the lead-acid type.

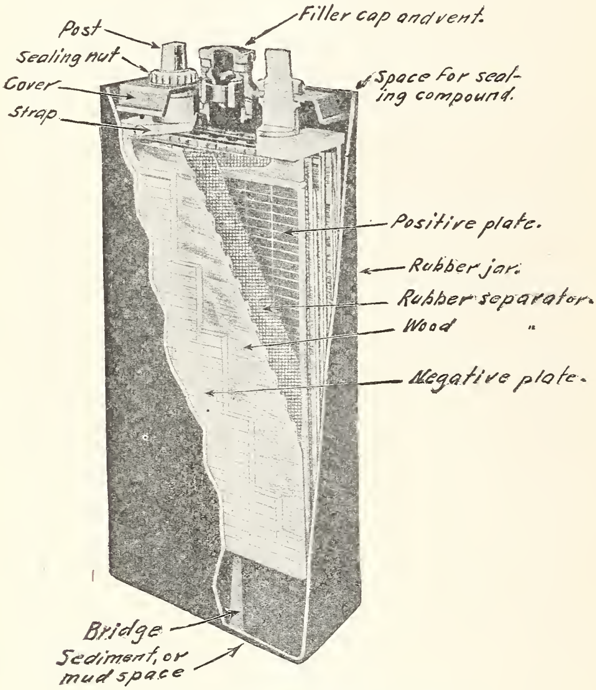


Fig. 13.—*Lead-acid type of cell*

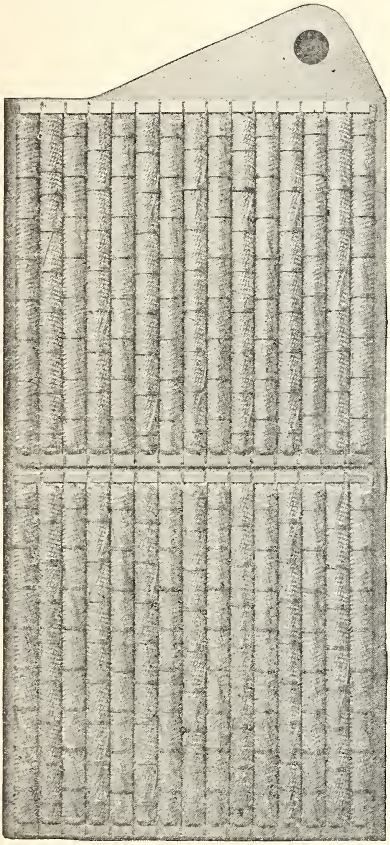
III. NICKEL-IRON TYPE BATTERIES

1. PLATES

The positive plates consist of tubes of perforated sheet steel mounted in steel frames or grids. The active material, nickel hydroxide, is tamped into these tubes in alternation with layers of nickel. Negative plates consist of thin rectangular pockets of perforated sheet steel mounted in steel frames or grids. The active material, iron oxide and metallic iron, is contained in the pockets. The grids, tubes, and pockets are nickel plated. Figs. 14 and 15 show positive and negative plates, respectively.

2. JARS

The jar, or container, is a can of cold-rolled sheet steel nickel-plated, with corrugated sides. The cover is of the same material, and contains a combined filling aperture and gas vent. All seams, including the connections between the jar and the cover, are welded.



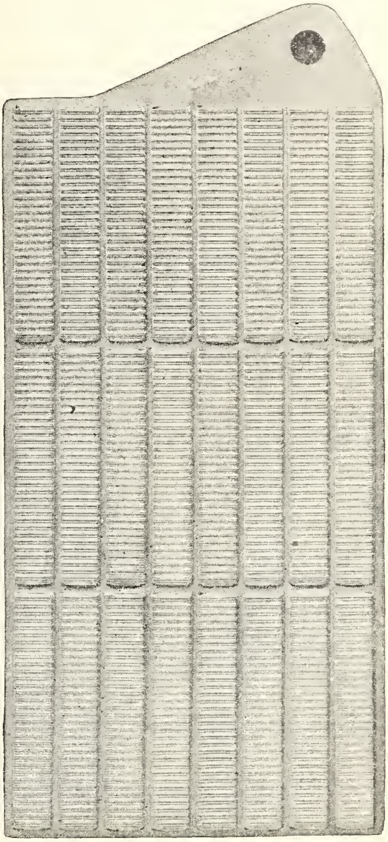


Fig. 14.—*Positive plate, nickel-iron type of cell*
Fig. 15.—*Negative plate, nickel-iron type of cell*

3. CONNECTORS

Tapered steel poles, or terminals from the plates, project through gas and water tight bushed holes in the cover. Intercell connectors consist of solid copper wire swedged into steel lugs having an inside taper corresponding to that of the poles or terminals. Intertray connectors consist of insulated, flexible copper conductors soldered into the lugs.

Insulation is of hard rubber throughout.

Fig. 16 illustrates the general details of construction of the nickel-iron type of cell.

IV. REACTIONS

1. LEAD-ACID TYPE

(*a*) Chemical Reactions.—The active material on the positive plate is lead peroxide (PbO_2) and on the negative plate is sponge or finely divided lead (Pb). The group of positive and negative plates, with separators, constitute an element for one cell. Both outside plates are negative, consequently there is always one more negative than positive plate and an odd number of plates in the cell. The plates are immersed in a solution of sulphuric acid (H_2SO_4) and water (H_2O), which constitutes the electrolyte. (See Sec. IX.)

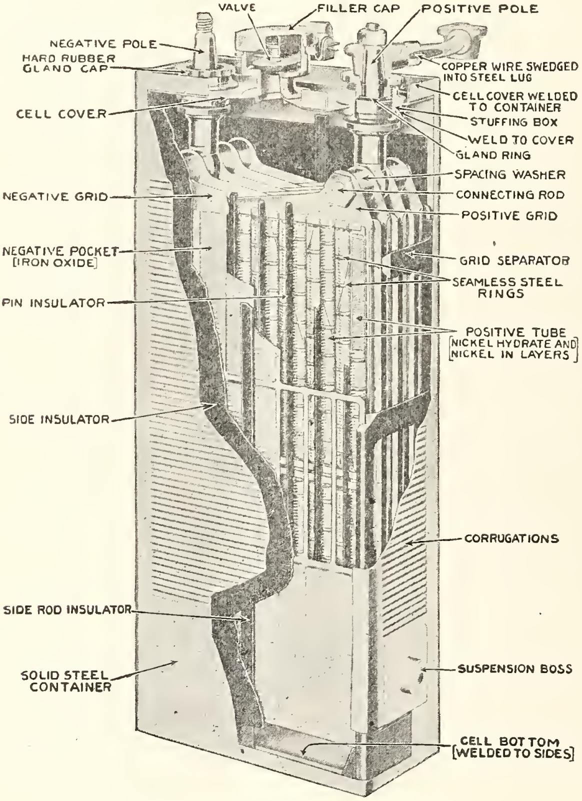


Fig. 16.—*Nickel-iron type of cell*

During the action of charge and discharge the specific gravity of the electrolyte varies. It is highest when the battery is fully charged and lowest when discharged. The range for vehicle-type batteries is from 1.275 to 1.290 charged, and from 1.115 to 1.130 discharged, at a temperature of 25° C (77° F). For other types of batteries the range varies, depending upon the design.

On discharge of the battery both active materials are converted into lead sulphate ($PbSO_4$) at the expense of the acid component of the electrolyte and accompanied by the formation of water. These reactions are most simply represented by the following equations:

Charge:

$PbSO_4 + H_2 = Pb + H_2SO_4$, negative plate.

$PbSO_4 + SO_4 + 2H_2O = PbO_2 + 2H_2SO_4$, positive plate.

Discharge:

$Pb + SO_4 = PbSO_4$, negative plate.

$PbO_2 + H_2 + H_2SO_4 = PbSO_4 + 2H_2O$, positive plate.

The combination of these four equations is represented by the following reversible equation:

$$PbO_2 + Pb + 2H_2SO_4 \rightleftarrows 2PbSO_4 + 2H_2O.$$

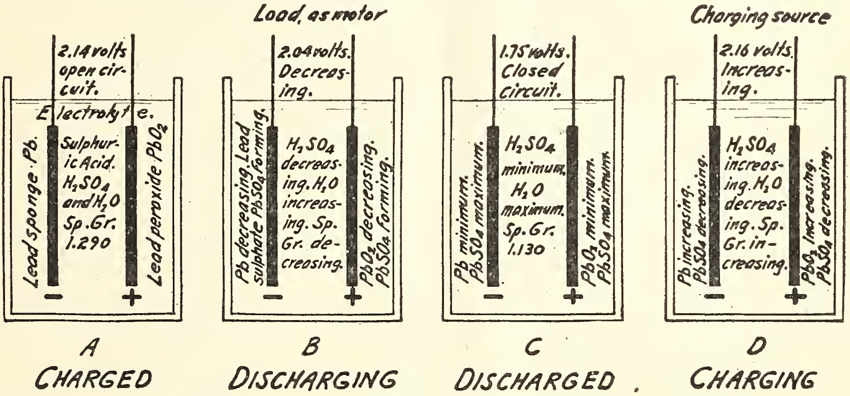


FIG. 17.—*Diagram of performance of lead-acid type of cell*

If impurities are present in the plates or in the electrolyte, the normal reactions stated above may be varied.

Fig. 17 illustrates graphically the reactions.

The active material of the positive plate after formation is of a dark-brown color, and that of the negative plate a slate gray. In respect to state of charge there is a slight change in the color of both plates, which can not be readily observed. The lead, lead peroxide, and lead sulphate are insoluble for practical purposes in the electrolyte, with the result that there is no transfer of material as in electroplating.

Considering the fact that, in batteries of the lead-acid type, the lead combines with the acid in the electrolyte in definite proportions to produce current, it would appear possible to have these materials in a cell in such quantities that each would be exhausted completely at the end of discharge. However, near the end of discharge, the electrolyte would be so weak as to be incapable of producing current at a rate sufficient for practical purposes. Similarly, if all the active material, lead peroxide (PbO_2) and spongy lead (Pb), were combined with the acid, the plates would lose their porosity and conductivity. On this account it is necessary to have acid in the electrolyte and active materials in the plates in excess of the actual requirements. Approximately 25 per cent of the theoretical capacity of the active material is used in the reactions, at the normal or five-hour rate of discharge.

(*b*) VOLTAGE.—The open-circuit voltage varies between 2.06 and 2.14 volts per cell, depending upon the strength of the electrolyte, the temperature, and the age of the cell. It is independent of the size of the cell. The final closed-circuit voltage at end of discharge varies according to the rate and is approximately as follows:

Normal rate	*Volts per cell*
½	1.77
1	1.75
2	1.70
3	1.65
5	1.57
10	1.34

The average voltage during discharge is approximately as follows:

Normal rate	*Volts per cell*
½	1.97
1	1.95
2	1.90
3	1.85
5	1.75
10	1.50

The voltages given are only approximate; that is, they will be greater or less, depending on the resistance of the particular type of battery and all connections.

(*c*) PERFORMANCE CURVES.[1]—Fig. 18 shows typical characteristic curves of performance at normal 5-hour rate of discharge, with constant-current charge.

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[1] The data from which the performance curves on lead and Edison batteries were plotted were obtained at the Bureau of Standards by C. L. Snyder, assistant physicist.

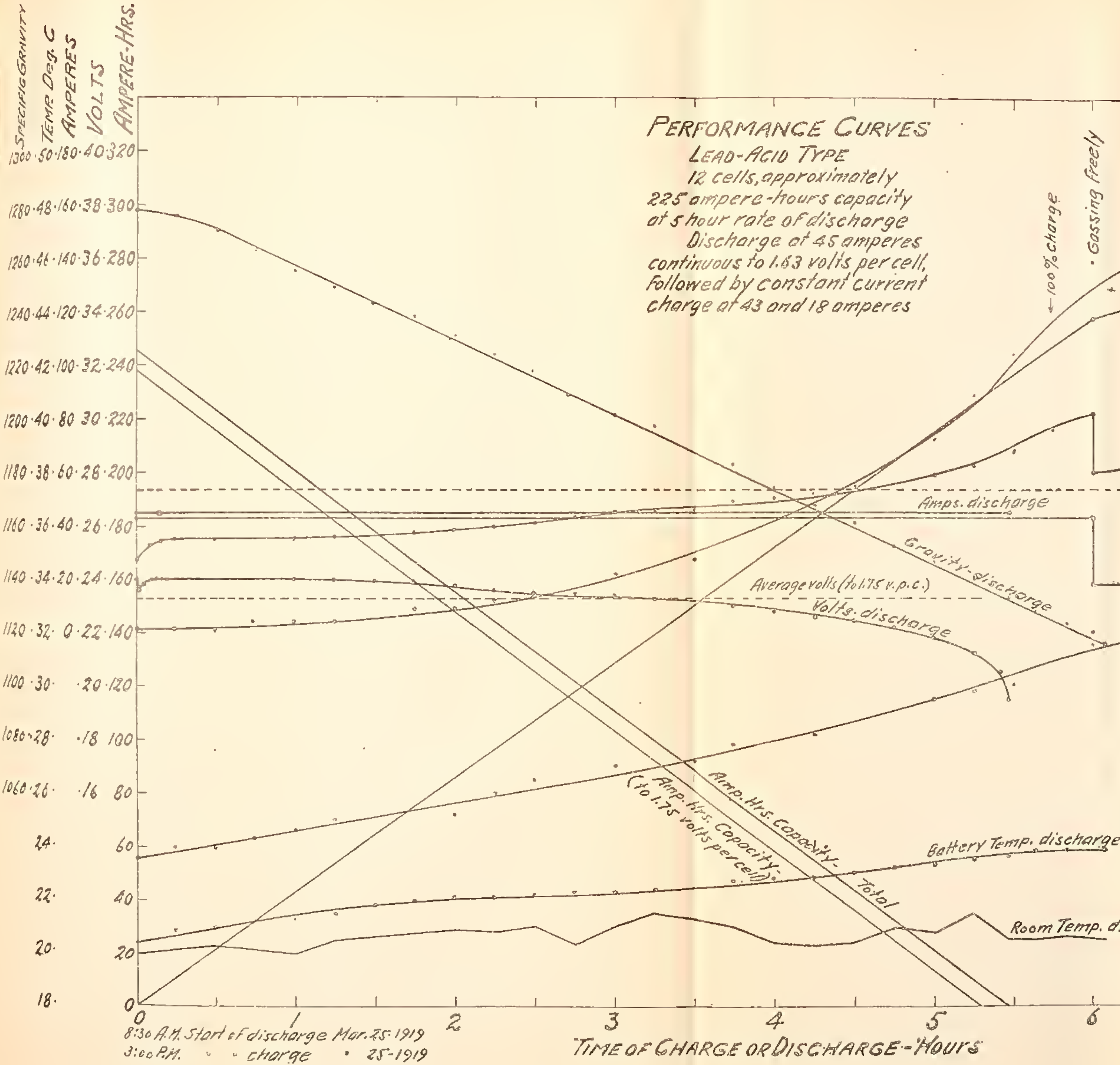
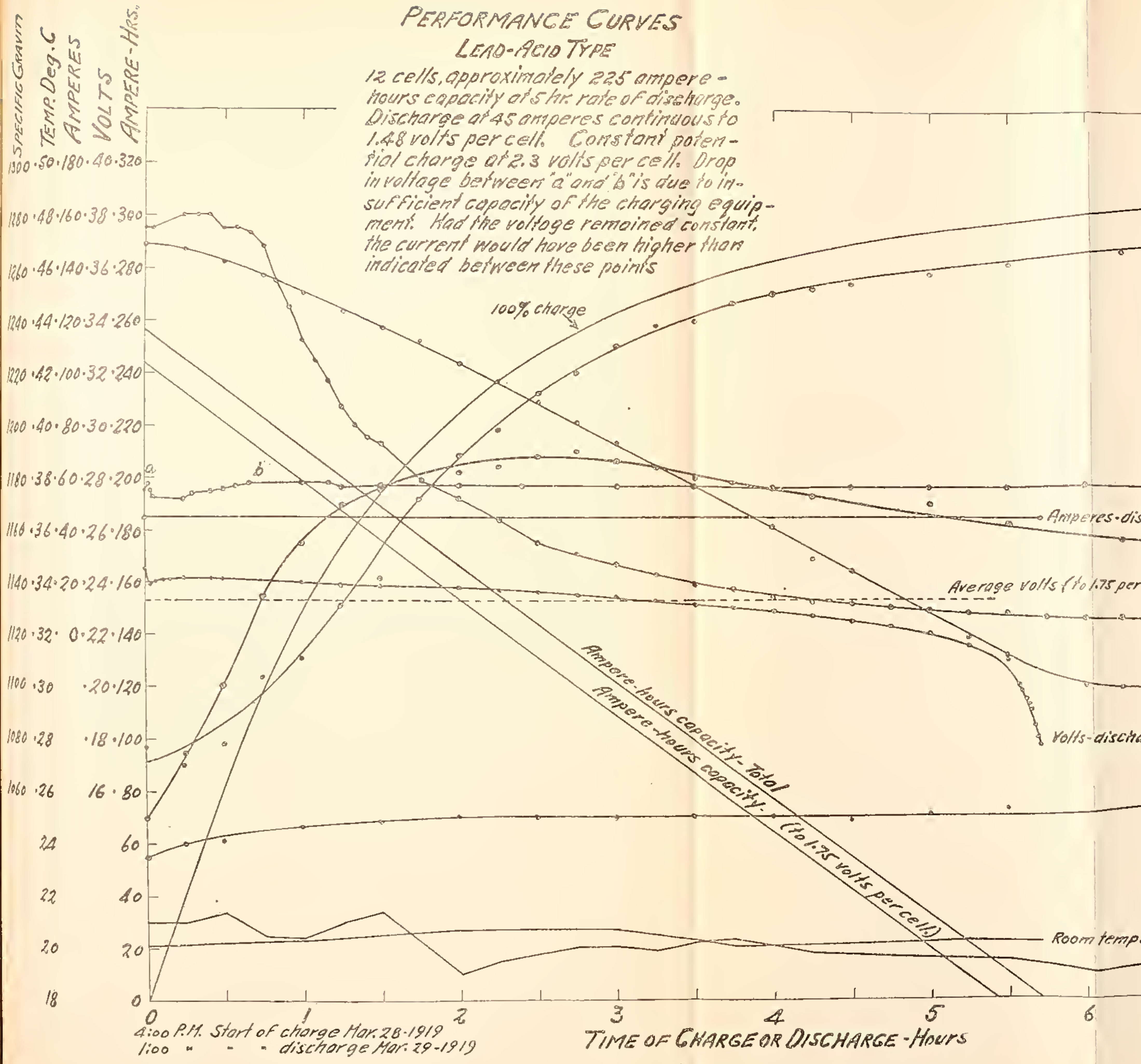

SPECIFIC GRAVITY
TEMP. DEG. C
AMPERES
VOLTS
AMPERE-HRS.
PERFORMANCE CURVES
LEAD-ACID TYPE
12 cells, approximately
225 ampere-hours capacity
at 5 hour rate of discharge
Discharge at 45 amperes
continuous to 1.63 volts per cell,
Followed by constant current
charge at 43 and 18 amperes
← 100% charge
• Gassing freely
Amps. discharge
Gravity-discharge
Average volts (to 1.75 v.p.c.)
Volts-discharge
Amp. Hrs. Capacity-Total
Amp. Hrs. Capacity (to 1.75 volts per cell)
Battery Temp. discharge
Room Temp. d.
1300·50·180·40·320
1280·48·160·38·300
1260·46·140·36·280
1240·44·120·34·260
1220·42·100·32·240
1200·40·80·30·220
1180·38·60·28·200
1160·36·40·26·180
1140·34·20·24·160
1120·32·0·22·140
1100·30·20·120
1080·28·18·100
1060·26·16·80
24·60
22·40
20·20
18·0
0
1
2
3
4
5
6
8:30 A.M. Start of discharge Mar. 25-1919
3:00 P.M. " " charge " 25-1919
TIME OF CHARGE OR DISCHARGE - HOURS

FIG. 18



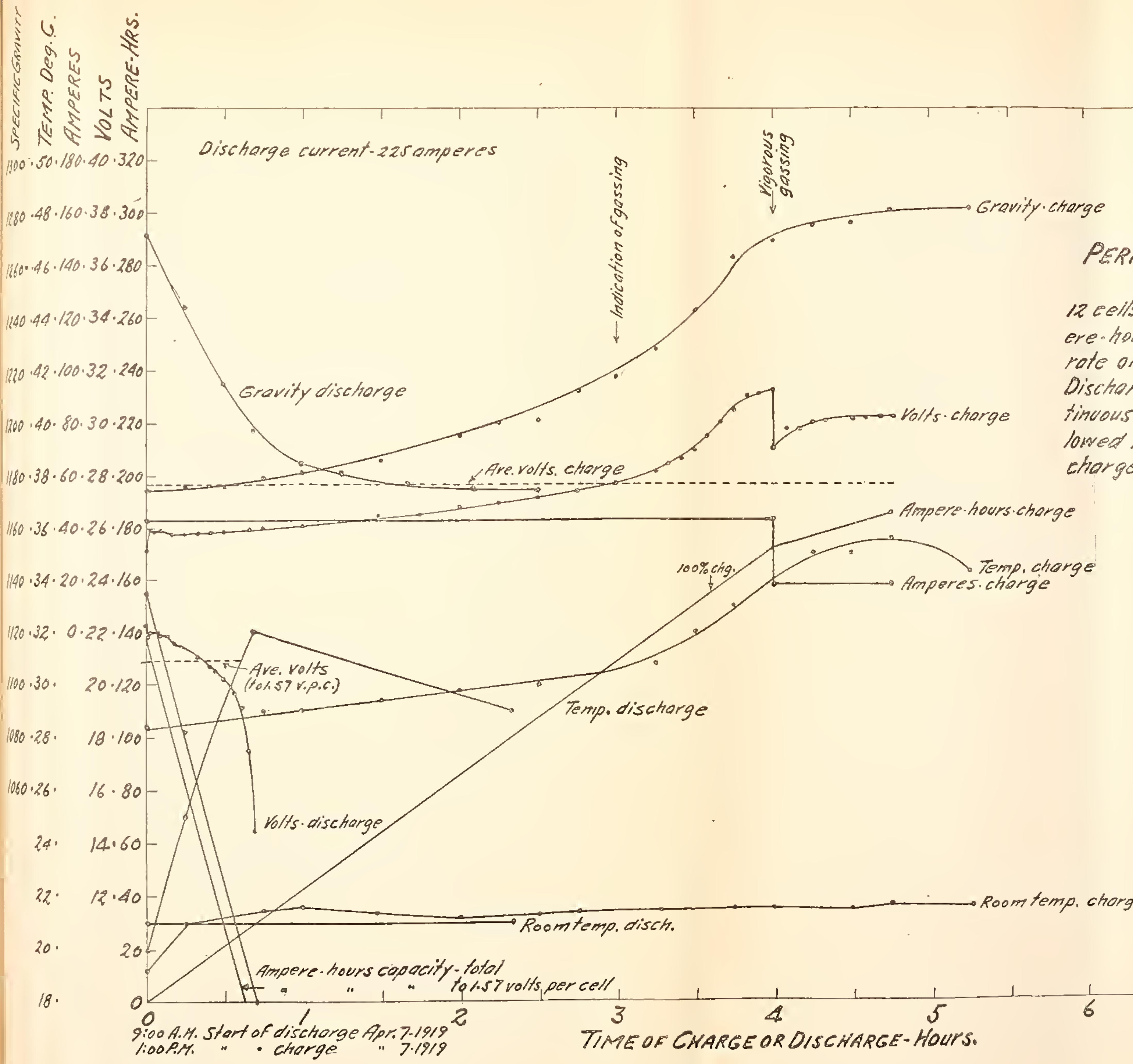
PERFORMANCE CURVES

LEAD-ACID TYPE

12 cells, approximately 225 ampere-hours capacity at 5 hr. rate of discharge. Discharge at 45 amperes continuous to 1.48 volts per cell. Constant potential charge at 2.3 volts per cell. Drop in voltage between "a" and "b" is due to insufficient capacity of the charging equipment. Had the voltage remained constant, the current would have been higher than indicated between these points

174541°—20 (Facing page 22.) No. 2

FIG. 19



174541°—20. (Face page 22.) No.3

FIG. 20

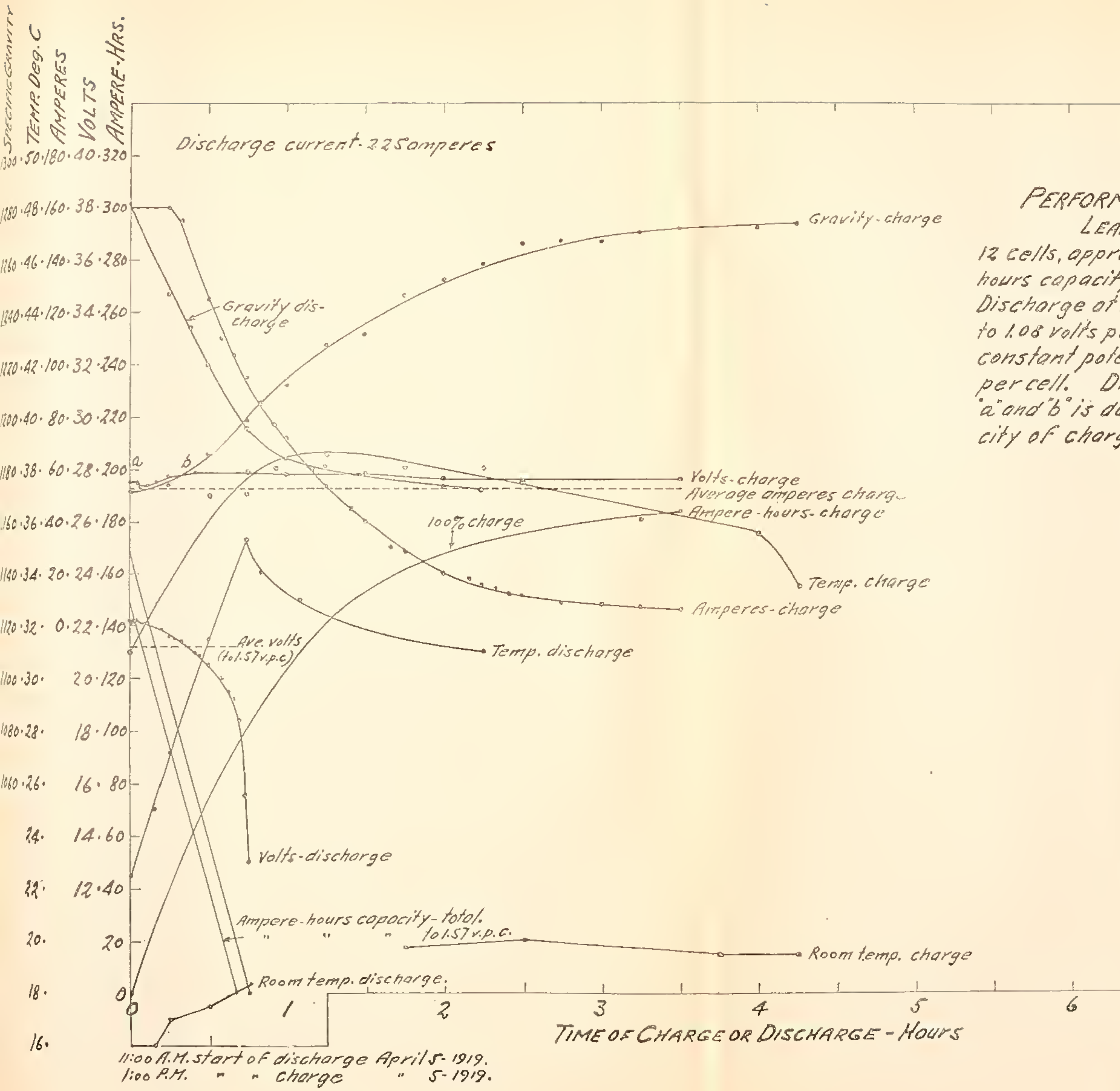

SPECIFIC GRAVITY
TEMP. DEG. C
AMPERES
VOLTS
AMPERE-HRS.
1300·50·180·40·320
1280·48·160·38·300
1260·46·140·36·280
1240·44·120·34·260
1220·42·100·32·240
1200·40·80·30·220
1180·38·60·28·200
1160·36·40·26·180
1140·34·20·24·160
1120·32·0·22·140
1100·30·20·120
1080·28·18·100
1060·26·16·80
24·14·60
22·12·40
20·20
18·0
16·
Discharge current-225 amperes
PERFORM
LEA
12 cells, appr
hours capacit
Discharge of
to 1.08 volts p
constant pote
per cell. D
"a" and "b" is d
city of charg
Gravity-charge
Gravity discharge
a
b
Volts-charge
Average amperes charge
Ampere-hours-charge
100% charge
Temp. charge
Amperes-charge
Temp. discharge
Ave. volts (to 1.57 v.p.c)
Volts-discharge
Ampere-hours capacity-total.
" " " to 1.57 v.p.c.
Room temp. charge
Room temp. discharge.
0
1
2
3
4
5
6
TIME OF CHARGE OR DISCHARGE - HOURS
11:00 A.M. start of discharge April 5-1919.
1:00 P.M. " " charge " 5-1919.

FIG. 21

Fig. 19 shows similar curves but with constant-potential charge.

Fig. 20 shows typical characterstic curves of performance at five times normal rate with constant-current charge.

Fig. 21 shows similar curves but with constant-potential charge.

By comparing Figs. 18 and 19, interesting differences in the performance of the batteries may be observed. The curves of these two figures are comparable, since the ampere-hours discharged are approximately the same. The ampere-hours put in at any period of the charge may be read from the curves given. When charging is done at constant current, this is a straight line; that is, the ampere-hours put in are proportional to the time. Since the charging current by the constant-potential method is not constant, the ampere-hours put into the battery are represented by a curved line which rises very rapidly at first. It will be seen from the curves that the time required to give the battery a 100 per cent charge (the ampere-hours previously discharged) by the constant-current method is 5¾ hours, but by the constant-potential method is about 2¾ hours. The charging of the batteries is not, however, to be stopped at this point. This is a point of advantage for the constant-potential method of charging.

The specific-gravity curve, when the battery discharges is practically a straight line, which indicates that the change of gravity of the electrolyte is approximately proportional to the ampere-hours discharged by the battery. This makes it possible to estimate closely the remaining capacity of the battery by hydrometer readings. When the batteries are being charged the specific gravity rises very slowly at first. When charging by the constant-current method there is no rapid rise in specific gravity during the first three hours. Using the constant-potential method, however, a rapid rise in the gravity is noted after about one hour. From this time on the gravity curve follows closely the curve of ampere-hours.

The temperature of the batteries rises slowly when they are discharging at the normal rate. The total rise in temperature is only a few degrees centigrade. When the batteries are being charged the rise in temperature is considerably more. Charging by the constant-current method causes the temperature to rise nearly uniformly to the end of the charge, but constant-potential charging causes the temperature to rise very rapidly at first, reaching a maximum at about the completion of the 100 per cent charge (ampere-hours previously discharged), following which the temperature falls continuously until the end. For this reason the temperature will not reach a dangerous point if the batteries are not abnormally hot when the charge is begun.

A sharp change in the voltage curve is noted when the charging current is reduced from the initial to the finishing rate. The time at which this reduction in rate should be made is when the batteries have received about 100 per cent of the previous discharge. In Fig. 18 the initial rate was continued slightly beyond this point.

In Fig. 19 a drop in the charging voltage is to be observed during the first half hour; this was due to the insufficient capacity of the charging equipment. Had the voltage remained constant during this period, as it should, the charging current would have been higher than indicated at this point.

Referring to Figs. 20 and 21, similar characteristics are to be noted. The most significant difference is in the temperature curves, which rise very rapidly at this high rate of discharge. After the discharge was stopped the temperature fell rapidly. It will also be noted that 100 per cent of the previous discharge was restored to the batteries on charge in less time than for the normal discharges shown in Figs. 18 and 19. This is because the ampere-hours taken out of the batteries at the high rate of discharge are considerably less than at the normal rate.

2. NICKEL-IRON TYPE

(*a*) Chemical Reactions.—The active material on the positive plate is nickel hydroxide and flake nickel, and on the negative plate is iron oxide and metallic iron. There is always an odd number of plates, because both outside plates are negative. The plates are immersed in a solution of potassium hydroxide and water or sodium hydroxide and water.

During the action of charge and discharge there is no appreciable change in the chemical composition of the electrolyte, consequently the specific gravity remains constant. There is, therefore, no indication of the state of charge by specific-gravity readings, as in the case of the lead-acid type.

The exact chemical changes that take place in the cell are not positively known.

The combined reaction at both plates as given by Allmand, Applied Electrochemistry, page 234, 1912, is:

$$2\ Ni(OH)_3 + Fe \rightleftarrows 2\ Ni(OH)_2 + Fe(OH)_2$$

This equation, read from left to right, represents discharge, and read from right to left represents charge.

Owing to the local action, the voltage of a cell which has been standing idle for some time is lower than that of a freshly charged cell.

The electrolyte of the nickel-iron battery does not change in chemical composition or specific gravity during charge or discharge, because the reactions at the electrodes are oxidation and reduction of the active-materials in equivalent amounts. Gassing occurs during the whole period of charge, limiting the ampere-hour efficiency. An excess of active-materials over the theoretical amounts is required, as in the case of the lead cells. Approximately 24 per cent of the theoretical capacity of the nickel active-material and 17 per cent of the iron active-material is used in the reaction at the normal rate.

(*b*) VOLTAGE.—The open-circuit voltage varies from 1.45 to 1.52 volts per cell, depending upon the temperature of the electrolyte and the rate of charge. It is independent of the size of the cell. The final voltages at end of discharge vary according to the rate of discharge, and are approximately as follows:

Normal rate	*Volts per cell*
1	0.90
2	.80
3	.70
5	.50

The average voltages during discharge are approximately as follows:

Normal rate	*Volts per cell*
1	1.14
2	1.05
3	0.95
5	.75

(*c*) PERFORMANCE CURVES.[2]—Fig. 22 shows characteristic curves of performance at normal rates of discharge, with constant-current charge.

Fig. 23 shows similar curves, but with constant-potential charge.

Fig. 24 shows the characteristics at five times normal rate of discharge, with constant-current charging. Fig. 25 shows similar curves, but with constant-potential charging.

---

[2] The conditions of the recent war have made it impossible to obtain materials of the same quality as before, consequently considerable variation in the performance of nickel-iron batteries may be expected from the results shown in the curves of Figs. 22, 23, 24, and 25. The performance is somewhat dependent upon the number of cycles of charge and discharge through which the battery has passed. An increase in capacity is noted with increasing use when the battery is new. These curves show results of tests made upon this battery after it had passed through 18 cycles since leaving the factory. The curves, however, can not be said to represent the best performance which might be expected from a product manufactured under normal conditions.

The curves of Figs. 22, 23, 24, and 25 are plotted on the same scales as Figs. 18, 19, 20, and 21, so that a direct comparison may be made, except in the case of temperature. It was necessary to change the temperature scale when plotting the results of the alkaline batteries, owing to the large temperature rise, on discharge. The ratio of the temperature scales for the lead-acid and nickel-iron batteries is two to five.

When charging nickel-iron cells by the constant-current method the normal charging current is continued throughout the entire period of charge.

The specific gravity of the electrolyte in these cells is not plotted, since it does not change during either the charge or discharge.

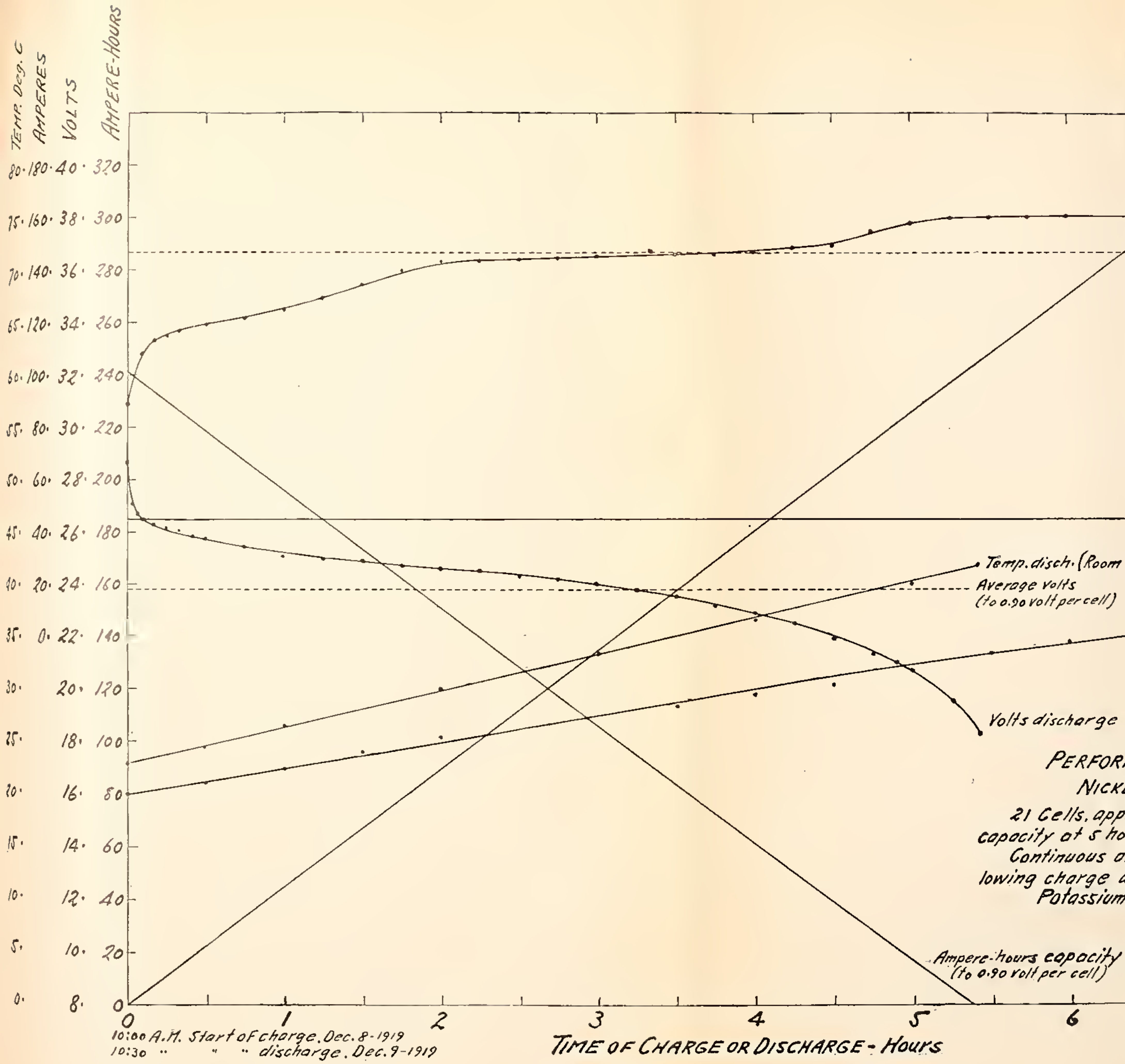
The temperature rises constantly when the batteries are discharging, but this is not the case when they are charging.

V. CAPACITY

The capacity of a cell is expressed in two ways, (a) ampere-hour, and (b) kilowatt-hour. The capacity in ampere-hours is represented by the product of a given rate of continuous discharge in amperes, called the normal rate, and a given number of hours. For stationary batteries this has been established arbitrarily as eight hours, for vehicle-type batteries as about five hours. The ampere-hour capacity of a single cell is dependent upon the number, thickness, and area of the plates, the basis for which is the amperes per positive plate. This in turn is dependent upon the character and amount of available active material, consequently this value varies for different types of plates. By available active material is meant the proportion of the total quantity which is actually used in producing current.

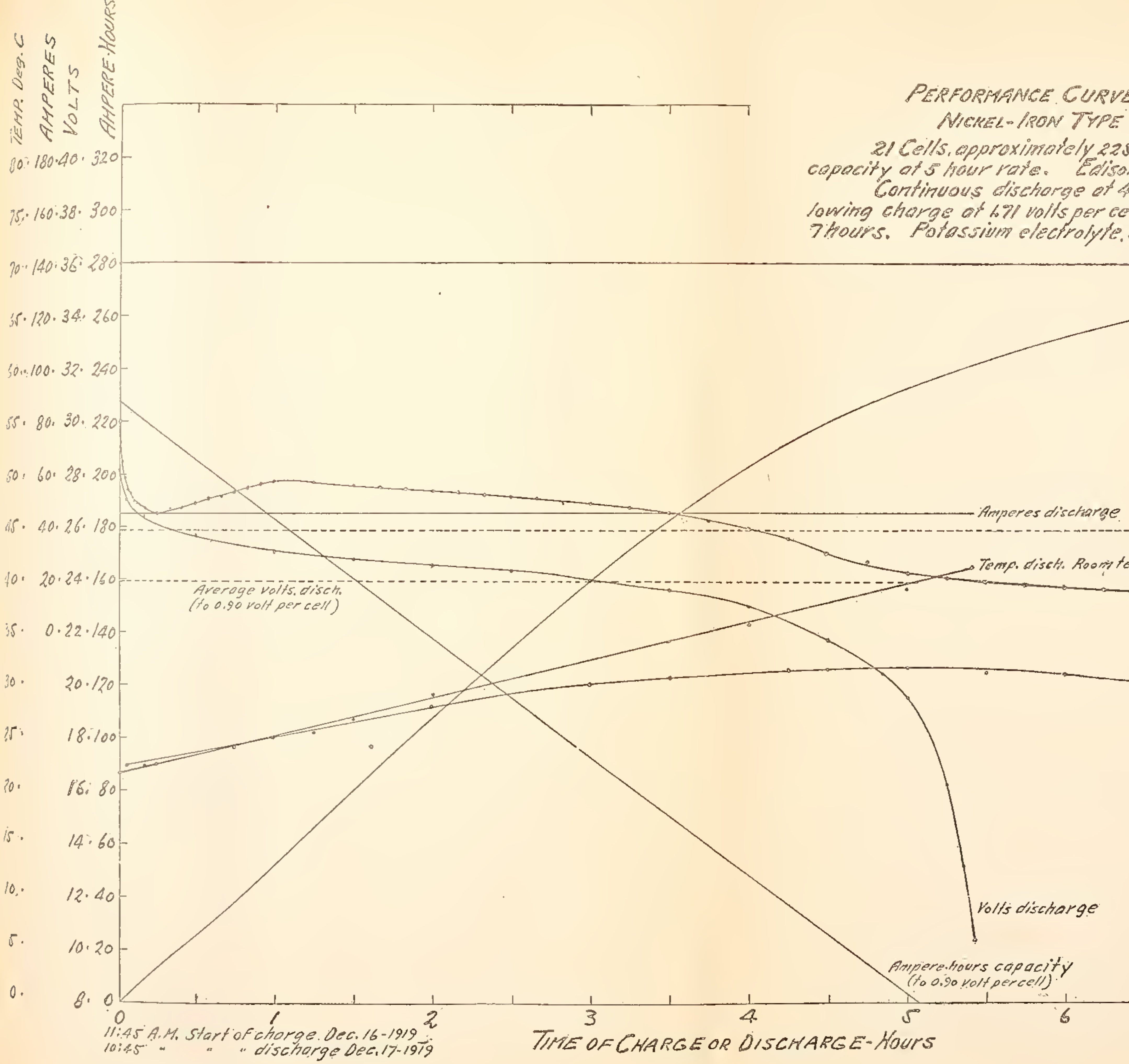
For lead batteries particularly at rates of discharge less than normal the capacity of a cell is greater and at rates of discharge exceeding the normal rate the capacity is less than at the normal rate of discharge. These characteristics are illustrated by Fig. 26. When the discharge is intermittent the capacity is greater than at corresponding rates of continuous discharge.

Both lead-acid and nickel-iron batteries show loss of capacity on standing idle. The approximate rates are shown in the curves of Fig. 27. In addition to the above, batteries of both types show temporary losses of capacity due to protracted idleness and to low temperatures. This is often referred to as "sluggishness." In lead batteries the pores of the plates become clogged with the



174541°—20. (Face page 26.) No. 1

FIG. 22



174541°—20. (Face page 26.) No. 2

FIG. 23

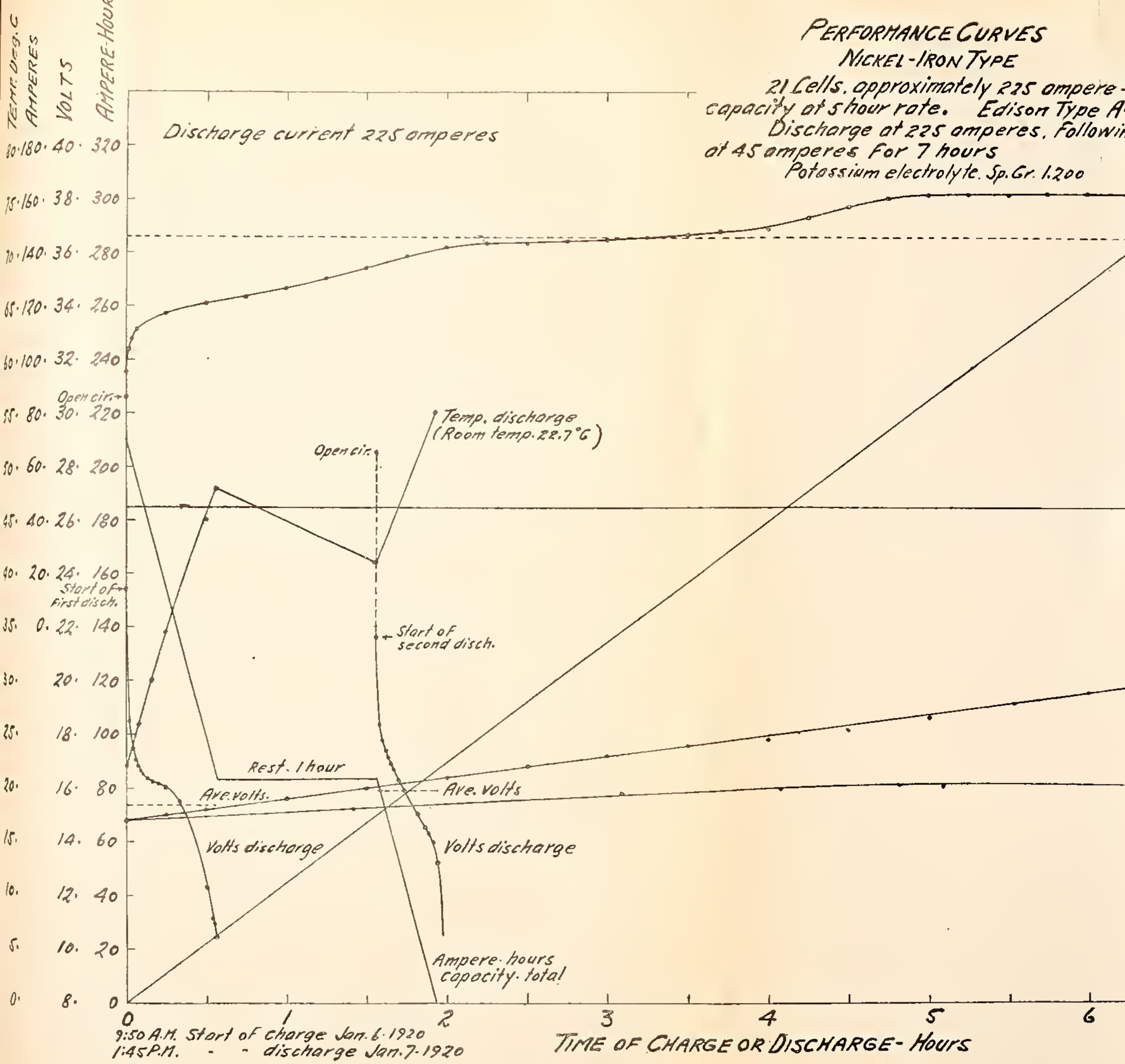

PERFORMANCE CURVES
NICKEL-IRON TYPE
21 Cells, approximately 225 ampere-
capacity at 5 hour rate. Edison Type A
Discharge at 225 amperes. Followi
at 45 amperes for 7 hours
Potassium electrolyte. Sp. Gr. 1.200
Discharge current 225 amperes
TEMP. DEG. C
AMPERES
VOLTS
AMPERE-HOUR
80·180· 40· 320
75·160· 38· 300
70·140· 36· 280
65·120· 34· 260
60·100· 32· 240
Open cir.
55· 80· 30· 220
50· 60· 28· 200
45· 40· 26· 180
40· 20· 24· 160
Start of first disch.
35· 0· 22· 140
30· 20· 120
25· 18· 100
20· 16· 80
15· 14· 60
10· 12· 40
5· 10· 20
0· 8· 0
Temp. discharge (Room temp. 22.7°C)
Open cir.
Start of second disch.
Rest. 1 hour
Ave. volts.
Ave. volts
Volts discharge
Volts discharge
Ampere·hours capacity·total
0
1
2
3
4
5
6
9:50 A.M. Start of charge Jan. 6·1920
1:45 P.M. - - discharge Jan. 7·1920
TIME OF CHARGE OR DISCHARGE - Hours

FIG. 24

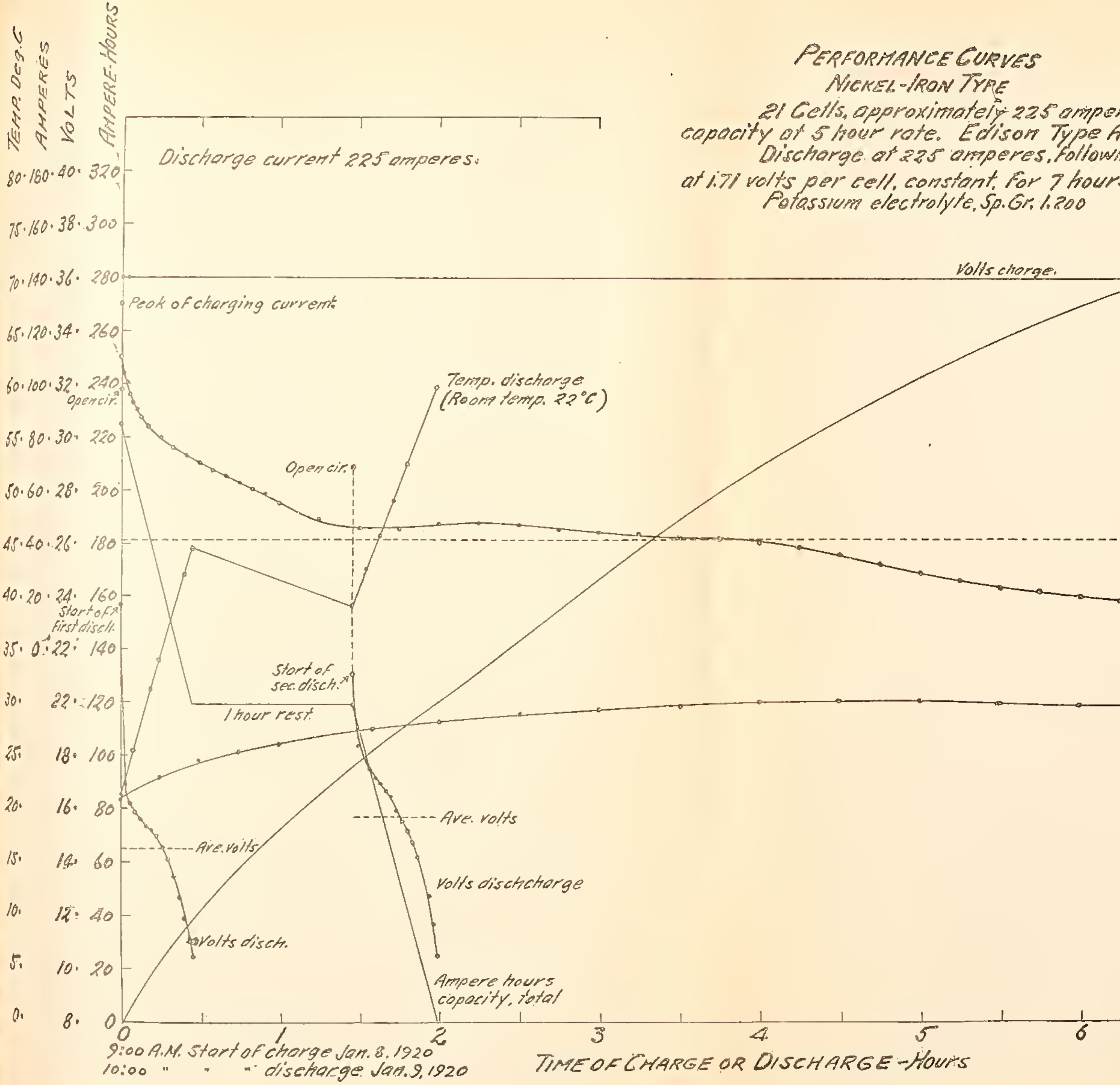
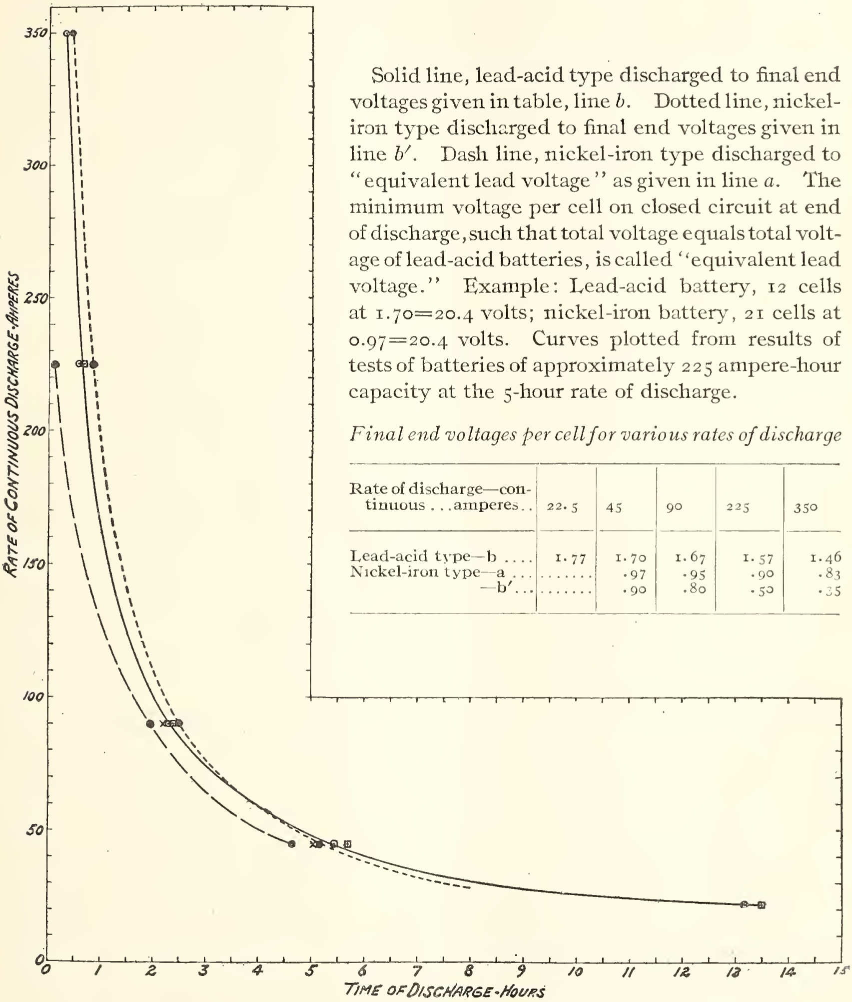

PERFORMANCE CURVES
NICKEL-IRON TYPE
21 Cells, approximately 225 amper
capacity at 5 hour rate. Edison Type A
Discharge at 225 amperes, followi
at 1.71 volts per cell, constant, for 7 hour
Potassium electrolyte, Sp. Gr. 1.200
TEMP. DEG. C
AMPERES
VOLTS
AMPERE-HOURS
80 · 160 · 40 · 320
75 · 160 · 38 · 300
70 · 140 · 36 · 280
65 · 120 · 34 · 260
60 · 100 · 32 · 240
55 · 80 · 30 · 220
50 · 60 · 28 · 200
45 · 40 · 26 · 180
40 · 20 · 24 · 160
35 · 0 · 22 · 140
30 · 22 · 120
25 · 18 · 100
20 · 16 · 80
15 · 14 · 60
10 · 12 · 40
5 · 10 · 20
0 · 8 · 0
Discharge current 225 amperes.
Volts charge.
Peak of charging current
Open cir.
Temp. discharge
(Room temp. 22°C)
Open cir.
Start of first disch.
Start of sec. disch.
1 hour rest
Ave. volts
Ave. volts
Volts dischcharge
Volts disch.
Ampere hours
capacity, total
0
1
2
3
4
5
6
9:00 A.M. Start of charge Jan. 8, 1920
10:00 " " " discharge Jan. 9, 1920
TIME OF CHARGE OR DISCHARGE – HOURS

FIG. 25

gradually formed sulphate crystals which may require several cycles of charge and discharge to eliminate. In the nickel-iron batteries a slow oxidation of the iron takes place which is not as easily reduced on the succeeding charge as the oxide formed by the discharge of the cell. The result of this is a temporary loss of capacity which may require several cycles of charge and discharge to overcome. A battery of the nickel-iron type which has stood idle for two months should receive the following treatment in order to restore it to full capacity. Discharge it at normal rate, through suitable resistance, to as low voltage as



Solid line, lead-acid type discharged to final end voltages given in table, line *b*. Dotted line, nickel-iron type discharged to final end voltages given in line *b′*. Dash line, nickel-iron type discharged to "equivalent lead voltage" as given in line *a*. The minimum voltage per cell on closed circuit at end of discharge, such that total voltage equals total voltage of lead-acid batteries, is called "equivalent lead voltage." Example: Lead-acid battery, 12 cells at 1.70=20.4 volts; nickel-iron battery, 21 cells at 0.97=20.4 volts. Curves plotted from results of tests of batteries of approximately 225 ampere-hour capacity at the 5-hour rate of discharge.

Final end voltages per cell for various rates of discharge

Rate of discharge—continuous . . . amperes . .	22.5	45	90	225	350
Lead-acid type—b	1.77	1.70	1.67	1.57	1.46
Nickel-iron type—a . . .	. . . .	.97	.95	.90	.83
—b′ . . .	. . . .	.90	.80	.50	.35

Fig. 26.—*Variation in discharge rate with time in hours for continuous discharge*

possible, zero preferably, then short-circuit for at least 5 hours. Charge at the normal rate for not less than 15 hours and discharge at the normal rate again to as low voltage as possible not short-circuiting. Charge again at the normal rate for not less than 12 hours and put in service.

Batteries of both types show a temporary loss of capacity at low temperatures. For lead-acid batteries this is practically uniform between 0° C (32° F) and 20° C (68° F) and amounts to about 13 per cent for each 10° C (18° F) when the battery is discharging at the 5-hour rate. The correction increases slightly for higher rates of discharge. Above 20° C (68° F) the correction is somewhat less. The nickel-iron batteries show a different phenomenon. They have a critical temperature, which varies with the rate of discharge, below which the output is very small. Above this critical temperature practically the full capacity of the battery may be obtained. Comparatively little information is available on this subject, but a paper by W. E. Holland in Central Station, November, 1911, gives data for currents from 15 to 75 amperes for a battery of the type A-6

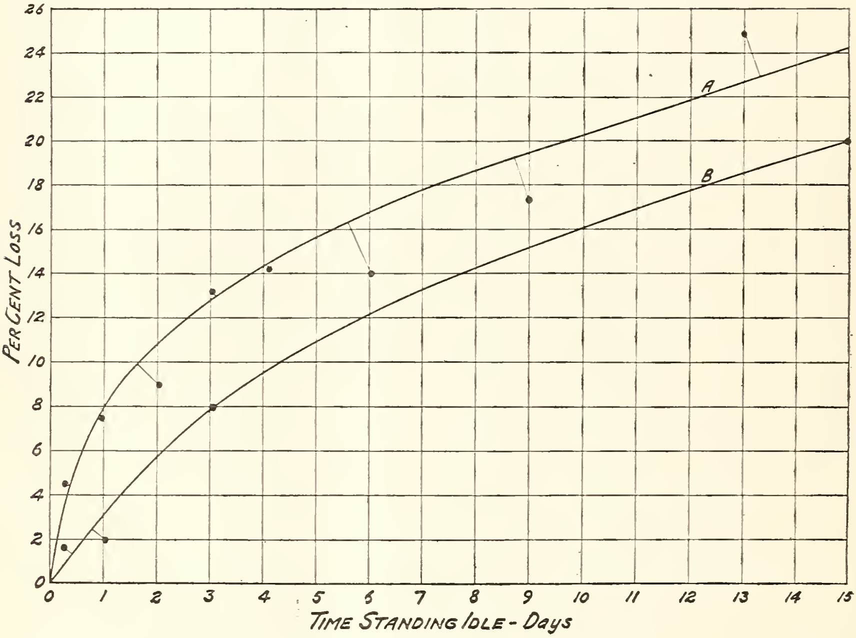


FIG. 27.—*Loss of capacity when standing idle*

Curve A, nickel-iron type: curve B, lead-acid type. All cells were maintained at constant temperature of 22° C (71.6° F).

for which the normal rate of discharge is 45 amperes. At the normal rate the critical temperature appears to be in the neighborhood of 5° C (41° F). For rates of discharge in excess of this it is higher, and at smaller rates it is lower than this.

The capacity in ampere-hours of a battery of any number of cells in series is that of single cell. The capacity in kilowatt-hours of a single cell is equal to the product of its capacity in ampere-hours and its average voltage during discharge, divided by 1000. The capacity in kilowatt-hours of a battery of any number of cells is equal to the product of its ampere-hour capacity and total average voltage divided by 1000.

Since the capacity of a given cell depends in part on the superficial area of the plates that it contains, the use of a greater number of thin plates is sometimes resorted to as a means of obtaining larger electrical capacity. The useful life of thin plates is usually shorter than that of similar plates which are thicker. The life of the plates depends, however, more on the quality of the materials and manufacture and the methods used for charging than on the actual thickness. When discharges are made at high rates the active material taking part in the reactions is that on or near the surface. At the normal or lower rates more opportunity is given for the diffusion of the electrolyte into the pores of the active material. At such rates, therefore, thick plates have considerably more capacity per plate than thin plates of the same porosity and area.

VI. VOLTAGE

Whenever the voltage of individual cells is to be determined a low-reading voltmeter, with scale from 0 to 3 volts, should be used. The flexible connections for the voltmeter should each be provided with a sharp metal point set in a wooden handle, the purpose of which is to obtain a good electrical connection. For cells of the lead-acid type the points are pushed or "stabbed" into the centers of the lead posts. For cells of the nickel-iron type the points serve to clean the surface of the steel posts by scratching, thus making good contact.

Another device for use with nickel-iron batteries consists of a fork of fiber three-eighths inch (0.95 cm) thick to which flat metal contacts are attached. The handle and branches are each 1 inch (2.54 cm) wide by 4½ inches (11.45 cm) long with the distance between the centers of the branches at the ends equal to that between the poles of the cell. The contact pieces of thin copper, seven-eighths inch (2.23 cm) wide, extend for a distance of 2½ inches (6.35 cm) on either side of the branches and are held in place by means of rivets. Flexible conductors are soldered to the contact pieces. To insure good contact the metal should be kept bright and clean and wet with water.

The open-circuit voltage of a cell does not indicate its state of charge, but does indicate internal troubles such as sulphation, short-circuited plates, etc. In all such cases the voltage will be below normal. The voltage will vary with changes in strength of electrolyte, temperature, and age of the cell. In the lead battery the state of charge may be determined by readings of the specific gravity. Gravity readings may be taken on open circuit. The closed-circuit voltage may also be used as an indication of the state of charge. Referring to the battery voltages given in Figs. 22 and 23, it is found that the voltage of a nickel-iron cell varies, at the normal rate of discharge, from 1.35 volts per cell at the beginning to 0.90 volts per cell at the end of discharge. An approximate method of determining the state of charge of these batteries is to allow normal current to flow through the battery for a few minutes and then read the voltage. Compare this reading with a curve of discharge at normal rate. The relation between the portion of the curve to the observed reading in proportion to the total length of the curve will represent the proportion of capacity that has been drawn from the battery. For example, if the voltage at normal discharge of the battery of 21 cells is 22.75, the distance in time from the beginning of the curve to this point is 80 per cent of the total distance in time, therefore, 80 per cent of the capacity of the battery has been used and 20 per cent remains. Care must be used in making these measurements as a small error in voltage will make a large error in locating the point on the curve.

On account of the resistance of the intercell and intertray connectors, the sum of the voltages of the individual cells on discharge will be greater than the voltage read across the terminals of the battery. The difference represents the value of the drop in voltage in the connectors. This drop is proportional to the current flowing and increases as the value of the current increases. For this reason it is desirable to have the resistance of the connectors as low as possible in order to insure the maximum voltage under heavy drafts of current.

VII. RESISTANCE OF THE BATTERY AND ITS RELATION TO THE EXTERNAL CIRCUIT

The internal resistance of a storage cell is very small and for many purposes may be neglected entirely. When large currents are required, however, as when a tractor begins to pull a heavy load, or in cranking an automobile engine, or when a vehicle is climbing a steep hill, the resistance of the battery and its intercell connections becomes of more importance. In this section is given a simple discussion of the applications of Ohm's law and the resistance characteristics of storage batteries.

Every electrical circuit offers some opposition to the flow of electricity through it. This is called resistance, and the unit of resistance is called the ohm. For any direct-current circuit of which the resistance is constant, the current of electricity which flows is proportional to the voltage applied to it. This relation is expressed by the equation (1) which is called *Ohm's Law:*

$$I=\frac{E}{R} \tag{1}$$

The current in amperes is represented by I, the voltage in volts by E, and the resistance in ohms by R. This law is of fundamental importance.

The current flows through the circuit from the lead-peroxide plate to the sponge-lead plate, or in the case of the alkaline battery it flows from the nickel-oxide tubes through the external circuit to the pockets containing the iron; that is, the current always flows from the positive to the negative terminal. The current, however, does not begin with one plate and end with another, but it flows through the cell as well. The resistance of the circuit is therefore not only the resistance of the external circuit, but includes the so-called internal resistance of the cell or battery. We may therefore write the equation (1) in the following form:

$$I=\frac{E}{R'+b} \tag{2}$$

where R' is the resistance of the external circuit, b the resistance of the cell, E is the total electromotive force of the cell or, as it is sometimes called, the "open-circuit voltage." The value of b varies somewhat with the state of the charge of the cell, being highest when the cell is completely discharged. The current I is the same in all parts of the circuit.

Equation (2) may also be written as

$$E=IR'+Ib \tag{3}$$

That is, the total voltage is divided into two parts, one of which is the potential difference or voltage drop, IR' across the terminals of the resistance R' due to the current I flowing through it; the other part is the potential difference within the cell itself. The quantity b is ordinarily so small in storage batteries that the product Ib may be neglected in comparison with IR'. If, however, the current I is very large, the product of Ib may amount to several tenths of a volt. The effect of this is to reduce the useful voltage of the cell.

The power developed in such a circuit is the rate of expenditure of the electrical energy or, in other words, it is the rate of doing work. The work which the electrical current does is proportional to the current, the voltage, and the time. It is expressed by a unit called the joule, designated by J. If the time is expressed by t, the work done by the electric current is

$$J = IEt \tag{4}$$

If the circuit contains resistance only, the energy of the electric current will be converted into heat. By combining equations (1) and (4)

$$J = I^2Rt \tag{5}$$

That is, the work done in heating the circuit of R ohms is given by equation (5), from which we may at once obtain the power expended by dividing the equation through by the time which gives the rate at which the work is done. Letting P represent the total power expressed in watts,

$$P = J/t = IE = I^2R \tag{6}$$

We may consider the complete circuit as made of two parts as before, viz, that external to the battery and the other the internal resistance of the battery itself. The power expended in each part of this circuit, considered as of resistance only, is obtained by combining equations (3) and (6):

$$P = P_1 + P_2 = I^2R' + I^2b \tag{7}$$

The part I^2b is expended in heating the cell and is lost. It should be noted that this loss increases as the square of the current. This factor reduces, therefore, the watt efficiency of the battery, particularly at high rates of discharge and limits the useful power which the battery can give.

When several cells are connected in series the resistance of the battery is the resistance of all the cells added together. If similar cells are connected in multiple, the resistance is reduced by a factor one divided by the number of rows in multiple. Ohm's law applied to a battery having s similar cells in series and p rows in multiple is, therefore:

$$I = \frac{sE}{R' + \frac{s\,b}{p}} \tag{8}$$

The circuit external to the battery absorbs part of the power which is designated as P, in equation (7). The voltage drop across the terminals of this part of the circuit will be E' which is less than the total value of E by the amount equal to Ib which is the drop within the cell itself. If the current is I the power expended in this part of the circuit will be

$$P_1 = I\,E' \tag{9}$$

If this part of the circuit consists only of resistance, all of the energy will be expended in the form of heat and from equation (7)

$$I\,E' = I^2\,R'$$

The external circuit may contain some apparatus for transforming electrical energy into something besides heat, as, for example, a motor to transform the electrical energy into mechanical energy. In this case

$$I\,E' \text{ is greater than } I^2\,R'$$

$$I\,E' - I^2\,R' = I\,(E' - I\,R') \tag{11}$$

The factor $(E' - I\,R')$ is called the counter electromotive force of the circuit. This is not strictly a constant quantity. The rate of conversion of useful energy of the battery into mechanical energy, for given conditions, is equal to the expression $I\,(E' - I\,R')$. The useful mechanical energy obtained is equal to this multiplied by the mechanical efficiency of the motor.[3]

Since the value of E and b are practically constant, the total power generated by the battery will be small by equation (7) if the value of I is small but will increase as the current increases. The maximum current is obtained when the external resistance R' is made equal to zero as shown by equation (8). In this case the power generated is a maximum, but it is all expended within the battery itself in the form of heat and no useful work is done. Between these two extreme conditions lies the maximum useful power delivered to the external circuit. The total power generated by the battery, equation (6) is $P = I\,E$, the power wasted

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[3] For complete discussion of operating characteristics of motors see chap. 8 of Standard Handbook for Electrical Engineers.

in the battery (considered as a single cell) is by equation (7) $P_2 = I^2 b$. The power delivered to the external circuit is then

$$P - P_2 = P_1 = I\,E - I^2\,b \tag{12}$$

$$\frac{P_1}{b} = -\left(I^2 - \frac{I\,E}{b}\right) \tag{13}$$

from which

$$\frac{P_1}{b} = -\left(I - \frac{E}{2\,b}\right)^2 + \frac{E^2}{4\,b^2} \tag{14}$$

The square of $I - \frac{E}{2\,b}$ is always positive. The maximum value for $\frac{P_1}{b}$ occurs when

$$I = \frac{E}{2\,b} \tag{15}$$

By combining equation (2) and equation (15)

$$R' = b \tag{16}$$

That is, assuming E and b to be constant, the resistance of the external circuit which receives maximum power from the battery is equal to the internal resistance of the battery. (See Practical Electricity by Ayrton and Mather, pp. 317–319.)

Owing to the counter electromotive force of the motor, E'', the equation for the current delivered by the cell (or battery) becomes

$$I = \frac{E - E''}{b + R'} \tag{17}$$

By equation (15) the condition for the maximum power in the external circuit is

$$\frac{E - E''}{b + R'} = \frac{E}{2\,b} \tag{18}$$

Since the voltage of the battery is fixed, if we assume a fixed value for E''

$$R' = b\frac{E - 2E''}{E}$$

The resistance of a storage battery is due to a number of factors, including resistance of the electrolyte, resistance of the active material which varies during charge and discharge, and resistance of the grids and terminals. The resistance of a storage cell rises toward the end of discharge to more than double its resistance when fully charged. When the discharged cell is charged the internal resistance falls again to its original value, corrected for temperature.

Although there is a considerable change in the density of the electrolyte for acid batteries, the change in conductivity of the electrolyte is small. The change in resistance taking place at the plates of a lead-acid battery is largely to be explained by the action of the lead sulphate. During discharge the lead and peroxide particles become more or less densely covered with a layer of nonconducting lead sulphate which is reduced on the subsequent charge. If this layer of sulphate is allowed to become hard and dense (see Sec. VIII), the internal resistance of the cell may rise to a high value.

The actual magnitude of the internal resistance of storage cells varies with the size and kind of cell. Lead cells of the size used in tractors (that is, about 225 ampere-hour capacity) have a resistance of approximately 0.001 ohm per cell when charged. Edison cells of equivalent size (that is, A–6) have a resistance of approximately 0.002 ohm per cell when charged. In both types the resistance increases slightly as the discharge progresses.

VIII. SULPHATION OF LEAD BATTERIES

Whenever a battery is discharging, lead sulphate ($PbSO_4$) is formed on both the positive and negative plates as a part of the process of producing current. After a normal discharge the sulphate is finely crystalline and of such a nature that it is easily reduced by the current flowing through the battery on charge. If charging is neglected and the battery allowed to stand in a discharged state, the crystalline condition of the sulphate gradually changes, filling the pores of the plates and eventually making the active material dense and hard, which prolongs the time required for a charge. It is this latter condition which is often referred to when a battery is spoken of as "sulphated."

Sulphation in this sense is always the result of some sort of abuse, as (*a*) standing discharged for some time, (*b*) neglecting evidence of trouble, (*c*) replacing loss of water by electrolyte, and (*d*) regular undercharging. A single cell in a tray may become sulphated by drying out as the result of failure to replace lost electrolyte or failure to replace a broken jar or by an internal short circuit. During an equalizing charge (see Sec. XI) where the specific gravity has reached a maximum in each cell it indicates that all of the sulphate in the plates has been reduced. It is the negative plates generally which require a prolonged charge to reduce the sulphate. The active material of this plate is of a light color and hard and dense when in the discharged condition. The active material of the positive plates is less seriously affected and is speedily restored to normal condition. The life of these plates, however, is shortened by sulphation.

Some of the evidences of sulphation are (*a*) continued low specific gravity, (*b*) continued low open-circuit voltage, (*c*) loss of capacity, (*d*) inability to take normal charge on account of increase of internal resistance, and (*e*) light color of positive and negative plates. The loss of capacity due to sulphation must not be confused with the natural loss of capacity during the life of the battery.

Whenever any of the above evidences seem to be present, it is well to give the battery an equalizing charge and then a continuous discharge at the normal rate down to 1.70 volts per cell. If it does not give its rated capacity, as in cases of stubborn sulphation, empty out the electrolyte and fill the cells with water (distilled water preferred) and then charge it in the usual manner. At the end of this charge read the specific gravity of each cell and the temperature of the pilot cell. Continue the charge at one-half the finishing rate, or as nearly this as possible. Read and record the specific gravity of each cell at regular intervals of, say, 4 to 6 hours. The charge at this rate is to be continued until the specific gravity of each cell has been constant for a period of at least 12 hours. The level of the electrolyte is to be maintained constant by the addition of water after the readings. If the water is added before the readings, it will not be properly mixed with the electrolyte and false readings will be obtained. Hydrometer readings are to be corrected for temperature. Should the specific gravity of any cell rise above 1.300, draw out electrolyte to the top of the plates and replace by water. If the gravity is deficient, electrolyte should be added.

The battery can not be considered as completely restored until the specific gravity of all cells has remained constant for a period of at least 12 hours of continuous charging at one-half the finishing rate. The temperature must not be allowed to exceed 43° C or 110° F. If necessary, the current must be reduced or temporarily cut off. When a single cell of a tray is found to be sulphated it should be removed and treated separately.

IX. ELECTROLYTE

1. FOR LEAD-ACID TYPE

The electrolyte consists of a mixture of chemically pure sulphuric acid and pure water. When first put in service, the specific gravity of the electrolyte, with the battery fully charged, should be between 1.275 and 1.290 at 25° C (77° F).

The specific gravity of the electrolyte is affected by the temperature but may be corrected to 25° C (77° F) as follows: For every 5° in temperature above 25° C three points in the third decimal place are to be added to the hydrometer reading, and for every 5° below, three points in the third decimal place are to be subtracted from the hydrometer reading. Example: 1.285 at 15° C equals 1.279 corrected to 25° C, and 1.285 at 35° C equals 1.291 corrected to 25° C. For temperatures expressed as Fahrenheit, the corrections for every 3° from 77° F is one point in the third decimal place, applied as specified above. Fig. 28 is a chart from which the correction may be obtained immediately for centigrade and Fahrenheit temperatures.

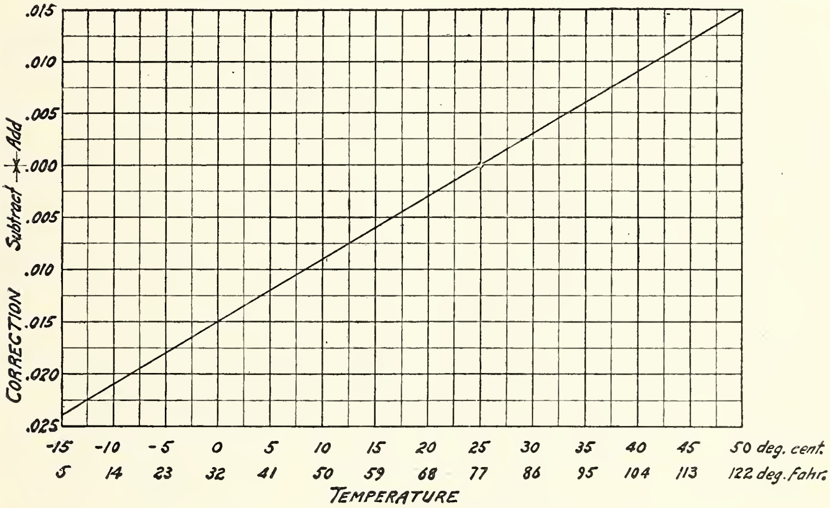


Fig. 28.—*Corrections for temperature, acid electrolyte*

Losses of electrolyte, often referred to as "evaporation," during the operation of storage cells are partly due to evaporation of the water but mostly to the gassing which takes place when the batteries are on charge. The gases given off are oxygen and hydrogen, which are the components of water. When electrolyte is lost in this way it is only necessary to fill the cells with distilled water, or if this is not obtainable, water of a sufficient purity. Electrolyte is to be added to the cells only in case the loss is due to spilling, a cracked jar, or a necessary replacement of electrolyte due to accumulating impurities.

Electrolyte is prepared from concentrated sulphuric acid, which is a heavy, oily liquid having a specific gravity of about 1.835 to 1.840. This acid should be chemically pure and colorless. By chemically pure is meant that it is free from appreciable amounts of detrimental impurities, but it does not refer to the strength of the acid. When the concentrated acid is diluted with distilled water the solution will become very hot. It is necessary in every case that the acid should be poured slowly into the water at the same time stirring the solution thoroughly. *The water should never be poured into the acid on account of danger to the person making the mixture.* A suitable vessel for mixing the electrolyte is one of china, earthenware, or glass if comparatively small quantities are required, or a lead-lined tank if large quantities are required. It should never be prepared in a metallic vessel other than lead. In order to prepare the electrolyte of proper specific gravity, the parts by volume or by weight may be obtained from the accompanying Fig. 29 to make the electrolyte of any desired specific gravity.

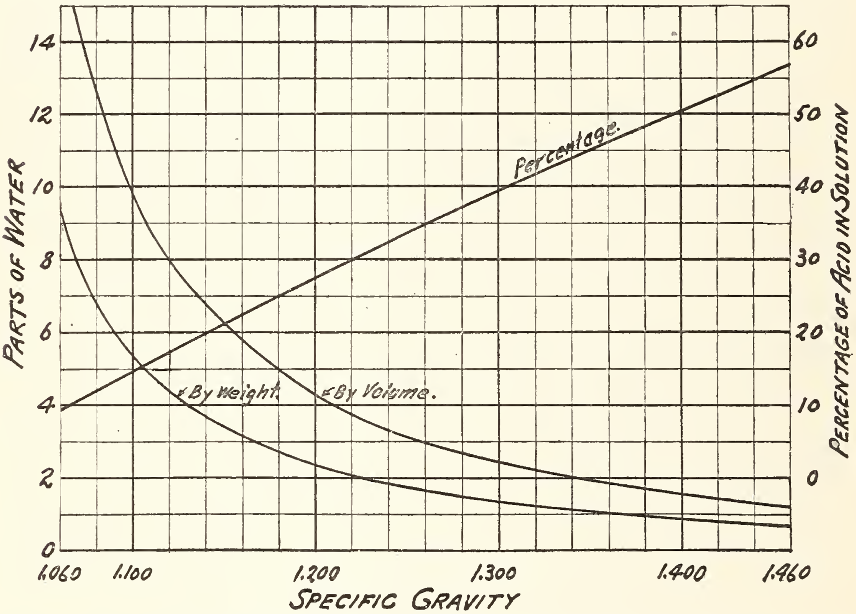


FIG. 29.—*Preparation of electrolyte of any specific gravity, based on acid of 1.835 sp. gr. 20° C (68° F)*

In keeping records of the electrolyte in a battery, one cell of each group is usually selected and known as the pilot cell. This should be a cell near the middle of the battery; that is, surrounded by other cells. Measurements of the temperature, the voltage, and the specific gravity are taken on this particular cell and the values so obtained are considered as representative of the battery. Once a month, however, after the equalizing charge, measurements should be made on each cell as well as on the pilot cell.

2. FOR NICKEL-IRON TYPE

The electrolyte for these cells consists of a water solution of potassium hydroxide or sodium hydroxide to which small amounts of lithium hydroxide and other substances have been added in accordance with the formula of the Edison Storage Battery Co. The electrolyte for these cells is obtained from the manufacturers in either the liquid or the dry form. If in the liquid form, it is ready for use in the cells as it is received. In the dry form it has to be dissolved in distilled water in accordance with the directions on the package. The electrolyte in this type of cell requires renewal at infrequent intervals which are determined by the gravity. Under normal conditions the gravity of electrolyte in the Edison cell should be from 1.200 to 1.220. When potassium electrolytes have fallen to 1.160 they should be renewed. Sodium electrolytes may be used down to 1.130. The gravity of the electrolyte in the Edison battery does not change during charge and discharge as in the case of the lead batteries, but a gradual decrease in gravity is noted as the battery is used.

X. TESTING

The principal tests of interest in connection with these batteries deal chiefly with their capacity, their efficiency, their life, and the purity of the electrolyte.

1. AMPERE-HOUR CAPACITY

The ampere-hour capacity is determined by discharging the battery at a fixed rate until the potential difference at the terminals falls to a certain point called the final or "end" voltage. The ampere-hour capacity is then the number of amperes multiplied by the number of hours of the discharge. In making such a test the rate of discharge is important. Generally some particular rate is spoken of as the normal rate and the capacity is usually expressed as the ampere-hours which the battery can deliver at this rate. When the rate of discharge is increased the ampere-hour capacity diminishes. At very low rates of discharge lead batteries should show capacities considerably in excess of their so-called normal or rated capacity.

In making a test of the capacity of any battery it is important that the end voltage for the discharge should be correctly chosen. It has been a more or less universal rule with stationary batteries that they are normally discharged in eight hours to a final voltage of 1.75 volts per cell. No ratings have been standardized for transportable batteries, but the normal period of discharge is frequently taken as five hours. In general, the appropriate final voltage is lower as the rate of discharge is higher. These have been given in Section IV.

In general, a larger ampere-hour capacity will be observed in cases of the intermittent discharges than for continuous discharges at the same rates. When intermittent tests are made they are usually designed to imitate the services to which the battery will be subjected. In making any measurements of the capacity of a storage battery it is desirable that the current discharge should be maintained at a fixed value by suitable resistances and that the terminal voltage and change in gravity of the electrolyte be followed throughout the course of the test.

2. WATT-HOUR CAPACITY

The watt-hour capacity is equal to the ampere-hour capacity multiplied by the average voltage. In determining the watt-hour capacity of a battery, it is customary to determine first the ampere-hour capacity and then compute the average voltage at the terminals of the battery or cell during the period of the discharge. When dealing with a tractor battery consisting of any number of cells it is customary to measure the voltage at the terminals of the battery rather than for each cell. There is, however, a small loss in voltage due to the resistance of the intercell connectors, so that the sum of the average voltages of the individual cells may be slightly higher than is indicated by the terminal voltage of the battery. To determine the watt-hour capacity, it is necessary that a careful calculation of the average voltage be made. This may be done in two ways. If the readings have been taken at equal time intervals, it is possible to calculate the average electromotive force from the individual readings and the time. It may also be done by plotting the voltage readings and integrating the curve with a planimeter from which the average voltage is calculated.

3. PRECAUTIONS TO BE TAKEN IN MEASURING CAPACITY

In addition to the effects produced by different rates of discharge and differences in the end voltages the following must be taken into account:

(*a*) TEMPERATURE.—In general, higher capacities will be observed with higher temperatures, although in making tests the temperature of the battery should never exceed 43° C (110° F) at any time.

(*b*) STRENGTH OF THE ELECTROLYTE.—Before making tests this should be adjusted according to the directions given in Sections IX and XI.

(*c*) PREVIOUS CHARGES AND DISCHARGES.—It often happens that unless the battery has been charged and discharged several times immediately before making the test the battery will not show its full capacity. For this reason, therefore, in making an accurate test it is desirable to ascertain by previous experiments that the battery is in a normal condition.

(*d*) PERIOD OF STANDING AFTER CHARGING.—The number of hours which the battery has stood after being charged will be of importance in some cases. In Section V the rate at which the batteries lose charge has been shown in Fig 27.

(*e*) AGE AND CONDITION.—The age and condition of the battery will also show an effect on its capacity. It frequently happens that new batteries will show increasing capacity with successive charges and discharges for a limited period, following which the capacity will remain practically constant for a considerable period and then gradually decrease; and when the battery is nearly worn out the capacity may be considerably lower than the so-called rated capacity.

4. PLATE CAPACITIES

It is sometimes desirable to determine the capacities of the individual plate-groups separately. For this purpose an auxiliary electrode is introduced into the cell and readings of the potential difference between this and the positive and negative plates made. A number of different electrodes have been used for this purpose, but the most common one has been the cadmium electrode for use with the lead batteries. In making such measurements, two difficulties arise. One of these is due to errors to which the auxiliary electrode itself is subject. The other source of difficulty arises in the case of certain types of batteries owing to the peculiarities of their construction.

The cadmium electrode must be well corroded by keeping it in an acid solution and it must be used with a voltmeter of sufficiently high resistance to avoid polarization. In Technologic Paper No. 146, the experiments made at this bureau are described showing the errors to which the cadmium electrode is subject, and the means of avoiding them. In general it may be said that the polarization of the cadmium electrode will be appreciable when measuring the positive plate if the resistance of the voltmeter is less than 1000 ohms. Potentials of the negative plate, however, may be measured with an ordinary voltmeter. From this reading and the cell voltage the potential of the positive plate may be correctly computed. For measurements in a laboratory where a potentiometer is available, the mercurous sulphate electrode is preferable. The potentials of the individual plates will depend somewhat on the age of the battery, and it is therefore necessary that in making this test that one should be familiar with the readings which a normal battery should show under similar conditions. In making any observations with an auxiliary electrode, the readings should be taken with the current flowing.

5. EFFICIENCY

The efficiency of a storage battery is usually expressed as the ampere-hour or the watt-hour efficiency. Sometimes the term "voltage efficiency" is also used. The ampere-hour efficiency is the ratio of the ampere-hours of output to the ampere-hours of input. The voltage efficiency is the ratio of the average voltage of discharge to the average voltage of charge. The watt-hour efficiency is the ampere-hour efficiency multiplied by the voltage efficiency. It is generally calculated directly from the watt-hours output and the watt-hours input. In considering the cost of operating a storage battery, it is the watt-hour efficiency which is to be used as one of the important factors.

In measuring the efficiency of any storage battery certain precautions are important. The conditions of charge and discharge should be carefully chosen and adhered to in all the tests. It is customary to express the efficiency at the normal rate of discharge. The efficiency is lower at the higher rates of discharge. Since temperature affects the capacity of the battery, as mentioned above, if the batteries can not be charged or discharged at a normal temperature, a correction to the results should be made. The preliminary cycles should be made at the same current rate of discharge and to the same voltages as are to be used in the efficiency measurement. If the efficiency is measured by charging the battery at constant potential and discharging at a constant current, it will be necessary to integrate the charging current and the discharging voltage. If, however, the efficiency is measured by the constant current charge and constant current discharge, the average voltages for both the charge and the discharge must be determined.

6. LIFE

The determination of the life of a storage battery requires a long time and automatic equipment. Although this test is very desirable, it is difficult and expensive to make and life tests are more often referred to as the period of service of the battery under working conditions rather than to a laboratory test. When laboratory tests are made it is desirable that the batteries should be charged and discharged a definite number of cycles per day. Capacity measurements are made only at infrequent intervals.

7. ELECTROLYTE

(*a*) Specific Gravity as an Indication of Charge.—One of the simplest and most familiar tests made on a lead-acid storage battery is the measurement of the specific gravity of the electrolyte. This is a convenient means of obtaining an approximate idea of the state of charge of the battery as the change in gravity is approximately proportional to the ampere-hours discharged. The specific gravity of the elctrolyte measured in this way, however, does not show the concentration of the acid in the pores of the plates exactly, and for that reason deviations in the proportionality are noted in the beginning and the end of discharge. The variation of the gravity of the electrolyte during charge and discharge may be seen by referring to Figs. 18, 19, 20, and 21.

(*b*) Purity. For lead-acid batteries the principal impurities to be avoided are organic matter, iron, manganese, chlorine, copper, arsenic, nitrates, acetates, and the noble metals. A very large number of specifications for storage battery acid are in common use by the manufacturers and users of storage batteries. The amounts of the above impurities which are allowed by these specifications vary considerably. The methods of testing storage battery acid have not been fully worked out or described. This bureau has made a large number of tests of different methods for determining quantitatively the impurities mentioned above, and has selected those methods which are the best adapted to the purpose, making such modifications as are necessary. It is expected that these will be published in several papers which are now in preparation. The electrolyte furnished for the alkaline type of battery is made exclusively for these batteries by the Edison Storage Battery Co. and it has been customary to take the electrolyte as they furnish it for this purpose.

XI. CHARGING

Direct current alone can be used for charging. If alternating current power only is available, it must be converted into direct current. This can be done by means of: (*a*) Synchronous converter, (*b*) motor generator, and (*c*) mercury arc rectifier.

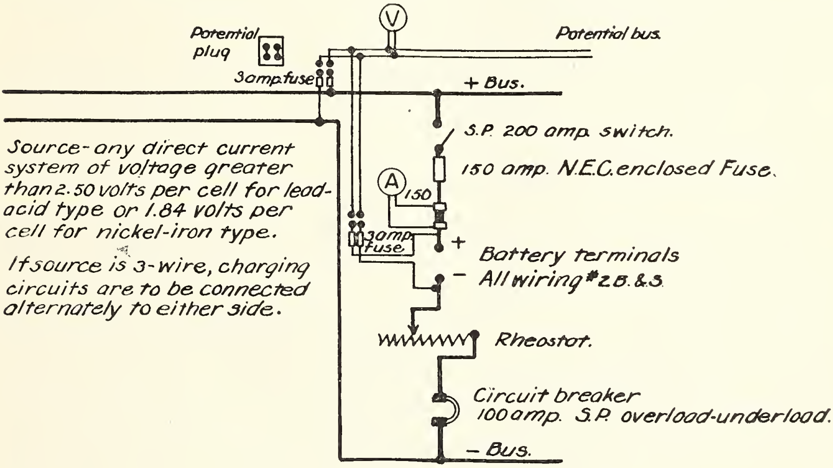
There are two systems of charging in general use: (*a*) Constant current, and (*b*) constant potential or constant voltage. This latter method is sometimes modified slightly by the addition of a fixed resistance of small value in series with the battery in order to limit the starting or inrush current. Such a system is called a semi, or modified, constant potential system.

1. CONSTANT CURRENT

In the constant-current system, as the name implies, the current is held constant by means of a rheostat in series with the battery.

The current is maintained constant at the normal rate by adjusting the rheostat, cutting out or decreasing the resistance as the charge progresses. This increases the voltage impressed on the battery. The value of the current flowing through the battery is dependent upon the difference between its voltage and that of the charging system. Therefore, when the voltage of the battery and the charging system are the same, no current will flow; when the voltage of the battery is lower than that of the charging system, current will flow into the battery and charge it and when the voltage of the battery is higher than that of the charging system, current will flow out of the battery and discharge it. As the voltage of the battery increases gradually with the progress of the charge, it is apparent that the voltage impressed across its terminals must be increased in order to maintain a constant value for the charging current. Figs. 18 and 22 show the characteristics of a constant current charge for the lead-acid and nickel-iron types, respectively. For batteries of the lead-acid type, this value of current, designated as the normal charging rate in amperes, is maintained until all cells are gassing freely and then reduced to a much lower value designated as the finishing rate, at which the charge is continued to the end. The value of the finishing rate is approximately 40 per cent of the normal rate. The ampere-hours required to produce free gassing of a lead battery at the normal starting rate of charge will be approximately 90 per cent of the ampere-hours previously discharged. At this point the current should be cut down to the finishing rate and the charge continued until the battery begins to gas freely again.

In order to obtain most efficient results with batteries of the lead-acid type, the voltage of the charging circuit should not exceed approximately 2.5 volts per cell at normal temperatures with current flowing at one-half the value of the finishing rate at ordinary temperatures. When the voltage of the circuit exceeds this value, the maximum resistance of the rheostat must be sufficient to permit of a reduction in voltage to this value. It is desirable that the ampere capacity be sufficient to permit a current value of four or five times the normal, to permit of boosting (see p. 52) provided that the wiring of the charging circuit can safely carry that current. In a new installation, this condition can be provided for readily. In modifying an existing installation, the current-capacity of the rheostat need not exceed the safe current-carrying capacity of the circuit. The effect of a voltage exceeding 2.5 volts per cell is a continuous loss during charging, in the extra amount of resistance needed to reduce the voltage to the proper value.



Source—any direct current system of voltage greater than 2.50 volts per cell for lead-acid type or 1.84 volts per cell for nickel-iron type.

If source is 3-wire, charging circuits are to be connected alternately to either side.

FIG. 30.—*Battery-charging circuit, constant-current method*

NOTE.—*A*=ammeter, numerals indicate range. *V*=voltmeter, range to suit system.

Fig. 30 is a diagram of connections for a typical constant-current charging circuit.

The value in ohms of such a resistance equals

$$\frac{A-(B\times C)}{D}$$

in which

A = voltage of system.
B = number of cells in battery.
C = volts per cell, a constant, 2.5 for all types and sizes of lead-acid type cells; for nickel-iron types $C = 1.7$ volts per cell.
D = 50 per cent of finishing rate in amperes.

Example: Assume a 17-plate battery of 24 cells having a normal charging rate of 45 amperes and a finishing rate of 18 amperes; charging circuit 110 volts—

Resistance in ohms equals

$$\frac{110-(24 \text{ x } 2.5)}{9}=5.6$$

The current capacity equals

$$5 \text{ x } 45 = 225 \text{ amperes.}$$

The temperature of the battery must not be allowed to exceed 43° C (110° F).

For batteries of the nickel-iron type charging at constant current is carried on at the normal rate for the full period of time required, normally 7 hours, or until the voltage becomes constant, at least 1.85 volts per cell. As the electrolyte of batteries of this type does not undergo any chemical changes during charge or discharge the specific gravity remains constant. Therefore the only indications of complete charge are the condition of voltage as stated above and the length of time taken for the charge. If the battery shows a temperature exceeding 46° C (115° F) it should be cut off immediately from charge and allowed to cool.

The constant current method of charging is more complicated than the constant potential method and therefore requires more careful attention to produce the best results.

2. CONSTANT POTENTIAL

In the constant potential, or constant voltage method the voltage is maintained at a constant fixed value per cell. The value of the initial, or starting, current of a completely discharged battery when first put on charge is much in excess of that of the normal rate. During the charge as the voltage of the battery gradually rises the current falls off to a value much below that of the normal rate and at the end of the charge is below that of the finishing rate of the constant current system. The average value of the current is about equal to that of the normal rate.

For batteries of the lead-acid type the maximum voltage should not exceed 2.4 volts per cell, and the minimum should not be less than 2.2 volts per cell. The average should be approximately 2.3 volts per cell. It is to be noted that these values of voltage are those at the terminals of the battery. In practice the voltage at the bus may range from 2.5 volts to 2.75 volts per cell. Where the voltage of the charging source can not be adjusted to its proper value counter cells are the best means for reducing the voltage. This, however, is but an approximation as a great deal is dependent upon local conditions.

With the average voltage thus established at approximately 2.3 volts per cell a battery in any state of discharge may be put on charge and it will automatically receive the proper charge without reaching the free gassing point or excessive temperature.

The time required for a completely discharged battery to receive a 100 per cent charge—the number of ampere-hours taken out on the previous discharge—will be approximately 3 hours, or 60 per cent of the time of normal discharge.

It sometimes happens that the charging unit or generator is of relatively small capacity. In such a case it is desirable to limit the initial, or starting, current and to accomplish this a fixed resistance of small value is placed in series with the battery. Such a system is known as a semiconstant potential or a modified constant potential system. Fig. 31 is a diagram of connections for such a system with a three-wire supply. For a two-wire supply the connections are the same as shown on this diagram for circuit B, or between the two outside wires.

Fig. 32[4] is a series of curves from which the value of fixed resistance and the initial current of a modified constant potential charging system may be obtained.

The horizontal scale shows the "bus voltage per cell"; that is, the total voltage of the charging system divided by the number of cells in the battery. The vertical scale for the lower set of curves shows values of resistance in ohms per cell which, when multiplied by the number of cells in the battery, gives the value of the fixed resistance to be used in the charging circuit. The vertical scale for the upper set of curves shows the initial value of

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[4] For a complete discussion of the constant potential method of charging, reference is made to Bulletin No. 177 of the Electric Storage Battery Co., Charging Equipment for "Ironclad-Exide" and "Exide" Storage Batteries in Locomotives, Trucks and Tractors, from which part of this discussion has been taken.

the charging current. The dotted line A, connecting the outer ends of the lower set of curves, gives the value of fixed resistance for any bus voltage which will reduce the final rate of charge in amperes to the finishing rate. The curves stop at this line, since points to the right would mean final rates higher than the finishing rate, which are not recommended. Points to the left mean final rates which are somewhat less than the finishing rate.

It is to be understood that the values of initial current and time for a complete charge obtained from these data are not absolutely fixed, but are subject to variations due to temperature, age of cells, time standing idle after discharge, etc.

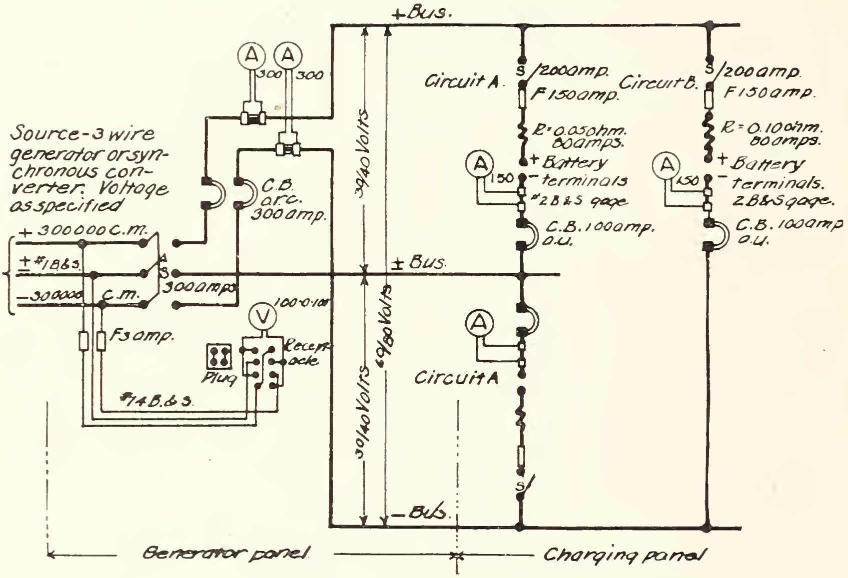


FIG. 31.—*Battery-charging circuit, modified constant-potential method*

NOTE.—A=ammeter, numerals indicate range; V=voltmeter; F=N. E. C. inclosed fuse; numerals indicate capacity; R=fixed resistance, capacity as indicated; S=switch, single or triple pole of capacity indicated; C. B.=circuit breaker, of capacity indicated (o. r. c.=overload, reverse current; o. u.=overload underload). Conductor sizes are based on 20 kilowatt generator or synchronous converter 250 amperes at 80 volts maximum. For nickel-iron type, resistance R is to be cut out. Where a constant current circuit is required for charging small batteries, such as those for starting and lighting, it may be connected in either side, with a suitable regulating rheostat.

The curves apply to a cell of 15 plates with a capacity of 238 ampere-hours at the 6-hour rate of discharge. In order to make them applicable to other cells, corrections must be made based on the capacity at the corresponding rate of discharge. Thus for a cell of 13 plates with a capacity of 147 ampere-hours at this rate $\frac{147}{238} = 0.62$ a constant by which the value of current read from the curve must be multiplied in order to obtain the correct value for this type of cell. The value of resistance read from the curve must be divided by this constant and multiplied by the number of cells in the battery in order to obtain the correct value. Assume a battery of 12 cells each having 13 plates and a capacity of 147 ampere-hours, a bus voltage of 2.5 volts per cell and 6 hours available time for charging. The initial current as taken from the 6-hour curve of the upper set corresponding to 2.5 volts per cell is 91 amperes which, multiplied by the constant 0.62 = 56.5 amperes, the correct initial current which must be provided for in the charging circuit. The resistance as taken from the corresponding curve of the lower set is 0.0033 ohm which, divided by the constant 0.62 and multiplied by 12, the number of cells, = 0.064 ohm, the value of the fixed resistance to be used in the charging circuit.

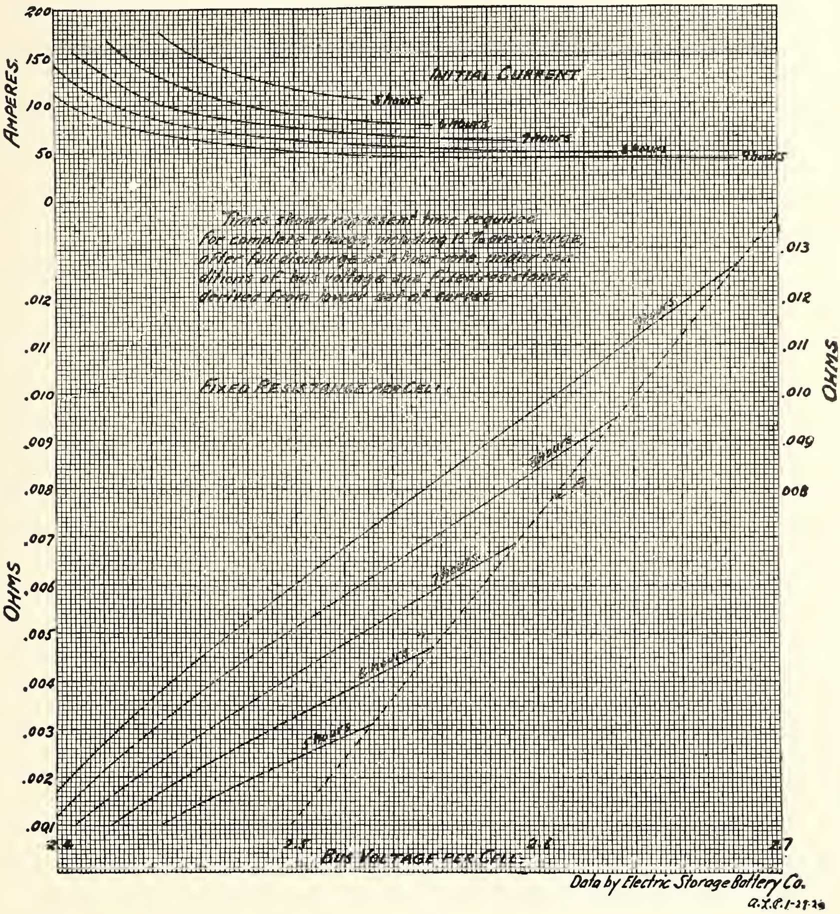


FIG. 32.—*Modified constant-potential charging data for lead-acid cells*

A resistor having a resistance of 0.07 ohm and a current carrying capacity of 60 amperes will be required. In order to provide for variation in results due to temperature, etc., it is well to provide taps on the resistor.

The resistor should always have a carrying capacity in amperes not less than the initial current. As such resistors ordinarily have very little overload capacity, a factor of safety should be used which will provide a margin to meet any unusually severe condition which may arise. Switches, circuit breakers, and wires have some overload capacity, but in order to comply with the Underwriters' requirements the continuous rating should be equal to the initial current.

When it is desired to make the charging system automatic an ampere-hour meter affords the most reliable means for terminating the charge. In this connection the circuit breaker must be provided with a shunt trip attachment having auxiliary contacts to open the tripping circuit and thus avoid arcing at the contact of the ampere-hour meter. The meter is to be provided with a zero contact, a resetting device and a fixed red hand set at the discharge limit. It may be adjusted to run slower on charge than on discharge. The meter must be connected in the battery circuit during discharge as well as during charge and is usually located in an accessible place on the tractor or truck.

For any battery, the higher the bus voltage the greater will be the loss in the resistance, with a decrease in efficiency and an increase in the length of time required for the charge. On the other hand, if the bus voltage is but a little higher than that of the battery, the charging current will become more or less unstable and subject to considerable variation with changes in temperature of the battery and slight changes in the bus voltage.

When the time available for charging is limited, or efficiency is of considerable importance, a bus voltage of approximately 2.6 volts per cell is found to be generally satisfactory.

As the bus voltage and resistance are increased for the same number of cells in the battery, the charging current becomes more nearly constant throughout the charge. thus approaching the constant current method.

Figs. 19 and 23 show the characteristics of a modified constant potential charge for the lead-acid and nickel-iron types respectively.

For the constant potential method, the voltage at the charging panel should be that delivered by the generator or other source of energy. If this is not so, counter cells may be used to reduce the voltage at the terminals of the battery to the proper value. A resistance of sufficient value, in series with the battery, to reduce the voltage will not produce the desired results. In such a case it is preferable to use the constant current system.

For batteries of the nickel-iron type, the impressed voltage should not be less than 1.70 volts per cell. As in the case of the lead-acid type, the voltage at the charging panel must be slightly higher than this value. In practice this will be about 2 volts per cell. When batteries of this type are to be charged from a semi-constant potential system, the resistance *R*, Fig. 31, must be short-circuited or cut out in order to permit the proper current to flow. Otherwise the voltage must be increased to overcome the drop in this resistance.

The constant potential system of charging is often to be preferred to the constant current system as it is automatic in its operation, requires a minimum amount of attention, and a shorter time is required for a complete charge.

3. EQUALIZING CHARGE

Once a week a lead battery which is used for operating a truck or tractor is to be given an overcharge known as an "equalizing charge." For this the daily charge is to be continued from the normal end at a rate equal to approximately one-half the value of the finishing rate until all cells are gassing freely and uniformly and until three consecutive readings of the specific gravity and voltage taken at half-hour intervals show no increase. If a battery shows a temperature exceeding 43° C (110° F) it should be cut off immediately and allowed to cool.

Once a month the voltage and gravity readings of each cell should be recorded. These will serve as an indication of trouble within the cells such as sulphation or leakage, if there is a progressive change of the gravity readings.

The gravity of the individual cells should be adjusted to the proper value when the battery is first put in service or when it has been necessary to add electrolyte to any cell to replace electrolyte which has been spilled or otherwise lost. This should be done at the end of the equalizing charge. If the gravity of the cell is too high, a portion of the electrolyte may be withdrawn with the hydrometer syringe and replaced by distilled water. Similarly the gravity may be increased by replacing the portion drawn off by electrolyte. Before considering the adjustment complete, the equalizing charge should be continued to mix the electrolyte of the cell. The final value is shown by several consecutive constant readings at 15-minute intervals. The gravity should be adjusted to within 5 points, corrected for temperature, of the proper value. Alkaline batteries do not require an equalizing charge. When the specific gravity of the electrolyte for these has fallen to the limits set in Section IX the electrolyte should be renewed.

4. BOOSTING

Under certain conditions the ampere-hour capacity of the battery may be insufficient for the day's work. In such a case, charging at a high rate of current for a short time may be resorted to. Such a charge is known as "boosting" and is usually given the battery during the noon hour.

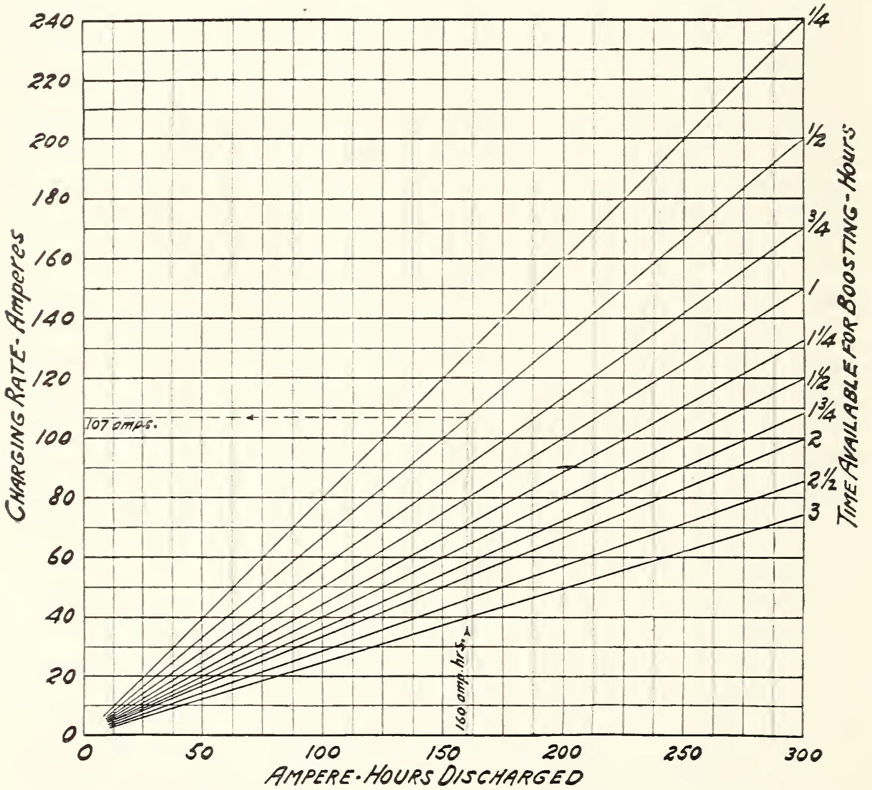


FIG. 33.—*Maximum rates for boosting for lead-acid cells of any capacity*

Example: If 160 ampere-hours have been discharged and one-half hour is available for boosting, follow the dash lines in the direction of the arrows. The proper value of the current to use is found to be 107 amperes.

Fig. 33 shows the value of current, with time, to be used for boosting, for the lead-acid type. Boosting batteries of the nickel-iron type may be done provided the temperature of the inside cells does not exceed 46° C (115° F). The rates of charge for cells of the A type recommended by the Edison Storage Battery Co. are as follows:

5 minutes at 5 times normal rate.
15 minutes at 4 times normal rate.
30 minutes at 3 times normal rate.
60 minutes at 2 times normal rate.

Frothing at the filler opening is an indication that the boosting has been carried too far.

With the constant-current system, the rheostat is adjusted in order to maintain the current at the constant value. When charging is to be done by the constant potential method in a given number of hours, reference should be made to Fig. 32.

The gases evolved by both lead-acid and nickel-iron batteries on charge are oxygen and hydrogen, which are odorless and invisible. The bubbles of these gases burst when they rise to the top of the liquid and cause a fine spray to be thrown into the air. This has a characteristic odor and is irritating to the membranes of the nose and throat.

A battery room should be well ventilated, not only because of the comfort of those who work in the room but more especially because of the inflammable nature of the gases evolved by the batteries when on charge. Oxygen and hydrogen explode with great violence and the explosive limits are rather wide. For this reason open flames or lighted matches should never be permitted in storage-battery rooms. Portable batteries, if charged in position in tractors or vehicles, also require good ventilation, with the same precautions regarding open flames. It is particularly dangerous to use a lighted match over the vent of a cell to see how high the liquid stands.

XII. RECEIVING A NEW BATTERY

The word "battery" as used herein means the total number of cells required for a given purpose. (See specifications, Appendix A.) When a new battery is received, it should be inspected carefully to make sure that it is in proper condition. When unpacking the battery, trays must be kept upright in order to prevent spilling of the electrolyte. All excelsior and packing should be removed from the top and sides of the trays.

All of the vent plugs should be removed or opened and the height of the electrolyte noted. This should be approximately one-half inch above the top of the plates. If the electrolyte is uniformly below the proper level, it indicates that evaporation alone has taken place and sufficient distilled or pure water must be added to bring the level to the proper height. If the level of the electrolyte is at its proper height in some cells and below in others, it indicates that electrolyte has been lost, due either to spilling or leakage from a broken jar. The low cells in acid batteries should be filled to the proper height with sulphuric acid electrolyte of specific gravity 1.250 approximately. (See Sec. IX.) If the loss is due to the tray having been overturned during the shipment, the excelsior and packing around the top will be wet and electrolyte probably will have been spilled from all cells. If the loss is due to a broken jar, the excelsior at the bottom of the tray and the bottom itself will be wet, while the excelsior at the top may be dry. The broken jar must be replaced (see Sec. XIII) and sufficient electrolyte added to make up for the loss.

Low cells in the nickel-iron type battery should be filled to one-half inch above the tops of the plates, or to such height as is indicated by instruction book for this type of cell, with distilled water, unless electrolyte has been spilled, in which case the alkaline electrolyte should be added as obtained from the Edison Storage Battery Co. (See Sec. IX.)

Each tray should be given a number for identification.

When all points mentioned have been attended to and the battery appears to be ready for use, lead batteries should be given an equalizing charge. (See Sec. XI.) If, after this charge, the specific gravity of the electrolyte is not at its proper point, approximately 1.275 in each cell, it is an indication that the same quantity of acid spilled or otherwise lost in transit has not been replaced. The specific gravity should then be adjusted. After this, the battery should be put on charge at the low rate stated on the name plate of each tray. The charge should be continued at this rate until all cells are gassing uniformly. The current then should be reduced to about one-half this value and the charge continued for about three hours, when the battery will be ready for service. Such a charge is called a "freshening" or "conditioning charge." Before putting the battery into service, however, the specific gravity of each cell should be recorded, with the date. Such readings serve to indicate the condition of the cells and to show approximately to what point the gravity should come at the end of future charges. (See Appendix C for forms for records of performance.)

When preparing alkaline batteries for service, after the electrolyte has been brought to the proper height, the batteries should be charged at the normal rate for rather more than the usual time.

XIII. DISMANTLING AND ASSEMBLY OF LEAD-ACID TYPE

First, clean the top of the battery thoroughly.

Before starting to dismantle the battery, make a sketch or diagram showing the relative locations of cells, intercell connectors, terminals, and any other data necessary to insure the correct assembly. It is desirable to have the battery about 30 per cent discharged in order to prevent excessive heating of the negative plates.

1. REMOVAL OF CONNECTORS

(*a*) Connector Puller.—Remove the filling plug on the cell to be dismantled and place the puller in position. With the puller vertical, screw the plunger down gradually until the connector is free from the post. (See Fig. 34.) This method is quick and easy to operate, eliminates boring out, but necessitates trimming the posts for reassembly of the cell.

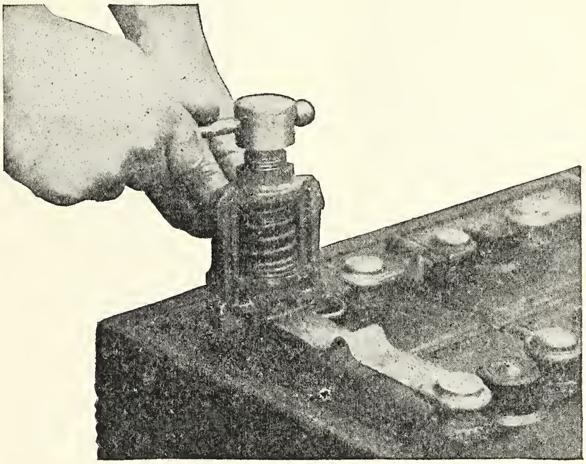


Fig. 34.—*Use of the connector puller to remove a connector. The vent plug must be removed before using the puller*

(*b*) Boring Out.—Bore out the connector, using a brace and bit. The bit may be either a twist drill or a wood bit, the latter preferred, and should be at least of the same size as the post, usually five-eighths inch (1.6 cm) or three-fourths inch (1.9 cm). Before boring, the bit should be centered carefully on the connector. The hole should be bored to a depth of about three-sixteenths inch (0.5 cm). The filling plug should be in position while boring out to prevent lead chips getting into the cell. (See Fig. 35.)

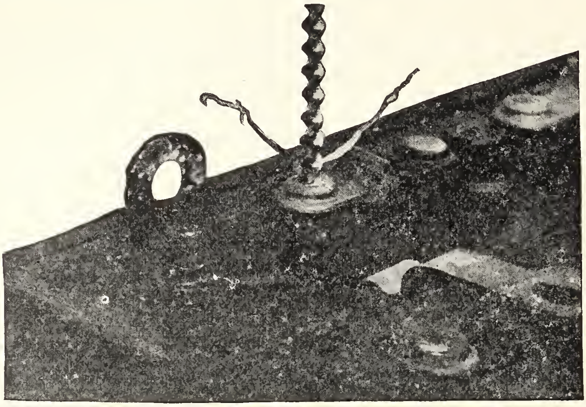


Fig. 35.—*Boring out the connector with a wood bit. The post from which connector has been removed by the puller shown in Fig. 34 can be seen at the left. The bit must be carefully centered*

When the hole has been bored to the proper depth, the connector will seem loose and the joint between the connector and the post can be seen. After boring out the connector, insert a screw driver between the underside of the connector and the sealing nut, if

Fig. 36.—*Prying off the connector after the boring-out operation shown in Fig. 35. Care must be taken in this operation not to break the cover of the jar*

there is one, and pry firmly but gently on the connector. Repeat this operation on the other side of the post and continue until the connector is free. (See Fig. 36.) If there is no sealing nut which can be used as a brace for prying up the connector, place a heavy strip of wood across the top of the cell next to the post and use this as a brace. Care should be taken not to put pressure on the cover. If the boring out of the connector is not done properly, as for instance the hole is not concentric with the post, heat can be applied gradually to the connector until the lead is softened sufficiently to permit pulling up the connector with a pair of pliers.

In all of the above operations care should be taken not to short circuit the cell by allowing pliers or other tools to come in contact with both posts at the same time.

2. REMOVAL OF CELL

Grasp each post with a pair of pliers and pull vertically. (See Fig. 37.) If the jar sticks, a hot putty knife may be inserted around the edges. This will usually loosen the jar so that it may be pulled out easily. After the jar had been pulled out, rest it on the edge of the tray so that the pliers may be removed and the cell lifted by the hands to a position for the next operation.

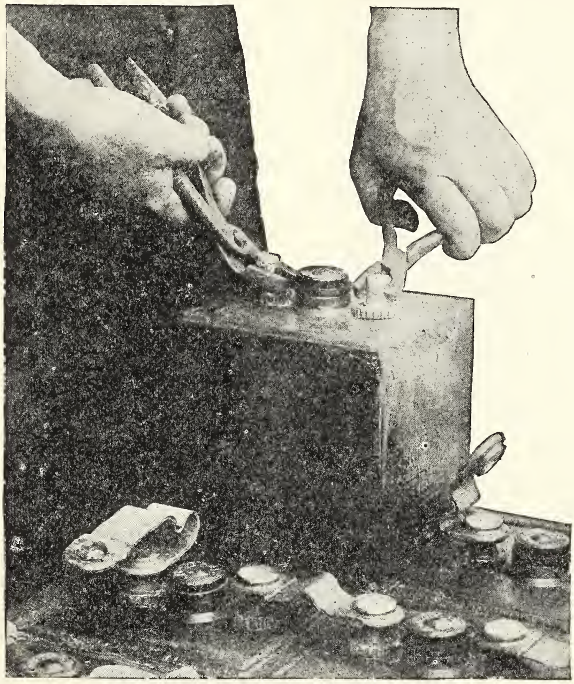


Fig. 37.—*Removal of cell from the battery. If the jar sticks, a hot putty knife may be inserted around the edges*

It is to be noted here that the positive post has more corrosion than the negative.

Fig. 38.—*Removal of the sealing nut. The sealing nut of the post on the right has been removed and is lying beside the post. Not all makes of batteries have sealing nuts. Sealing nuts are of several different types, varying with the manufacturer*

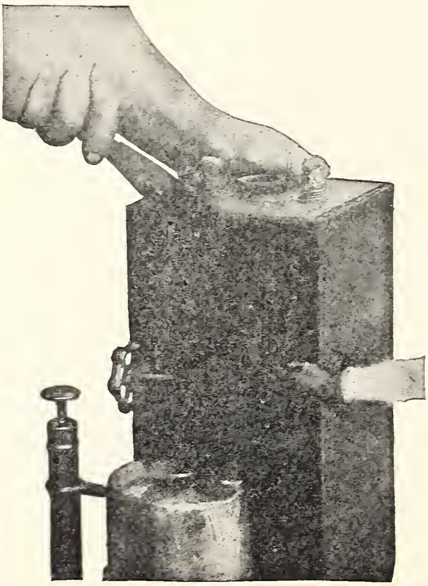


Fig. 39.—*Use of a hot putty knife to melt the compound around the edge of the cover. Before doing this, the gases should be blown out of the cell to avoid a possible explosion when using the blow-torch*

The sealing nuts, if used, should be removed next by means of a special wrench. If such a wrench is not available, use a pair of pliers, and only as a last resort use a monkey wrench or a pipe wrench. (See Fig. 38.) Note the shape of pliers used. The sealing nuts are sometimes held in place by scoring the threads on the post with a prick punch.

3. REMOVAL OF ELEMENT

With the filling plug out, blow the gases out of the cell. This is to reduce to a minimum the possibilities of an explosion. Warm the outside of the jar at the top with a flame and then insert a hot putty knife around the inner edge of the jar, melting out the compound to a depth of about half an inch. (See Fig. 39.) This operation should be performed as rapidly as possible, as the compound cools quickly. Next, place the finger in the filling aperture and lift vertically on the cover. If the cover does not pull readily, remove all of the sealing compound possible by means of the hot putty knife and reheat the sides of the jar before again pulling on the cover.

After the cover has been removed, clean it thoroughly and wipe off the edges, where sealing compound is to be poured, with a cloth damp with dilute ammonia.

Place the jar, with the cover removed, on the floor with one foot on each side and grasp each post with a pair of pliers. Pull the element upward while holding the jar with the feet. (See Fig. 40.) When the element is nearly out, place it slightly out of plumb on the top of the jar and let it drain for about 5 minutes. (See Fig. 41.) The element should not remain out of the jar for more

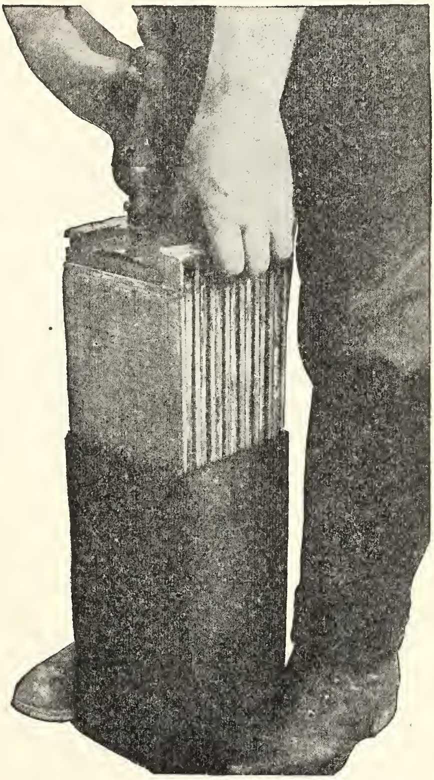


Fig. 40.—*Removal of the element from the jar. After the cover has been removed, the element may be pulled vertically upward, holding the jar between the feet. This figure shows also the proper method of replacing the element in the jar*

than 15 minutes on account of injurious heating. Should the negative plates begin to dry out and heat, sprinkle them with water until they can be taken care of.

4. REMOVAL OF SEPARATORS

Place the element on the edge of a table or bench. When it is necessary to use the separators again it is desirable to use a special tool called a "separator inserter." The broad side is used next to the negative plate to loosen the separators so that they can be pushed and pulled at the same time from between the plates. (See Fig. 42.) In case the separators are not to be used again, a putty knife may be inserted between each separator and the negative plate to loosen them and then they may be pushed from the top and pulled from the bottom until free from the plates.

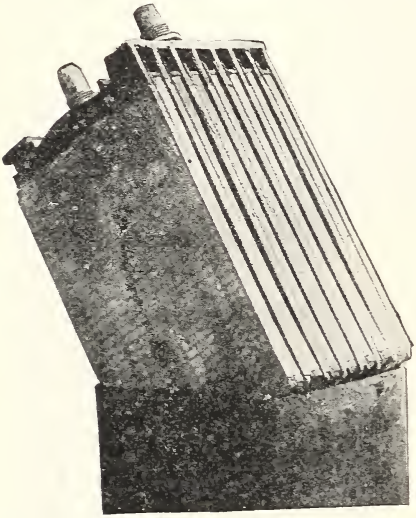


FIG. 41.—*Draining the element. Five minutes is sufficient time for draining. The plates should not be left in this position indefinitely because the negative plates will oxidize in the air and become hot*

Separate the positive and negative groups of plates and soak each of them in water for about 20 minutes. They are then ready to be placed away on a shelf if the battery is to be stored.

Pour the electrolyte out of the jar and wash it out with distilled water.

5. ASSEMBLY OF A CELL

To install new separators, place the elements on edge as explained for removal of separators. Insert the new separator from the bottom. The smooth side of the wood separator is to be placed next to the negative plate and perforated rubber separator between it and the positive plate. (The Ironclad-Exide battery has only a smooth wood separator between plates.)

Place the element on edge, projecting slightly over the edge of the bench, and place jar over the plates. Then lift the jar and plates in this position (similar to position for draining the element, Fig. 41) to the floor and push element into position. The electrolyte may be in the jar at this time, but it is preferable not to have it so. The inside edge of the jar at the top should be cleaned of compound and wiped with a cloth dampened with dilute ammonia after inserting the element as above. It is necessary to have the jar and cover free from all acid, as otherwise the compound will not adhere properly to the surfaces. Care should be taken that no ammonia is allowed to get into the electrolyte.

Before putting on the cover, place the soft rubber gaskets, if used, over the posts. The cover should be replaced while the jar is cold, unless it will not fit readily, in which case warm the outside of the jar with a flame until it becomes flexible enough to allow the cover to fit properly. Care should be taken not to burn the jar. Heat the compound and pour it into position, then trim with a hot putty knife until a level, smooth surface is obtained. Clean off all compound not needed to seal the cover. Replace the cell in the tray in the same position as it was in the beginning.

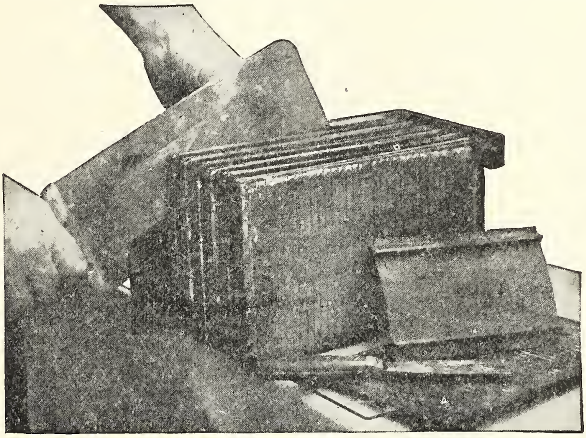


Fig. 42.—*Use of the separator inserter. It is possible to remove separators and put in new ones without this tool, but the wooden separators are generally broken in removing them. It is seldom desirable to use the same wooden separators again, but they may be removed without breaking with this tool and put back if necessary. If a rubber separator is also in the battery, this may be saved and used again. A splash cover from the top of the cell is to be seen resting against the plate*

If there is electrolyte in the cell, first clean the posts with dilute ammonia to neutralize the acid and allow them to become dry before doing anything further.

Trim each post, if a connector puller has been used, until its top is about three-sixteenths of an inch below the top of the connector. This may be best done by means of end-cutting pliers. Clean off the top and sides of the posts thoroughly. A file brush is good for cleaning the top and gas pliers for cleaning the sides of the posts.

Always have the cover firmly in place and sealed before putting on the connector. If the intercell connector is not of the right length it should be adjusted, and in no case should it be forced into position over the posts, as the jar or cover may be broken on account of undue strains.

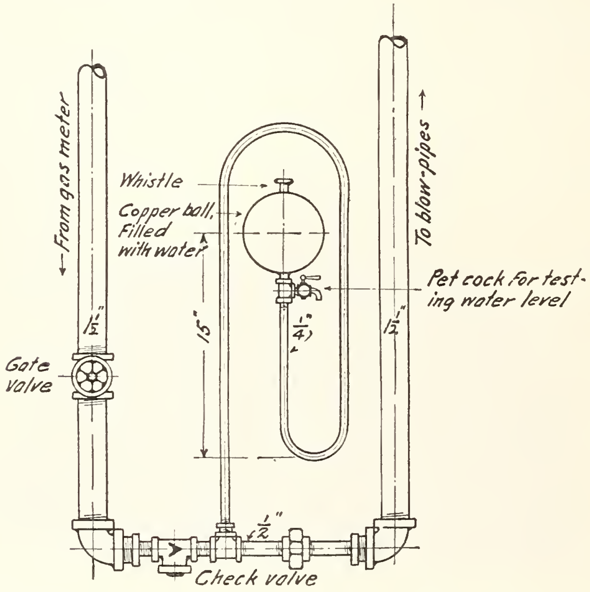


Fig. 43.—*Device for protection of gas main. Operation: When pressure becomes excessive, as when the tip of a burner is clogged, the check valve closes, preventing the back pressure reaching the meter. Should a flame from a burner run back through the pipe, the check valve will close, forcing the flame through the small pipe into the ball, where it will be extinguished by the water. Whistle indicates low water*

6. LEAD BURNING

This is a welding process for making a good mechanical and electrical connection between the plates and the strap and between the posts and connector. Burning is done by means of illuminating gas and oxygen, acetylene and air, hydrogen and compressed air, or an electric arc. Illuminating gas and oxygen is the most convenient of the gas methods. The gas is taken from the supply main and the oxygen from a storage tank. Care must be taken to adjust the burner properly and to prevent explosions. If the tip of the burner becomes stopped, the oxygen will flow into the gas main, due to its higher pressure, and an explosion may follow. To prevent such an occurrence, a safety device of some sort must be used in the gas main or at each burner. Fig. 43 shows a simple device which is in use at a service station for the protection of a number of burners. A similar device is obtainable in the market. The pressure of the oxygen should be about 4 to 5 pounds when used with illuminating gas. The reducing valve on the oxygen tank is usually of the diaphragm type, provided with a gage for indicating the pressure on the outlet side. The design of the valve is such as to maintain a practically constant pressure when a number of burners are being used. The pressure of oxygen is to be set at approximately the right amount by the valve on the tank when the reducing valve is partially open. The fine adjustment of the pressure is then made by opening or closing the reducing valve. Some valves are so constructed that the adjusting screw is to be turned to the right to open the valve or increase the pressure. For this reason it is sometimes thought that the valve is being opened when in reality it is being closed. Use a reducing flame, as it is not desirable to oxidize the lead. Work with the tip of the inner blue flame and use a rotary motion, working from the center of the post upward and outward. The top of the post should be melted first and then fused to the wall of the hole in the connector; then lead from a piece of burning strip can be run in until the joint is flush with the top of the connector. Finish with a file and file brush. All parts must be thoroughly cleaned of dirt or foreign matter, as absolute cleanliness is necessary for a successful piece of work. Fig. 44 illustrates the burning process above described.

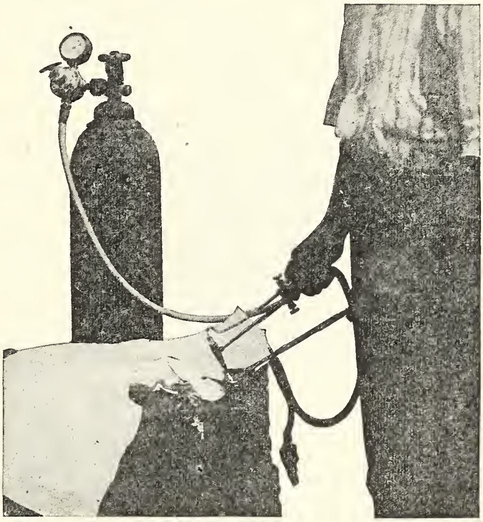


Fig. 44.—*Lead burning with a gas and compressed oxygen flame. The vent plugs of the cells should be open and the top of the battery covered with a damp cloth to avoid possible explosions. The oxygen tank should be provided with a reducing valve, the pressure of the oxygen not exceeding 5 pounds*

The electric arc outfit consists of a carbon holder, with connecting cable and clamp and a carbon rod about one-fourth inch in diameter. The battery on which work is to be done is usually used as a source of current. From two to four cells are required, according to the state of charge. Fig. 45 illustrates this method of burning. The clamp is attached to an intercell connector a sufficient number of cells away to give the proper voltage. Care should be taken to have a good connection between the clamp and connector. The carbon rod should be sharpened to a point and project about 2 inches beyond the clamp. The carbon should be brought to a bright glow by contact with the post which is being worked on. The same process as described for gas is to be followed for making the joint. The carbon should be worked with a rotary motion from the center of the post outward without drawing an arc. The carbon holder should be cooled occasionally by plunging it, with the carbon, into a pail of water. After a time the carbon may fail to work properly, due to a film of lead oxide, which may be removed by a file or scraping with a knife. It is necessary that the operator use a pair of dark glasses to protect his eyes. If the battery is not available as the source of current, a 6-volt "starting" battery may be employed. In this case one terminal is connected to the clamp of the carbon holder and the other to the connection to be burned.

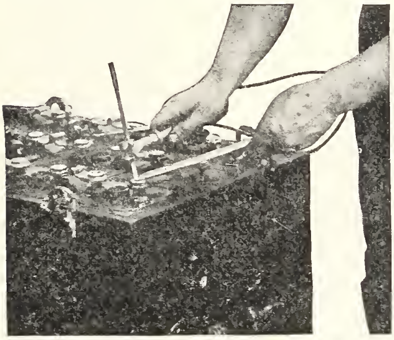


Fig. 45.—*Lead burning with the electric arc. The battery on which the work is done is generally used as the source of current. The voltage required varies from 4 to 8 volts. The eyes of the operator should be protected by dark glasses*

XIV. CLEANING (LEAD-ACID TYPE ONLY)

1. DEPOSIT OF SEDIMENT

During the normal operation of a cell there is a constant wear of the plates which causes a deposit or sediment to settle in the bottom of the jar. A space, usually referred to as the "mud space," having considerable capacity is provided for the sediment.

The rate at which the sediment accumulates depends to a great extent upon the care which the battery receives in charging. If charging is carried on at such a rate as to cause violent gassing, the gas coming through the pores of the positive plate will tend to dislodge the active material, causing it to be deposited in the bottom of the jar. This condition is frequently referred to as "shedding of active material," and very materially shortens the life of the plate. This is one of the reasons why the charging current is reduced, when the battery begins to gas freely, to a lower value called the "finishing rate." If a battery is regularly undercharged, the sulphate which remains unreduced on the negative plate will gradually accumulate and finally be washed away and deposited in the bottom of the jar. This is one of the reasons for giving a battery a regular equalizing charge in order to completely reduce the sulphate. If a cell is neglected and cleaning is delayed until the sediment accumulates sufficiently to reach the bottom of the plates, the wear will be increased on account of the local action caused by short circuits through the sediment and the cell will be discharged. Indications of this condition are low open-circuit voltage and low specific gravity.

2. TO DETERMINE NECESSITY FOR CLEANING

As the nature of the service requirements of a battery varies considerably, it is difficult to state definitely any means by which the necessity for cleaning may be determined. The best method of determining the condition of a battery appears to be a bench discharge test at normal rate, after an equalizing charge, with voltage readings of all cells in the battery. If, on such a test, any cell is found to be much below the others in capacity and the capacity of that cell can not be restored by an overcharge, it should be removed and inspected for short circuits or other trouble. This should be done after, say, 150 cycles of normal operation. Some types of cells are provided with extra high ribs, which allow the accumulation of sediment during the entire life of the plates, thus eliminating the necessity of cleaning on this account. The cells should be removed and opened in accordance with instructions given in Section XIII.

3. METHOD OF PROCEDURE

If the battery is found to be sulphated, but with the sediment below the bottom of the plates, it should be treated in accordance with instructions in Section VIII before cleaning. If the sediment has been allowed to reach the bottom of the plates, the battery will be sulphated and should be cleaned in accordance with instructions given in this section before receiving treatment for sulphation.

The wood separators are to be renewed completely; and while many of the rubber separators may be used again, it is well to provide about 25 per cent new ones. Three or four new jars and covers should also be provided.

The trays should be examined to determine their suitability for further use. If found to be in good condition, they should be washed out with water, to which soda has been added to counteract the effect of the acid. When thoroughly dry they should be painted with two coats of acid-resisting paint. If new trays are required, accurate sketches of the old ones should be made, noting particularly the inside and outside dimensions, size and location of ears for anchor bolts and size and location of handles.

If the active material of the negative plates is swollen it must be pressed back into position before it is allowed to dry. A smooth board of suitable thickness is to be placed between each pair of plates and the whole group squeezed between smooth boards in a vise. Any loose particles adhering to the positive plates are to be removed by means of a smooth piece of wood, or paddle. The plates are not to be washed. All of the sediment is to be washed out of the jars. The elements are now ready to be assembled.

The jars are to be filled with electrolyte of specific gravity 1.250 to one-half inch above the top of the plates. If the battery is sulphated, water is to be used instead of electrolyte.

After the cells have been placed in the trays, and the old connectors pressed into position the battery is to stand for several hours (some manufacturers recommend as long as 10 hours) after which it is to be put on charge at the finishing rate. At the end of about 15 minutes, the voltage of each cell is to be read and recorded. This is to insure that the cells are connected right as to polarity. Any cell indicating less than 2 volts is probably connected backward and should be examined. The cells are now to be reconnected, if the battery is not sulphated, and after an equalizing charge it will be ready for service. A sulphated battery should be restored before reconnecting the cells permanently.

The relatively simple operation of cleaning is often referred to erroneously as "rebuilding a battery."

XV. STORAGE

1. LEAD-ACID TYPE

There are two ways in which a battery may be put in storage, the one or the other to be used according to the condition of the battery and the length of time it is to be out of service. A battery which is to be out of service for less than a year will generally be put in wet storage unless it will soon require such repair as to necessitate dismantling. The battery should be examined as to condition of plates and separators and the amount of sediment in the bottom of the jars noted. If conditions are such as to require dismantling and cleaning, instructions in Sections XIII and XIV should be followed and the battery then put away in dry storage.

(*a*) Wet Storage.—If the battery, upon examination, is found to be in good condition, it should be given an equalizing charge and the specific gravity of all cells brought to the proper point. It may then be put in wet storage.

Benches are to be provided in a convenient location with ventilation. The batteries are to rest upon wood strips and the trays are to be separated in order to allow a free circulation of air. When the charging station is such as illustrated in Appendix B the battery racks should be used. No wood strips are required if the racks are provided with rollers.

In order to maintain the battery in good condition, it should be kept on continual charge at a low rate, known as a "trickle charge." The amount of current required is just enough to offset the local action and to keep the specific gravity constant. Roughly, this is equal to about 1 per cent of the finishing rate in amperes. As many cells of the same capacity as possible should be charged in series. A bank of lamps is an inexpensive and convenient means of regulating the charging current, and at the same time provides a visual indication that the batteries are on charge. On a circuit of 110 volts, one 25-watt lamp will permit a current of about 0.25 ampere and one 50-watt lamp a current of about 0.5 ampere to flow. These two sizes are the most useful and any value of current may be obtained by combination of suitable lamps in parallel. At regular intervals, while on charge, the filling plugs should be removed and water added if necessary. Shortly after the charge is started the specific gravity of each cell should be read and recorded. By experiment, the correct value of current will soon be determined.

In cases where it is impracticable to provide for the trickle charge, the batteries should be given, at least once in two months, a charge at the normal rate until all cells are gassing freely and uniformly. At this time, the filling plugs should be removed and water added if required.

(*b*) Dry Storage.—After the battery has been cleaned and dismantled, the parts may be put away in dry storage.

The shelves, or racks, used for storage must be in a dry location, free from dust.

Positive and negative groups are to be soaked in cold water for at least 15 minutes. The positive plates can then be put aside to dry. The negative plates will probably heat when removed from the water and should be soaked again until they are cool. Care should be taken that the positive and negative groups do not come in contact.

If the trays are in good condition, they should be washed out with water to which soda has been added to counteract the action of the acid, dried, and put away for future use.

Wood separators should be kept in water made acid by the addition of a small quantity of sulphuric acid. This is to keep the separators free from slime.

2. NICKEL-IRON TYPE

The cells should be filled to a uniform level and the tops cleaned of deposit. The batteries can then be put away in a dry, clean place for an indefinite length of time, without attention, in any state of charge.

Washington, January 27, 1920.

APPENDIXES

Appendix A.—STORAGE BATTERIES (for Industrial Trucks and Tractors)

WAR DEPARTMENT SPECIFICATION NO. 223-1-38, MAY 1, 1919

(Authority of Supply Circular No. 27, P. S. & T. Div., June 28, 1918)

Types of Batteries.—Batteries shall be of the lead-acid or alkaline types.

Capacity.—The normal capacity or service rating of each battery shall be not less than 220 ampere-hours at the five-hour discharge rate.

Number of Cells.—(*a*) *For tractor.*—Each battery shall consist of 24 cells of the lead-acid type (nominal volts 48) or 42 cells of the alkaline type (nominal volts 50.2).

(*b*) *For trucks.*—Each battery shall consist of one-half the number of cells required for tractors or 12 and 21 cells for the lead-acid and alkaline types, respectively.

Jars.—(*a*) *For lead-acid type.*—Hard rubber, nominal thickness three-sixteenths inch, minimum thickness 0.175 inches, of compound having a nominal tensile strength of 5000 pounds per square inch, with an elongation of 6 per cent; tensile strength to be not less than 4000 pounds per square inch, with an elongation of not less than 7½ per cent; elongation to be not less than 5 per cent, with a tensile strength of not less than 6000 pounds per square inch; for intermediate values of tensile strength the product of the figures of tensile strength and per cent elongation shall be not less than 30 000.

(*b*) *For alkaline type.*—Cold-rolled steel, corrugated and heavily nickel plated, with seams welded.

Covers.—(*a*) *For lead-acid type.*—Shall be of the same material as the jar, with molded flat top, not recessed and not below the top of the jar. A minimum amount of sealing compound consistent with the design shall be used to make the cover gas tight. Sealing compound shall not be ignited easily and must not flow when heated to 120° F. Cover shall be provided with combination filling aperture and gas vent.

(*b*) *For alkaline type.*—Shall be of cold-rolled steel, nickel plated, and welded to jar. Cover shall be provided with combination filling aperture and gas vent.

Leads and Connectors.—(*a*) *For lead-acid type.*—Leads from end cells to tray terminals shall be No. O B. & S. gage extra flexible rubber-covered cable. The connections between individual cells shall be burned on to terminals. Bolted intercell connections may be furnished at the option of the purchaser. The intercell connections shall be capable of carrying continuously 125 amperes without injury. Tray terminals or connectors when used shall be of the wing nut type. (See Fig. 46.)

(*b*) *For alkaline type.*—No leads shall be provided. Tapered steel terminals on each cell shall be designed for bolted connections. Connectors between individual cells shall be swedged into steel lugs having inside taper corresponding to that of the terminals. Connectors between trays shall be similar, but of flexible insulated conductor soldered into the lugs. The end terminals of each battery shall be provided with a steel lug for No. O B. & S. gage stranded conductor. All connectors and lugs shall be nickel plated.

Electrolyte.—(*a*) *For lead-acid type.*—Shall be sulphuric acid of 1.275 to 1.290 specific gravity at 80° F when fully charged.

(*b*) *For alkaline type.*—Shall be potassium hydrate of appropriate strength. Sodium hydrate may be furnished at the option of the purchaser.

Assembly of Cells.—(*a*) *For lead-acid type.*—Cells shall be assembled in trays each of four cells arranged end to end, with a single tie partition across the center.

(*b*) *For alkaline type.*—Cells shall be assembled in trays of one row of seven cells.

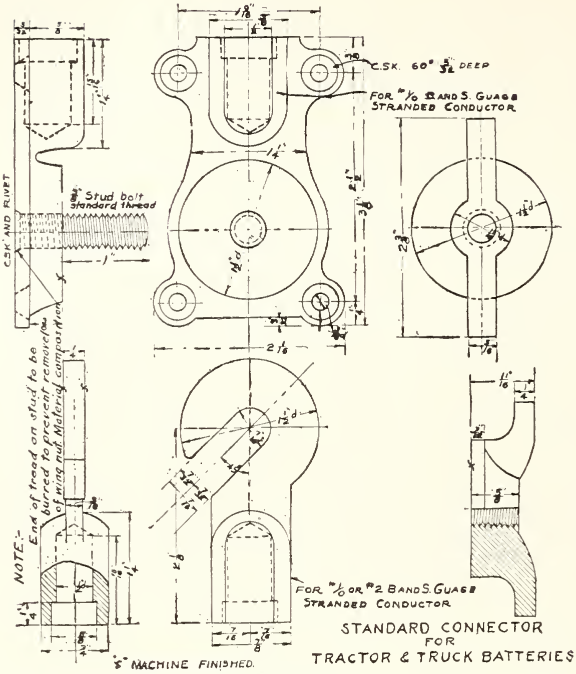


Fig. 46

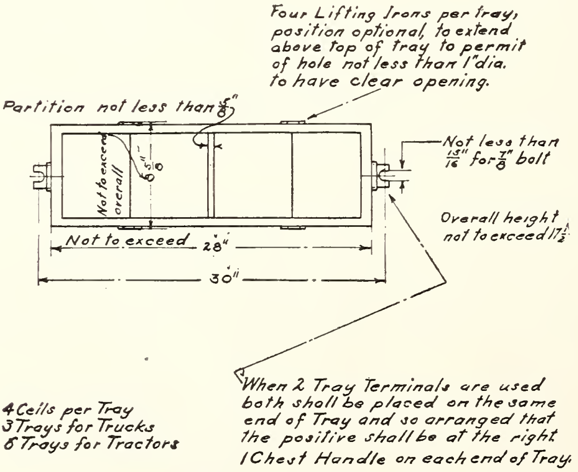


Fig. 47.—*Standard lead battery for trucks and tractors*

Trays.—(*a*) *For lead-acid type.*—Shall be of hardwood, fitted with one chest handle on each end and with four lifting irons. Dimensions and general arrangement shall be as shown in Fig. 47.

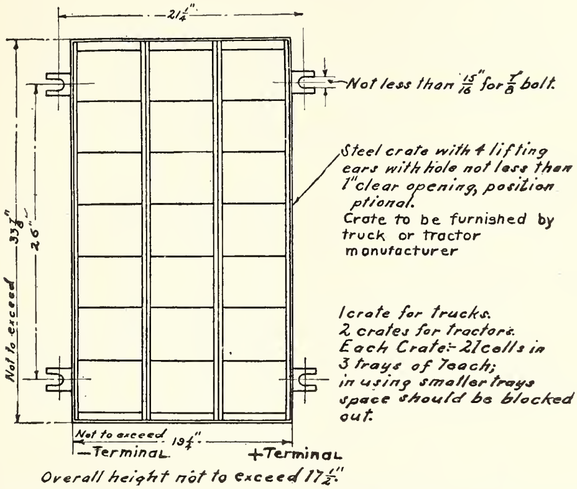


Fig. 48.—*Standard Edison battery for trucks and tractors. Types A6 and G9 cells*

(*b*) *For alkaline type.*—Shall be in accordance with the standard design of the Edison Storage Battery Co. (See Figs. 48 and 49 for general arrangements.)

Trays for both types of batteries shall be painted with two coats of appropriate protective paint.

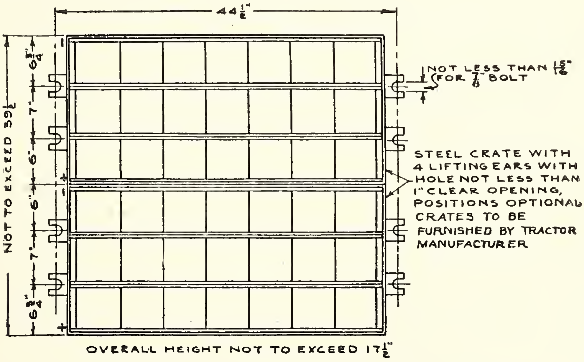


Fig. 49.—*Edison type A8 battery for tractors*

Life.—*For both lead-acid and alkaline types.*—Each battery shall be capable of giving not less than either 250 cycles of charge and discharge, or one year of life to not less than 80 per cent of its rated ampere-hour capacity, when operated under service conditions and maintained in accordance with instructions from the manufacturer.

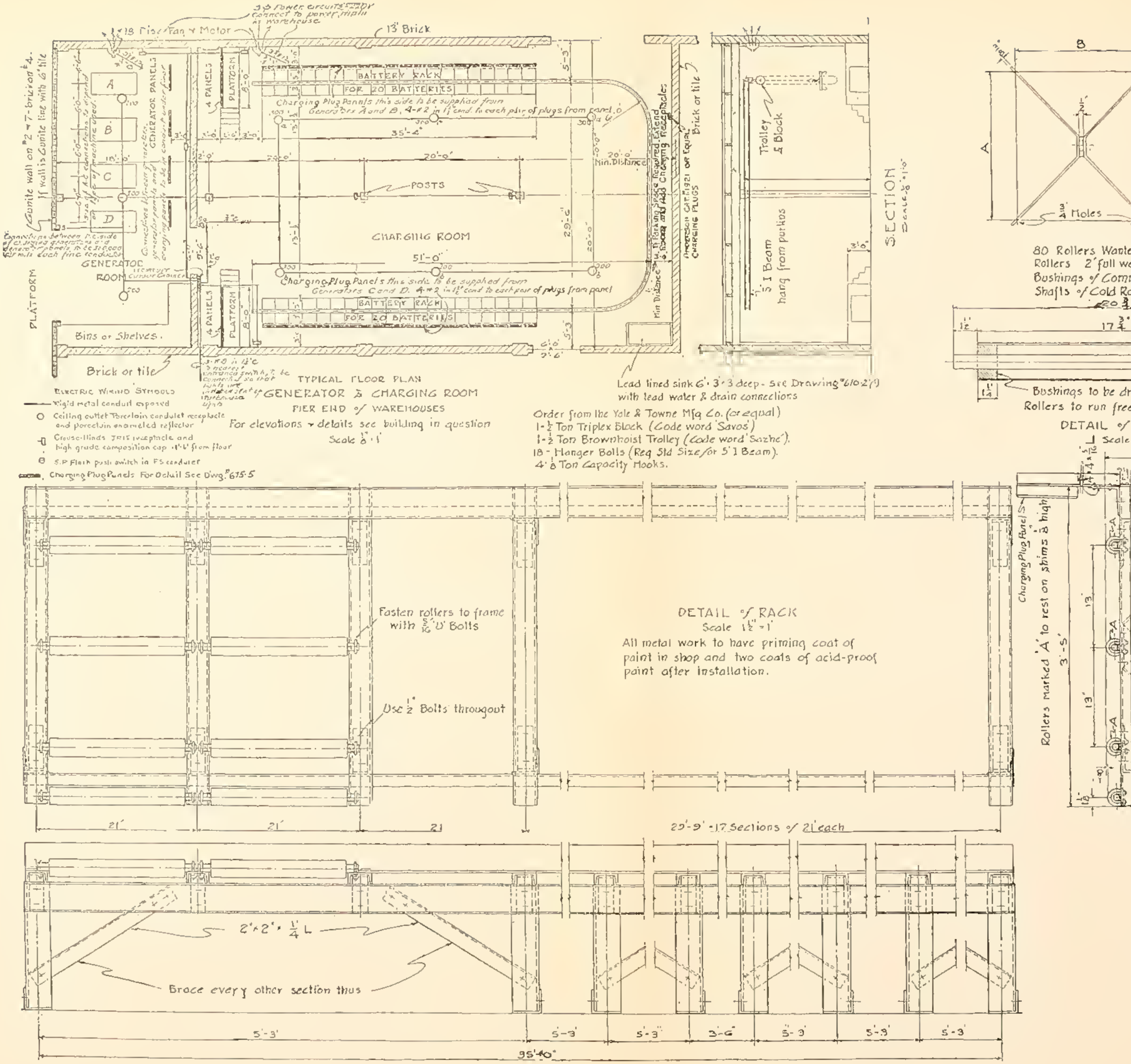


FIG. 50.—*Typical battery charging station for 20 standard tractors.* (*Drawing No. 610–252 of the Construction Division of the Arm*

174541°—20. (Face page 73.)

For control of each generator the following equipment is to be provided:

One 300-ampere T. P. S. T. knife switch.

One 300-ampere S. P. overload and reverse current circuit breaker.

Two ammeters, 0–300-ampere scale, 7-inch round pattern.

One voltmeter, 100–0–100-volt scale, 7-inch round pattern.

One 8-point receptacle, with 4-point plug, for voltmeter. To read voltage between either outside and neutral and total voltage.

One field rheostat mounting.

The control panel for the synchronous converter is to be equipped for similar duty. The transformer shall be mounted upon the framework of the control panel with all connections complete.

For control of each 60 to 80 volt battery-charging circuit the following equipment is to be provided:

One 200-ampere S. P. S. T. knife switch.

One 150-ampere 250-volt inclosed fuse (in line with switch).

One 100-ampere S. P. overload and underload circuit breaker with opening adjustment of from 7.5 to 15 amperes.

One fixed, grid type, resistor of 0.10-ohm resistance and 80 amperes capacity.

One ammeter, 0–150-ampere scale, 4-inch round pattern.

The studs on each grid shall be of sufficient length to permit the use of a jumper.

For control of each 30 to 40 volt battery-charging circuit the equipment is to be as above except that the resitor is to have a resistance of 0.05 ohm.

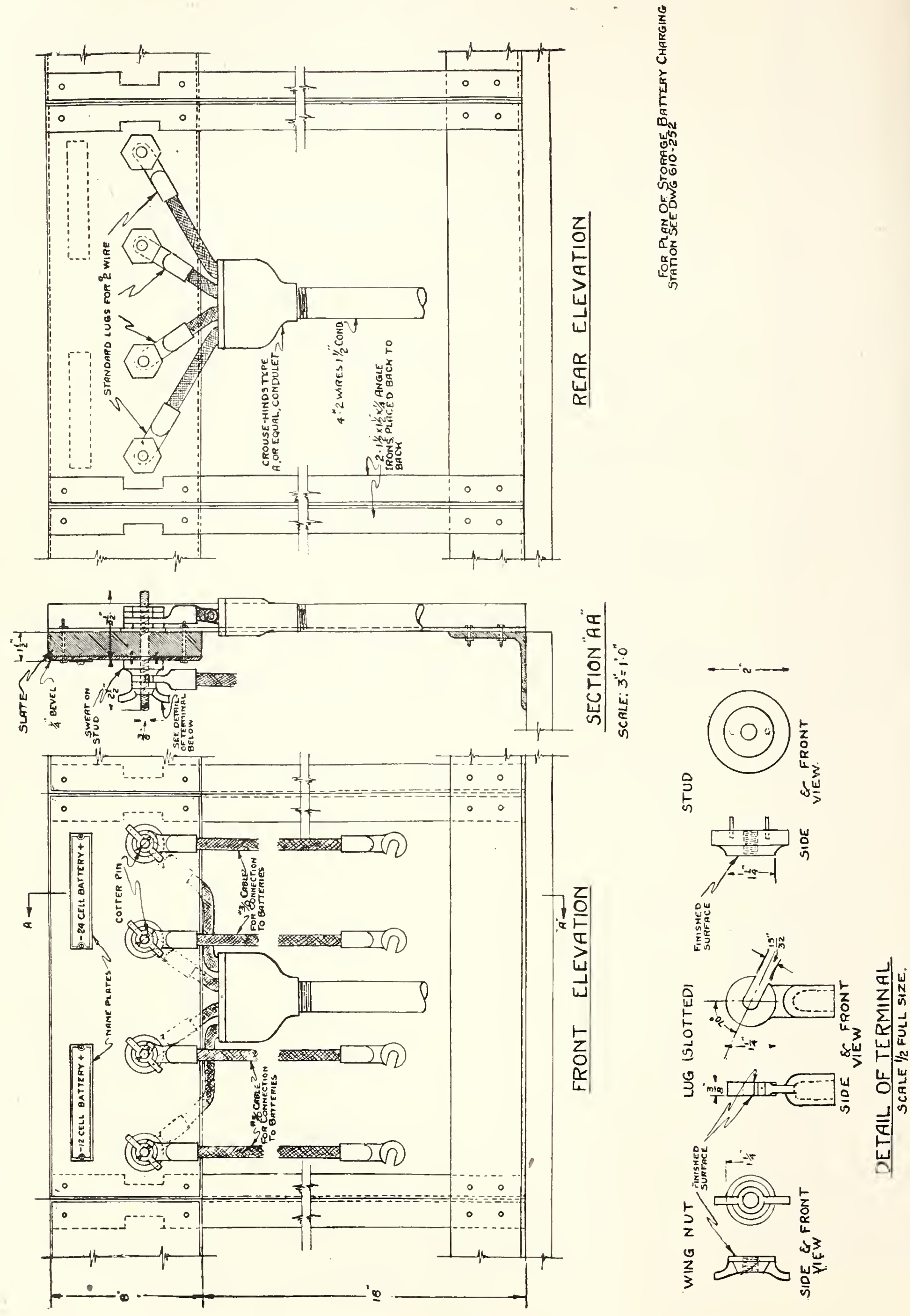
Blue print showing general arrangement of apparatus, together with wiring diagram, is to be submitted by the manufacturer.

CHARGING STATION

For general arrangement and details of battery-charging station, see the following drawings, which are a part of these specifications, and are reproduced herewith:

Const. Div., War Dept., No. 610–252. Fig. 50. "Typical Battery-Charging Station."

Const. Div., War Dept., No. 675–5. Fig. 51. "Detail of Charging-Plug Panel."



For Plan Of Storage Battery Charging Station See Dwg 610-252

Fig. 51.—*Typical charging plug panel for standard battery charging station.* (*Drawing 675-5 of the Construction Division of the Army*)

Appendix C.—RECORD FORMS

Forms 1, 2, 3, and 4 are forms in use at a Government port terminal. The batteries are charged in the trucks or tractors by the modified constant potential method. The details of the charging equipment and layout of the battery stations are practically in accordance with those outlined in Appendix B. Form 2 does not apply directly to performance of the battery but is given here as it shows the data required to obtain information as to the cost of handling freight. All repairs made to the trucks, tractors, or batteries are noted on Form 3. All of the data obtained daily is summarized on Form 4, from which the cost of operation may be obtained.

Form 5 is in use at an ordnance depot. The charging equipment and layout at this place are substantially as covered by Appendix B. In addition, this station has a number of constant current circuits of small ampere capacity for charging portable batteries used for miscellaneous purposes.

Form 6 is in use at a railroad terminal for baggage trucks. The batteries are charged out of the truck by the constant current method. There are racks for the batteries, and a hoist is provided to facilitate handling.

The lower portion of Form 5 is an excellent one for keeping a record of the weekly equalizing charge of batteries of the lead-acid type.

All of the above forms are for transportable batteries.

Forms 7 and 8 are for use with stationary batteries.

DAILY CHARGING RECORD

Station No. .... **Date**........................

Truck No.	Time		Amperes		Spec. Gravity		Temperature	
	On	Off	On	Off	On	Off	On	Off

Remarks

Charged by:

Form 1

Operators Daily Report

Date............................

Truck No. ....

No. Trailers..........................

Ave. Wt. of Pkg.......................

No. Pkgs. per Load...................

No. Trips...............................

Dept. ....

R. R. Car No. ....

R. R. Car Initial......................

Total Wt. Carried.....................

Hours Worked.........................

Contents.................................

Warehouse..............................

Remarks

Sig. Operator.

Form 2

DAILY REPAIR SHEET

Station No. .... Date........................

Truck No.	Remarks	Operator	Mechanic

Form 3

Truck No. .... **Month**........................

Date	Battery No.	Total tons	Kw.-hrs. in	Repairs	Remarks
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
31					

Form 4

BATTERY CHARGING RECORD

Battery No.	Out	Truck	In	Truck	Volts		Gravity		Elapsed time	Wattmeter				Odometer
					Start	Finish	Start	Finish		No.	Start	Finish	Watt hours	

Inspector.

FORM 6

STORAGE BATTERY RECORD FOR THE MONTH OF.........................

Depot................................ At................................ Date in service................................

Battery of................cells. Type................................ Battery No. ....

DAILY READINGS—DIRECTIONS: Start Charge as given in the Methods Bulletin recording time and amperes. Select a conveniently located cell as a pilot cell, and immediately after the daily charge is completed record the specific gravity and temperature of this cell. Once every week give battery an equalizing charge; replace evaporation with pure water before the charge is started. Note on reverse side of sheet any unusual condition or attention given the battery.

Date	BOOST				REGULAR CHARGE AT END OF DAY						
	START		FINISH		START OF CHARGE			END OF CHARGE			
	Time	Amp.	Time	Amp.	Time	Amp.	Sp. Gr.	Time	Amp.	Sp. Gr.	Temp.
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											
16											
17											
18											
19											
20											
21											
22											
23											
24											
25											
26											
27											
28											
29											
30											
31											

Monthly or Individual Cell Reading Directions: Once each month immediately after an Equalizing Charge, take and record Sp. Gr. of each cell in the battery.

Sp. Gr. Taken................................A. M. / P. M.

Voltage Taken................................A. M. / P. M.

Charging Amps. while read. Volt...............

Date................

Cell	Sp. Gr.	Volts	Temp.
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			
22			
23			
24			

WEEKLY OR EQUALIZING CHARGE READINGS—DIRECTIONS: Once every week after the daily charge has been completed give the battery an equalizing charge (see Methods Bulletin) and record readings called for at half-hour intervals, below. Note any cells that do not gas as freely as the rest, on the reverse side of sheet.

DATE....................					DATE....................				
Time	Amps.	Volts	Sp. Gr.	Temp.	Time	Amps.	Volts	Sp. Gr.	Temp.

WATER ADDED.

DATE....................					DATE....................				
Time	Amps.	Volts	Sp. Gr.	Temp	Time.	Amps.	Volts	Sp. Gr.	Temp.

REMARKS.

READINGS TAKEN BY

REPORT ON BATTERY PLANT

Plant of.. At..

Number of Cells.. Type..

Temperature of electrolyte..............................°F of battery room..............................°F Charging Current..............................amperes. Voltage readings to be taken if possible at end of charge with current still flowing. Take gravity readings immediately after voltage readings. If on regulation during readings, current fluctuations were from..............................amp. charge to..............................amp. discharge.

POSITIVE SIDE

Cell	Volts	Sp. Gr.	Cell	Volts	Sp. Gr.	Cell	Volts	Sp. Gr.
1			41			81		
2			42			82		
3			43			83		
4			44			84		
5			45			85		
6			46			86		
7			47			87		
8			48			88		
9			49			89		
10			50			90		
11			51			91		
12			52			92		
13			53			93		
14			54			94		
15			55			95		
16			56			96		
17			57			97		
18			58			98		
19			59			99		
20			60			100		
21			61			101		
22			62			102		
23			63			103		
24			64			104		
25			65			105		
26			66			106		
27			67			107		
28			68			108		
29			69			109		
30			70			110		
31			71			111		
32			72			112		
33			73			113		
34			74			114		
35			75			115		
36			76			116		
37			77			117		
38			78			118		
39			79			119		
40			80			120		

NEGATIVE SIDE

Cell	Volts	Sp. Gr.	Cell	Volts	Sp. Gr.	Cell	Volts	Sp. Gr.
1			41			81		
2			42			82		
3			43			83		
4			44			84		
5			45			85		
6			46			86		
7			47			87		
8			48			88		
9			49			89		
10			50			90		
11			51			91		
12			52			92		
13			53			93		
14			54			94		
15			55			95		
16			56			96		
17			57			97		
18			58			98		
19			59			99		
20			60			100		
21			61			101		
22			62			102		
23			63			103		
24			64			104		
25			65			105		
26			66			106		
27			67			107		
28			68			108		
29			69			109		
30			70			110		
31			71			111		
32			72			112		
33			73			113		
34			74			114		
35			75			115		
36			76			116		
37			77			117		
38			78			118		
39			79			119		
40			80			120		

REMARKS

Specific Gravity Readings by.. A. M. P. M. .... (Date)

Voltage Readings by.. A. M. P. M. .... "

Ampere Watt Hour Meter Reading.................................... Charge.................................... Discharge. Constant of Meter....................

Water added to replace Evaporation.. (Date)..

Cells late in gassing on overcharge, Positive side..

....

Cells late in gassing on overcharge, Negative side..

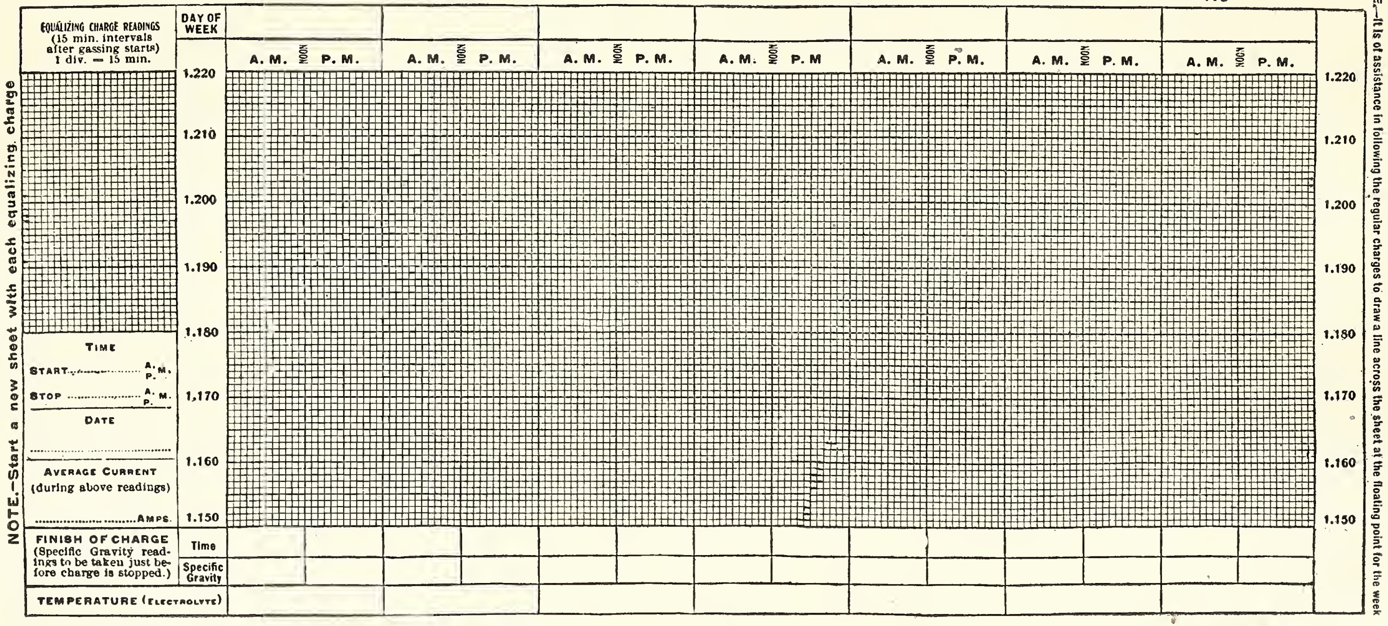
....

Form 7

PILOT CELL SPECIFIC GRAVITY READINGS

Plant of.. Located at.. Battery No..................

Week Beginning........................191...... Cell No.................. Are Readings Corrected for Temperature? Yes No



EQUALIZING CHARGE READINGS (15 min. intervals after gassing starts) 1 div. = 15 min.

DAY OF WEEK

A. M. NOON P. M.

1.220

1.210

1.200

1.190

1.180

1.170

1.160

1.150

TIME

START.................. A. M. P.

STOP.................. A. M. P.

DATE

....

AVERAGE CURRENT (during above readings)

..............................AMPS.

FINISH OF CHARGE (Specific Gravity readings to be taken just before charge is stopped.)

Time

Specific Gravity

TEMPERATURE (ELECTROLYTE)

NOTE.—Start a new sheet with each equalizing charge

NOTE.—It is of assistance in following the regular charges to draw a line across the sheet at the floating point for the week

READINGS TAKEN BY..

FORM 8

Appendix D.—COST OF OPERATION

An estimate of the cost of operation usually is made for the purpose of determining the economy of a battery installation or of comparing one type of battery with another to meet a given condition of service. In making such an estimate, the following items must be taken into consideration:

Equivalent batteries must be compared, that is, batteries having approximately the same watthour capacity at a given rate of discharge.

Interest must be paid on the investment which is the cost of the initial battery and the renewals.

Depreciation is the amount of the capital investment to be written off per year and is equal to the total investment in the battery divided by the number of years for which the cost of operation is to be estimated. At the close of the period, the battery last in service may have a small scrap value. The amount of money set aside each year for depreciation is a sinking fund to amortize the debt.

The *watt-hour efficiency* of the battery is to be used in computing the cost of power for charging.

The *life* is the period of useful service, usually expressed in years.

The quantity of *electrolyte* is that required for renewal, or to replace losses by leakage, etc.

The quantity of *water* is that required to replace the losses by gassing on charge, that is, the quantity decomposed by the ampere-hours of charge exceeding 100 per cent of the previous discharge. It is, therefore, dependent upon the ampere-hour efficiency of the battery.

The quantity of *power* required is that for charging, expressed in kilowatt-hours.

Cleaning for lead batteries includes renewal of wood separators, trays and minor parts. This is to be done once during the life of the battery.

Labor is that required for normal maintenance. It depends upon the size and kind of battery.

Example.—Assume a battery of the lead-acid type of 24 cells, as follows:

Capacity	ampere-hours	225
	kilowatt-hours	10.5
Average voltage on discharge	volts per cell	1.95
Watt-hour efficiency	per cent	75
Ampere-hour efficiency	do	90
Life	years	2.5
Initial cost	per cell, complete	$30.00
Renewal cost	do	$25.50
Jars	each	$4.00
Covers	do	$1.00
Wood separators	do	$0.04
Intercell connector	do	$0.35
Wood trays	per cell	$1.66
Period for which estimate is to be made	years	10
(This will require one initial battery and three renewals.)		
Rate of interest	per cent	6
Cost of initial battery		$720
Scrap value, 15 per cent		$108
Cost of renewal		$612
Efficiency of charging system (synchronous converter)	per cent	88
Working days per year		300
Cycles of charge and discharge	per day	1

Interest—

Initial battery	720 x 0.06 x 2.5=	$108. 00
First renewal	612 x 0.06 x 2.5=	91. 80
Second renewal	612 x 0.06 x 2.5=	91. 80
Third renewal	612 x 0.06 x 2.5=	91. 80
Total interest		$383. 40
Per year		38. 34

Depreciation—

Initial battery	$720. 00
Three renewals, at $612	1, 836. 00
Total investment	$2, 556. 00
Scrap value	108. 00
Net investment	$2, 448. 00
Per year	244. 80

Electrolyte.—None required for lead batteries except to replace loss by spillage or leakage, which is negligible if battery is properly taken care of.

Water.—Assume daily charge to be at 90 per cent efficiency—

$\frac{225}{.90}$=250 ampere-hours input.

250
225

25 ampere-hours overcharge per day.
25 x 300= 7,500 ampere-hours per year.

Weekly equalizing charge:

30 ampere-hours x 52=1,560 ampere-hours per year.
7,500

Total, 9,060 ampere-hours per year.

1 ampere-hour decomposes 0.01185 ounce of water.
9,060 x 0.01185=107.4 ounces per cell per year.
107.4 x 24=2,578 ounces per battery per year.
=19.3 gallons at $0.10=$1.93.

Power.—1 cycle of charge and discharge per day:

$\frac{10.5}{.75}$=14 kilowatt-hours input per battery per day.

$\frac{14.00}{.88}$=15.92 kilowatt-hours input per battery per day, with allowance for losses in charging outfit.

15.92 x 300=4,776 kilowatt-hours per battery per year.
At $0.02 per kilowatt-hour=$95.52, cost per battery per year.

Cleaning.—

336 wood separators, at $0.04	$13. 44
5 intercell connectors, at $0.35	1. 75
1 jar, at $4	4. 00
3 covers, at $1	3. 00
2 trays, at $1.66 per cell	40. 00
Cost of materials	$62. 19

As cleaning is done once during the life of the battery—that is, after it has been in service for 15 months—the cost per year=

$$\frac{62.19}{1.25}=\$49.75.$$

The labor required is included in the next item.

LABOR.—

1 battery man, at $200 per month	per year	$2,400
2 assistants, at $25 per week	do	2,600
Total	do	5,000

As the above is sufficient for 10 batteries, the proportionate cost for one is $500.

SUMMARY.—

Interest	$38.34
Depreciation	244.80
Water	1.93
Power for charging	95.52
Cleaning	49.75
Labor	500.00
Cost per battery per year	930.34

It is to be noted that the unit costs used in this estimate are approximate and are to be taken as illustrative only of the method of procedure.

Appendix E.—GLOSSARY

ACCUMULATOR.—A common term for a storage battery; more used in Europe than in this country.

ACID.—A colloquial name for the electrolyte in lead-acid batteries. Always a water solution of sulphuric acid.

ACTIVE MATERIALS.—For lead-acid batteries these are lead peroxide on the positive plate, sponge lead on the negative plate; for nickel-iron batteries these are nickel peroxide in the positive tubes, iron in the negative pockets.

ACID-RESISTING PAINT.—An asphaltum paint used on trays and racks.

ACID SPACES.—Net contents of jar available for electrolyte.

ALKALI.—A colloquial name for the electrolyte in the nickel-iron or Edison cell. It is principally potassium or sodium hydroxide.

ALLOY.—A combination of lead and antimony used in making the grids of lead-acid batteries.

ALLOY BURNING STRIP.—An alloy of lead and antimony used in burning on the connectors of lead-acid batteries.

AMMETER.—An instrument for measuring electric current.

AMPERE.—The unit of electric current.

AMPERE-HOURS.—The product of the current in amperes by the time in hours. The ampere-hour is frequently used as the unit of capacity for storage batteries.

AMPERE-HOUR CAPACITY.—The number of ampere-hours which can be delivered by a battery under normal conditions of temperature and at any rate of discharge.

AMPERE-HOUR EFFICIENCY.—The ratio of the ampere-hours of output to the ampere-hours of input.

ANTIMONY.—A metal alloyed with lead to improve its mechanical properties for making grids.

APRON.—A reinforcing web at back of connecting strap for lead plates. This also serves to hold the separators in place.

ARC BURNER.—A pointed carbon rod used for lead burning.

ASPHALTUM PAINT.—A protective paint for resisting acid; used on trays and racks.

AUTOMATIC FILLER.—A device for filling small Edison cells with water to the proper height.

AVERAGE VOLTAGE.—The average value of the voltage during the period of charge or discharge; may be obtained by integrating the voltage curve with a planimeter.

BAFFLE PLATE (Cover).—A perforated disk used in some forms of filler caps to prevent excessive loss of electrolyte through the vent.

BATTERY.—A group of cells electrically connected.

Line battery is a battery connected directly across a line with varying voltage so that it charges or discharges according to whether the line voltage is above or below the open circuit voltage of the battery. This is also called a *floating battery*. This battery is usually located at a point remote from the power house.

Load regulating battery is usually located near the generator and is for the purpose of taking up the monentary fluctuations of current.

Peak-load battery is connected to the line near the generator and is provided with end cells (q. v.). The object of this battery is to help carry the load during periods of high power consumption at constant voltage. It is charged during periods of low-power consumption.

Oil switch and exciter reserve battery.—This is a battery of relatively small ampere-hour capacity used in large plants to operate the oil switches and to provide current temporarily for excitation in emergencies.

Stand-by battery is a battery to insure continuity of service. Such a battery is commonly used in large cities and railroad terminals. A battery of this type may be floated on the line.

Telephone storage batteries are used for energy in telephone exchanges. These batteries are floated on the line and their capacity is usually sufficient to carry the entire load for at least 24 hours.

All of the above batteries are of the lead-acid type and are called stationary batteries. Other stationary batteries which sometimes are of the nickel-iron type include farm lighting and railway signalling. Portable batteries, with the exception of those for *starting and lighting* on automobiles are of either the lead-acid or nickel-iron type. They include principally *vehicle batteries, car lighting batteries, locomotive batteries, mine-lamp batteries* and *ignition batteries.*

BOLTED CONNECTOR.—A form of connection in which the terminal post may be threaded and the connectors attached by bolts or nuts or flat with hole to take a bolt and nut.

BOOSTING CHARGE.—A charge at a high rate for a short period. Such a charge is seldom complete.

BOSSES (STEEL).—Studs on the sides of Edison cells to hold them in position in the trays.

BOX NEGATIVE.—A form of plate for stationary battery described in Section II, 1.

BRIDGES.—Vertical supports for the plates in the bottom of the jar. The space between the bridges allows for the collection of sediment. These are also called ribs, rests or plate supports.

BUCKLED PLATE.—A distorted plate.

BURNING.—A colloquial expression for the welding of lead terminals, connections, and seams in lead-lined tanks.

BURNING BARS.—See Alloy burning strip. A term used for the iron plate placed under the strap to align the plates and prevent run downs in burning.

BUSHINGS.—Fiber collars of distinctive colors around the terminal posts of Edison cells. These are used for insulation and to indicate polarity.

CADMIUM.—A piece of metallic cadmium used as an intermediate electrode for determining the potentials of the positive and negative plates separately.

CAN.—A common name for the steel container of the Edison cell.

CAPACITY.—The rating of a battery usually expressed in ampere-hours, at a given rate of discharge. It may also be expressed in watt-hours. The temperature should be specified.

CASE.—See tray.

CAUSTIC POTASH.—Potassium hydroxide used in electrolyte in Edison cells.

CAUSTIC SODA.—Sodium hydroxide commonly used in electrolyte in Edison cells as a substitute for potassium hydroxide.

CELL.—The complete unit of a battery. It consists of the positive and negative plates with separators, terminals, electrolyte, and container.

CENTIGRADE TEMPERATURE.—See Temperature.

CHARGE.—The restoration of the active materials of a battery by passing a direct current through it in the opposite direction to that of the discharge.

CHARGING RATE.—The proper value of current, expressed in amperes, to use in charging a battery. The value of the current first used in the constant current method of charging is usually called the normal charging rate, the lower value, the finishing rate. The normal charging rate is sometimes referred to as the initial charging rate, but the initial charge is, strictly speaking, the forming charge.

CHEMICALLY PURE.—A term applied to the material for the electrolyte indicating the absence of injurious impurities. It does not mean 100 per cent strength, as chemically pure acid and distilled water is a chemically pure solution, although dilute.

CLEANING.—Removal of the sediment in the bottom of jars of lead batteries. When cleaning is done, minor repairs such as straightening plates, renewing separators, etc., are usually made. This is often referred to erroneously as "rebuilding." For the Edison battery this word refers to the removal of the deposit on the top of the jars by means of a jet of steam or compressed air.

CLOSED CIRCUIT VOLTAGE.—The voltage at the terminals of the battery when current is flowing.

COMPOUND.—The material used for sealing the covers to the jars of portable type batteries. This is usually a bituminous pitch.

CONCENTRATION.—Strength of the electrolyte.

CONDENSATION.—A word incorrectly used to mean the collecting of the spray.

CONDITIONING CHARGE.—The charge given a battery before putting it in service. This is sometimes called a freshening charge.

CONNECTING ROD.—A bolt supporting a group of positive or negative plates of the Edison cell and connecting them electrically. It passes through the eyes at the top of the plates.

CONNECTOR PULLER.—A device for removing a burned-on connector of a lead cell. For an Edison cell a similar device is called a jack.

CONNECTORS.—The connections to the terminals of the cells. These may be intercell connectors, intertray connectors, or connectors to the external circuit.

CONSTANT CURRENT CHARGE.—A charge in which the current is maintained constant at its proper value. For lead batteries this usually involves two rates, called the initial and finishing rates.

CONSTANT POTENTIAL CHARGE.—A charge in which the voltage is held at a constant value at the terminals of the battery. To limit the initial current, a fixed resistance may be inserted in each charging circuit. Such a system is called a "modified constant potential system."

CONVERTER.—A common name for a synchronous converter (sometimes called a rotary coverter).

CORRUGATIONS.—Ridges as on a wood separator or on the sides of the steel container for an Edison cell.

COUNTER CELLS.—These cells consist of grids or unformed plates, and therefore have practically no capacity. In order to carry the current they must have the same number of plates of the same size as the rest of the battery. They are used to reduce the voltage of the constant potential charging circuit when it is excessive, since this cannot be satisfactorily done by resistance. They may be used to reduce the voltage of a constant current charging circuit to avoid waste of energy in a rheostat. They may be used to provide voltage regulation in a discharge circuit in place of end cells. In computing the number of counter cells required each of these cells is to be considered as opposing the main voltage by approximately 2.8 volts per cell. Reversal of counter cells should be avoided to prevent an increase in their capacity.

COUPLE.—A positive and negative lead plate for adjacent cells, connected together as a unit.

COVER.—The top of the jar, usually made of the same material as the jar itself. Covers are referred to as flat, molded, or top and bottom, according to the kind. Molded covers may be of the single or double flange type.

CRITICAL TEMPERATURE.—A temperature below which an alkaline battery becomes inoperative. This does not refer to the freezing point of the electrolyte.

CROSSBARS.—See Straps.

CROWN.—Flange at top of lead lining for a wooden tank.

CYCLE.—One charge followed by a discharge.

DENSITY OF ELECTROLYTE.—The mass per unit volume. For practical purposes this is about the same as specific gravity the definition of which should be consulted.

DEVELOPING CHARGE.—Same as conditioning charge.

DISCHARGE.—Conversion of the chemical energy of the battery into electrical energy.

DISMANTLE.—Taking apart a cell or battery.

DISTILLED WATER.—Condensed water vapor. Water which has been properly distilled is free from the impurities in natural water.

DOUBLE FLANGE COVER.—See Cover.

DOWEL.—A reinforcing of wood separators used in stationary batteries.

DRY BATTERIES (Secondary).—Storage batteries in which the electrolyte has been rendered immobile by an absorbent or as a jelly.

DRY STORAGE.—Storage of batteries without the electrolyte.

DUMMIES.—Flat sheets of lead used in a cell when the positives or negatives are treated separately.

EDISON CELL.—A storage cell of the nickel-iron or alkaline type.

EFFICIENCY.—The ratio of useful output to total input. This may be expressed as the ampere-hour, the watt-hour, or the voltage efficiency.

ELECTRIC FILLER.—An automatic filling device for use with batteries.

ELECTROLYTE.—A water solution of sulphuric acid for lead batteries or of certain hydroxides for the nickel-iron batteries.

ELECTROMOTIVE FORCE.—The total voltage of the cell or battery. This is an open circuit measurement.

ELEMENT.—The positive and negative groups with separators, assembled.

END CELL.—A cell at the terminal of a stationary battery which may be cut in or out of the circuit for adjusting the voltage.

END OF DISCHARGE.—The point of the discharge at which the voltage of the cell has fallen to a predetermined value. The end voltage is usually chosen so that the full useful capacity of the cell is realized.

ENERGY.—The ability to do work. The chemical energy of the battery is transformed into electrical energy during discharge which in turn may be transformed into mechanical energy by a motor.

EQUALIZATION (Diffusion).—Circulation and diffusion of the electrolyte within the cell. This has an important bearing on the relative capacity at different rates of discharge. A discharged battery is sometimes said to "pick up" due to the equalization of the electrolyte.

EQUALIZING CHARGE.—A charge given a lead battery periodically to insure the complete reduction of the lead sulphate. The rate of charge is normally one-half of the finishing rate.

ESBALITE.—A protective coating used on Edison cells.

EVAPORATION.—A word used to cover not only evaporation in its true sense, but also loss of water due to gassing.

EXPANDER.—Inert material mixed with the active material of the negative plates to prevent shrinkage.

EXPLOSIVE GASES.—The combination of oxygen and hydrogen given off by storage cells, particularly when they are on charge.

FAHRENHEIT TEMPERATURE.—See Temperature.

FAURE PLATE.—A pasted plate.

FERRULES.—Seamless steel rings around the tubes of an Edison positive plate.

FILLER CAP.—See Filling plug; this term is particularly applied to the Edison cells.

FILLING APERTURE.—The hole in the top of the cell through which the electrolyte or water is introduced. Sometimes called a filling vent.

FILLING PLUG.—A device containing a gas vent, for closing the filling aperture of a cell. This is frequently referred to as a filling vent or a filling cap. For lead cells they are commonly of the threaded or bayonet types; for the Edison cell they are frequently hinged.

FILLING TUBE BARREL.—A part of the vent on a certain make of lead storage cell.

FINISHING RATE.—The rate of charge, expressed in amperes, to which the charging current for lead batteries is reduced near the end to prevent excessive gassing.

FIRST FILLING ELECTROLYTE.—The electrolyte used in the cells when they are first put in service. For lead batteries the specific gravity should be in accordance with the instructions of the manufacturer. The composition of electrolyte used for first filling Edison cells differs somewhat from that used for refilling them.

FLOODING.—Overflowing of the electrolyte. This is generally the result of an excessive quantity of electrolyte.

FLUSHING THE CELLS.—Adding water as necessary to replace evaporation.

FORMATION.—Oxidation and reduction of the raw materials for the positive and negative plates, respectively. Without this process the plates would lack capacity.

FORMING AGENT.—An acid or salt used for hastening the process of formation of lead storage plates of the Planté type.

FRESHENING CHARGE.—See Conditioning charge. The periodic charge of batteries in wet storage is also called a freshening charge.

FROTHING.—Bubbling of electrolyte out of the vent cap due to excessive gassing or to impurities in the solution.

GAS BURNER.—A blowpipe used for lead burning.

GASKETS.—Soft rubber rings used to prevent leakage of the electrolyte around the terminal posts of some lead cells.

GASSING.—The evolution of oxygen and hydrogen when the batteries are on charge. Small amounts of gas are also given off by Edison cells when standing idle and both lead and Edison cells give off gas when reversed, the quantity being greater from the latter.

GAS VALVE.—A vent for permitting the escape of gases from a storage cell.

GLAND CAP.—An insulating bushing around the terminals of an Edison cell. The color of the gland cap serves to indicate the polarity.

GLAND RING.—Packing around the terminals of an Edison cell.

GREASE.—Vaseline or other similar material used on the terminals of lead cells to prevent corrosion.

GRID.—A casting of lead-antimony alloy for supporting the active material of a lead battery. A nickel-plated steel frame for holding the tubes and pockets of the Edison battery.

GROUP.—Assembly of a set of positive or a set of negative plates.

GROWTH OF PLATES.—The increase in size of the lead plates with use. This is most often observed in positives of the Planté type. Excessive oxidation of the iron electrode of the Edison battery causes an expansion of the pockets.

HEATING OF NEGATIVE PLATES.—Rise in temperature due to oxidation of the active material of the negative plates when exposed to the air. This is most noticeable when the plate is fully charged.

HIGH FORM.—Edison cells with extra space above the top of the plates for electrolyte.

HOLD-DOWNS, Battery.—Clamps for holding batteries in position in tractors, trucks, or other vehicles.

HOLD-DOWNS, Separator.—Strips of insulating material for preventing separators from rising to the top of the electrolyte. For stationary batteries these are usually of glass, but for transportable batteries they are hard rubber or wood.

HYDROMETER.—An instrument used for measuring specific gravity. For transportable batteries this is ordinarily contained within the glass barrel of a syringe which is called a "hydrometer syringe."

INDUCTION MOTOR.—An alternating-current motor, either single phase or polyphase.

INITIAL CHARGE.—See Charging rate.

INPUT.—The quantity of electricity, expressed as ampere-hours, or the energy, expressed as watt-hours, received by a cell or battery during the period of charge.

INSULATION.—Separation of the metallic parts of opposite polarity by nonconductors such as glass, porcelain, hard rubber, or oil from each other and from surrounding objects.

INTERNAL RESISTANCE.—The total resistance within the cell.

"IRONCLAD" CELL.—A particular type of cell made by the Electric Storage Battery Co. The active material of the positive plate is contained within slotted tubes of hard rubber. These contain no iron, as the name would imply.

IRON OXIDE.—The active material of the negative plate of the Edison battery.

JACK.—A connector puller for an Edison cell.

JAR.—The container for a cell. This applies particularly to the lead-acid type cells, as the container for an Edison cell is usually referred to as a "can."

JOULE.—The unit of work (see Sec. VII); also the word "work."

JUMPER.—A short piece of wire or cable used for temporary connections, as to bridge a resistance. If used across a cell in a battery, one terminal of the cell must always be disconnected.

KILOWATT-HOURS.—The product of power expressed in kilowatts by the time in hours.

LEAD BURNING.—A common name for the process of lead welding.

LEAD-BURNING STRIP.—Lead in convenient form for burning on connectors of lead-acid batteries.

LEAD SULPHATE.—A crystalline substance formed on both positive and negative plates during the process of discharge of a lead battery. $PbSO_4$.

LIFE.—The period of useful service of a battery. This is usually expressed as the number of cycles of charge and discharge of the battery.

LIFTING IRONS.—Iron straps made an integral part of the tray and provided with holes to which a hoist may be attached.

LINK.—A term sometimes used for intercell connector.

LITHARGE.—Yellow oxide of lead, PbO. This is one of the common raw materials for making the paste of the pasted plate lead batteries.

LITHIUM HYDROXIDE.—One of the components of the electrolyte for the Edison battery.

LOCAL ACTION.—Parasitic currents within the cell itself due to differences of potential between different parts. In a well designed and constructed battery the local action should be small.

LOG.—A record of performance showing periodic readings of the cells in a battery.

LUG.—Projection from grid for connection to the strap.

LUG CUTTER.—Heavy pliers for use in trimming-posts or cutting intercell connectors.

MANCHESTER POSITIVE.—A plate of the Planté type in which the active material is formed on a spiral of corrugated lead ribbon which is forced into holes in the plate. The coils are sometimes called "buttons."

MERCURY-ARC RECTIFIER.—A device for transforming alternating into direct current through the medium of a mercury arc.

MIDDLE WIRE.—The neutral wire of a three-wire system.

MIXING ACID.—Preparing a solution of sulphuric acid in water for use in storage batteries. The acid should always be poured into the water slowly, stirring continuously. It is dangerous to pour water into the acid.

MODIFIED CONSTANT POTENTIAL CHARGE.—See Constant potential charge.

MOTOR-GENERATOR SET.—A transforming device consisting of a motor coupled to one or more generators.

MUD.—A colloquial name for the sediment deposited in the bottom of a storage cell. The space between the bridges in the bottom of the cell is called the sediment or "mud space."

MULTIPLE CONNECTION.—The connection of like poles of two or more cells (see Fig. 1-b). This is also called "parallel connection."

NAME PLATE.—A metal plate attached to the tray giving the operating data for the battery. It should state the name, the type, the capacity, the charging rate and the proper specific gravity of the electrolyte when charged.

NATURAL WATER.—Local water supply may be used sometimes, if free from injurious substances, but distilled water is to be preferred. Rain water, if used, must be taken from clean roofs only and should not be stored in metal containers. Well water or cistern water is to be avoided. Condenser water from steam plants is often contaminated with cylinder oils or boiler compounds and should not be used without analysis.

NEGATIVE PLATES.—The grid and active material after formation to which the current flows from the external circuit when the battery is discharging.

NEGATIVE POCKET.—A perforated rectangular compartment used to contain the iron oxide of the negative plate of a nickel-iron battery.

NICKEL FLAKE.—Finely divided nickel put in the tubes of the positive plate of the nickel-iron battery in alternate layers with the nickel hydrate to increase the conductivity.

NICKEL HYDRATE.—Nickelous hydroxide $Ni(OH)_2+H_2O$. A light green powder used as the raw active material for a positive plate of the nickel-iron cell.

NICKEL-IRON BATTERY.—A storage battery of the alkaline type, such as are made by the Edison Storage Battery Co.

NORMAL CHARGING RATE.—See Charging rate.

NORMAL DISCHARGE RATE.—The current which the battery will deliver in a specified time. For a stationary battery this is generally the current which the battery will deliver continuously for 8 hours. For transportable batteries this period is more often taken as about 5 hours.

OIL OF VITRIOL.—A common name for sulphuric acid. This is ordinarily not sufficiently pure for use in a storage battery.

OPEN CIRCUIT VOLTAGE.—The total electromotive force of a cell or battery. This may be measured with a potentiometer or high resistance voltmeter. It does not indicate the state of charge of the battery.

OUTPUT.—The quantity of electricity, expressed as ampere-hours, or the energy, expressed as watt-hours-delivered by a cell or battery during the period of discharge.

OVERCHARGE.—A prolonged charge. Lead batteries deteriorate if excessively overcharged, but overcharges are occasionally given to reduce all the sulphate (see equalizing charge). Overcharges are occasionally desirable for Edison batteries also.

OVERDISCHARGE.—Discharge carried beyond the proper end voltage. This is generally harmful to the battery if done repeatedly.

PARALLEL CONNECTION.—See Multiple connection.

PASTED PLATE.—A plate of the Faure type. The active material is applied in the form of a paste to the grid which is a lead-antimony casting.

PERFORATED SEPARATORS.—See Separator.

PERMANIZING.—A process of introducing certain inert substances into the pores of the plates after formation to prevent shrinkage. This is a substitute process for the use of expanders.

PEROXIDE.—An abbreviation of lead peroxide, the active material of the positive plate of a lead cell.

PILLAR STRAP.—See Strap.

PILOT CELL.—A selected cell upon which temperature, voltage, and gravity readings are made and assumed to indicate the condition of the other cells of the battery.

PIN INSULATOR.—A long thin strip of hard rubber used between the plates of an Edison cell.

PLANTÉ PLATE.—A lead plate on which the active material is formed electrochemically.

PLATE.—See Pasted and Planté plates for lead batteries. Plates in the Edison battery consist of steel grids with the active material in tubes or pockets.

PLATE CAPACITY.—The capacity of the individual groups of positive and negative plates. This may be measured by an auxiliary electrode. The rating of a battery is usually expressed on the basis of the rate of discharge per positive plate. The capacity of the negative group in a normal battery is always in excess of that of the positive group.

PLATE FEET.—Small lugs at the bottom of the plates of some lead batteries. These rest on the bridges and support the plates.

PLATE LUG.—See Lug.

PLATE STRAP (L type).—See Strap.

PLATE SUPPORT.—See Bridges.

POCKETS.—Containers for active material of the negative plate of an Edison cell.

POINT (of electrolyte density).—A colloquial expression for one unit in the third decimal place of a reading of specific gravity. (See "specific gravity.")

POLARITY.—An electrical condition denoting the direction of flow of current. The terminology as to positive and negative of the storage battery is confusing, but the discharge current is said by common usage to flow from the peroxide plate through the external circuit to the lead plate. The lead peroxide plate is universally called the positive, but from an electrochemical standpoint it is negative.

POLE.—The terminal of a cell. The current flows out of the positive pole and into the negative pole when the cell is discharging.

POSITIVE PLATES.—The grid and active material after formation from which the current flows through the external circuit when the battery is discharging.

POST.—The terminal of a connecting strap.

POST STRAP.—See Strap.

POST WASHERS.—Soft rubber gaskets to prevent leakage of electrolyte around the posts.

POTASSIUM HYDROXIDE.—One of the principal constituents of the electrolyte for the Edison cell.

POTENTIAL DIFFERENCE.—The difference in electrical pressure between two points of a circuit. It is expressed in volts.

POWER.—The rate of expenditure of energy. The unit of electrical power is the watt. For a direct current circuit the power in watts is equal to the product of the volts and amperes.

PRODS.—See Stabbers.

PULLER.—See Connector puller and Jack.

RACKS.—Supports for cells of a stationary battery or for transportable batteries on charge or in storage.

RAIN WATER.—Substitute for distilled water in filling storage batteries. It should be used with caution since it is often contaminated by metallic or organic impurities.

RATED CAPACITY.—See Capacity.

REACTION.—Chemical process by which electric current is produced.

RECTIFIERS.—Devices for transforming alternating into direct current through the medium of an arc or the electrochemical properties of the substances used.

RED LEAD.—Red oxide of lead Pb_3O_4. This is one of the common raw materials for making the paste of the pasted plate lead batteries.

REDUCING FLAME.—The inside bright tip of the flame as used for lead burning.

REDUCING VALVE.—A valve for changing the pressure of gas from that of a high-pressure cylinder to that required for a blowpipe. This is a necessary part of the equipment for lead burning by the gas method.

RENEWAL SOLUTION.—Electrolyte used to replace electrolyte lost or discarded. For lead-acid batteries, this should be of the same composition as the original. Renewal solutions for the Edison battery differ slightly in composition from original electrolyte.

REPLACEMENT.—Renewal of various parts.

RESISTANCE.—The resistance of any direct current circuit is equal to the quotient of the electromotive force by the current flowing. The unit of resistance is the ohm.

RESTS.—See Bridges.

RETAINERS.—See Hold-downs (separator).

RETAINING CAN.—The container of an Edison cell.

REVERSAL.—Change in polarity of a storage cell due to excessive discharge.

REVERSIBILITY.—The property of the chemical reactions by which the original state may be restored by the passage of current in the opposite direction to that of the discharge.

RHEOSTAT.—A regulating resistance used for controlling the current.

RIBS (plate).—Crossbars on the grids. Furrowed surface on the Planté plates which are plowed or spun.

RINGS (steel).—Reinforcing bands on the tubes of an Edison positive plate.

RUBBER BUTTON.—Insulating support in tray slat for holding Edison cell in position. The boss on the side of the can fits into the button.

SAND TRAY.—A common support for a glass cell of a stationary battery. The trays are of either glass or wood and are filled with dry sand.

SEALING COMPOUND.—See Compound.

SEALING NUT.—A threaded ring around the terminal posts of some lead cells to prevent leakage of electrolyte. This is usually used in connection with a soft rubber gasket under the cover.

SEALING WELLS.—Space between the cover (some molded types) and the side of the jar to hold the sealing compound.

SECONDARY BATTERY.—A storage battery.

SEDIMENT.—Particles of the active material deposited in the bottom of a storage cell.

SEDIMENT SCOOP.—A device for collecting the sediment in the bottom of a stationary battery.

SEDIMENT SPACE.—The space in the bottom of the jar below the plates for the collection of sediment during the life of the battery.

SEPARATOR.—A device for preventing the plates of opposite polarity from coming in contact within the cell. Separators for portable batteries of the lead-acid type may be of wood suitably treated, smooth or corrugated; of thin sheets of hard rubber, slotted or perforated, sometimes with soft rubber ribs; or of threaded rubber in which cotton threads run transversely to the surface of the separator. When the perforated hard-rubber separators are used they are generally in combination with wood separators. Separators for stationary batteries of the lead-acid types may be glass or wood rods or wood plates reinforced with dowels or are sometimes corrugated. Separators for Edison cells consist of hard-rubber rods and strip and plain sheets. These are referred to as pin insulators and side insulators, respectively.

SEPARATOR.—Part of an Edison gas vent which permits the escape of the gas but retains the spray.

SEPARATOR INSERTER.—A special tool for the insertion or removal of the wood separators of a lead-acid battery. (See Fig. 42.)

SEPARATOR RETAINER.—A separator hold-down.

SERIES CONNECTION.—The connection of the positive of one cell to the negative of the adjoining cell throughout the battery. (See Fig. 1, *a*.)

SHEDDING.—Loss of active material from the plates of a lead battery. The shedding of active material is a gradual process, the particles falling to the bottom of the cell. See Sediment.

SHORT CIRCUIT.—The contact of plates of opposite polarity within the cell. This may be due to the breaking down of the separator, the accumulation of sediment in the bottom of the cell or the bridging of a separator by foreign material falling through the vent.

SIDE INSULATOR.—A sheet of hard rubber lining the inside of the Edison cell.

SIDE ROD INSULATOR.—A flat hard-rubber strip between the pockets of the outside negative plates and the sides of a can of an Edison cell.

SINGLE FLANGE COVER.—See Cover.

SKIDS.—Porcelain insulators placed on the under side of locomotive trays to facilitate moving them and to provide insulation.

SLOTTED SEPARATORS.—See Separator.

SLOTTED TUBE.—A hard-rubber tube holding the active material of the Ironclad Exide battery.

SLUGGISH BATTERY.—A battery deficient in capacity, due to periods of idleness.

SODIUM HYDROXIDE.—A common ingredient of the electrolyte for Edison cells.

SPACERS.—Blocks of wood used between the plates of a group of a lead cell when the group is shipped or when the plates are being straightened. See also Space washer and Spacing guide.

SPACE WASHER.—A steel ring on the connector rod to separate the plates of a group of an Edison cell.

SPACING GUIDE.—A form used in the assembly of plates of a group of a lead-acid cell before they are burned to the connecting strap.

SPECIFIC GRAVITY.—The ratio of the weight of a given volume of a liquid to the weight of the same volume of water at a definite temperature. It is usually measured in storage-battery work by a hydrometer. When the specific gravity is 1.280 it is usually spoken of as twelve-eighty acid. One unit in the last decimal place is called a point; that is, 1.280 and 1.288 differ by eight points. The change in specific gravity due to different temperatures is about one point for each 3° F difference in temperature from 77° F. The Baumé scale for storage-battery work is obsolete.

SPLASH COVER.—A perforated sheet of rubber placed over the top of the plates in some forms of lead batteries.

SPONGE LEAD.—The active material of the negative plate of a lead battery.

SPRAY.—Fine particles of electrolyte thrown out of the cell by the gas bubbles when charging. The spray of a lead-acid battery produces a choking sensation, but the gas itself has no odor. Spray from an Edison battery makes a white crust on the top of the cells.

SPUN PLATE.—A sheet of lead, the surface of which has been increased by the spinning of rapidly rotating disks preparatory to its formation as a Planté plate.

STABBERS.—Sharp points on ends of voltmeter leads for making connection to the terminals of the cells; also called "prods."

STARVATION.—The result of consistent undercharging.

STATIONARY BATTERY.—A battery for use in a fixed location. These are usually lead batteries in glass jars or lead-lined tanks. They are variously referred to as line batteries, load-regulating batteries, oil switch and exciter reserve batteries, stand-by batteries, etc., according to the usage. In small stationary batteries, such as farm-lighting batteries, pasted plate lead batteries, and alkaline batteries are commonly used.

STEEL TUBES.—Containers for the active material of the positive plates of an Edison cell.

STRAP.—A lead or lead-antimony casting for connecting the plates of a group. The individual plates are burned to the strap. The terminal post is usually cast with strap. (See Fig. 12.) Straps having a central round terminal are called pillar-post straps. Straps with terminals in the form of an inverted L are called plate straps. Straps are sometimes called "cross bars."

STRINGER.—Horizontal rail of a rack for stationary batteries or for storage.

STUFFING BOX.—A device to prevent leakage of electrolyte around the terminal posts of an Edison cell. This consists of a gasket, a gland ring, and a hard-rubber gland cap screwing into a steel ring welded to the cover.

SULPHATE.—A colloquial name for lead sulphate formed during the discharge of a lead cell.

SULPHATE VOLTAGE READING.—A high voltage reading sometimes observed when badly sulphated plates are on charge.

SULPHATION.—A colloquial name for the formation of hardened sulphate of a lead cell resulting from improper treatment.

SULPHURIC ACID.—The principal ingredient of the electrolyte for a lead storage battery. The commercial grade is not sufficiently good for this use.

SUSPENSION BOSS.—See Boss.

SWEDGED CONNECTOR.—An intercell connector for an Edison battery. The copper rod is swedged into the steel terminal lug. Another spelling of swedged is "swaged."

SYNCHRONOUS CONVERTER.—A machine which converts from alternating to direct current or vice versa. It has a single armature winding with commutator and slip rings.

TANK.—A lead-lined wooden container for a stationary cell.

TAPER CHARGE.—A constant potential charge.

TEMPERATURE.—Temperature is usually expressed in terms of one of three scales: Centigrade, Fahrenheit, or Réaumur. Temperatures expressed in one scale may be easily converted to the others by the following relations in which C°, F°, and R° represent temperatures in these scales, respectively:

$$F^\circ = 9/5\ C^\circ + 32.$$
$$C^\circ = 5/9\ (F^\circ - 32).$$
$$F^\circ = 9/4\ R^\circ + 32.$$
$$R^\circ = 4/9\ (F^\circ - 32).$$
$$C^\circ = 1.25\ R^\circ.$$
$$R^\circ = 0.8\ C^\circ.$$

TEMPERATURE LIMITS.—Lead-acid batteries and nickel-iron batteries should not be subjected to temperatures in excess of 110° F.

The freezing point of a lead-acid cell depends on the specific gravity of the electrolyte. The following are the approximate freezing points: Sp. gr. 1.280 − 94° F; sp. gr. 1.240 − 50° F; sp. gr. 1.200 − 17° F; sp. gr. 1.160 + 1° F; sp. gr. 1.120 + 14° F.

The freezing point of an Edison cell is—40° F. Below 0° F a snowlike condition is apparent.

TERMINALS.—Fittings to provide electrical connection to storage cells or batteries. These vary with the size and kind of the battery as well as with the manufacturer. Taper terminals are made in rights and lefts with different tapers for the positive and negative. Other common forms are the cable and bolt terminals. Tray terminals are commonly of the wing nut or box types. In addition to those mentioned there are many other kinds.

THERMOMETER.—An instrument for measuring the temperature.

THUMB SCREW.—A lead-plated screw with knurled head for fastening a taper terminal on a lead acid battery.

TIE BOLTS.—Reinforcing bolts through the tray of a lead battery.

TOP NUT.—Nut on terminal post of Edison cell to hold the connector in place.

TRACTOR BATTERY.—A battery of the vehicle type for the operation of an industrial tractor. (See Appendix A.)

TRAY.—A container for a group of storage cells. Also called a case.

TRICKLE CHARGE.—A charge at very low rate used when lead batteries are in wet storage. It is approximately 1 per cent of the finishing rate.

TRUCK BATTERY.—A battery of the vehicle type for the operation of an industrial truck. It is generally made up of 12 lead cells or 21 Edison cells of about 225 ampere-hour capacity. When tractors and trucks are used together, it is a matter of convenience that the tractor battery should contain twice the number of cells in the truck battery and that both are identical as to arrangements of trays. (See Appendix A.)

TUBES.—Containers for the active material of the positive plates of an Edison cell. These are of steel.

Containers of active material for positive plates of the Ironclad-Exide battery. These are of hard rubber.

TUDOR POSITIVE.—A particular form of Planté plate.

VALVES.—Part of the gas vent on an Edison cell. It permits the escape of gas from within, but prevents the escape of spray or the ingress of foreign material.

A ring in the filling aperture of the Exide cell. Its purpose is to prevent overfilling the cell.

VEHICLE BATTERIES.—Storage cells for the propulsion of vehicles, trucks, and tractors. In the larger sizes they are spoken of as tractor or locomotive batteries according to the use.

VENT PLUGS.—Plugs to close the filling apertures or vents in the top of the cells. The plugs must be provided with a suitable means of permitting the escape of gas from within the cell, but hold back the spray or splashing electrolyte and protect the cell from foreign material from outside.

VOLTAGE.—Electrical pressure. The unit is the volt. The total voltage of a cell is called its electromotive force, but the voltage at the terminals when a current is flowing is the potential difference. Similarly the fall in voltage across any part of the circuit is the potential difference.

VOLTAGE EFFICIENCY.—The ratio of the average voltage of the cell or battery on discharge to the average voltage on charge. The average voltage is the average determined for the entire period of charge or discharge.

VOLTMETER.—An instrument for measuring voltage.

WASHING.—A colloquial word used occasionally in place of cleaning.

WATT.—The unit of electrical power. The watts expended are equal to the product of the electrical pressure in volts by the flow of current expressed in amperes. In terms of electrical energy the watt is equal to the expenditure of one joule per second. The joule is the unit of electrical energy.

WATT-HOUR CAPACITY.—The capacity of a cell expressed in terms of watt-hours. The watt-hour capacity is equal to the ampere-hour capacity multiplied by the average voltage during discharge.

WATT-HOUR EFFICIENCY.—The ratio of the watt-hours of output to the watt-hours of input of a battery.

WATT-HOUR METER.—An instrument for measuring watt-hours.

WEB.—The central sheet of lead of a Planté plate.

WET STORAGE.—Storage of cells containing electrolyte.

WORK.—Work in the mechanical sense is the product of the force by the distance through which it acts. The mechanical unit of work is the erg. The work done in a direct-current circuit by an electric current in a given time is equal to the product of the current in amperes by the voltage in volts by the time in seconds. It is expressed in a unit called the joule. The work done expressed in joules divided by the time in seconds is the rate of doing work or the power expended. The unit of power is the watt (q. v.).

Electrical energy (or work) is ordinarily measured in watt-hours or kilowatt-hours.

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