NBS CIRCULAR 503

Statutory Net-Content Marking Requirements for Packages (Undefined) and Packages of Foods, Drugs, and Cosmetics

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UNITED STATES DEPARTMENT OF COMMERCE

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Statutory Net-Content Marking Requirements for Packages (Undefined) and Packages of Foods, Drugs, and Cosmetics

by Kathryn M. Schwarz and Ralph W. Smith

National Bureau of Standards Circular 503
Issued November 16, 1950

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Foreword

The summary and tabulation of statutory requirements for net-content declarations on packages in general and on packages of foods, drugs, and cosmetics in particular, which are presented herein, are based upon the latest available statutes of the United States and of the States, Territories, District of Columbia, and organized island possessions of the United States.

In some jurisdictions there is an overlapping of requirements resulting from the fact that there are in effect statutes requiring the marking of packages of essentially all commodities, and in addition statutes relating specifically to foods, drugs, and/or cosmetics; in these cases the requirements of both statutes are included in the tabulation.

Numerous statutes relating specifically to commercial feeds, fertilizers, insecticides, fungicides, and the like also contain package-marking requirements, but these are excluded from consideration here. Also, consideration is not given here to the requirements of city ordinances, some of which are known to contain package-marking provisions.

Statutory Net-Content Marking Requirements for Packages (Undefined) and Packages of Foods, Drugs, and Cosmetics

Summary of Requirements

1. Jurisdictions that require, in general, that packages of *all commodities* be marked with statements of net content:

Alabama
California
Florida
Illinois
Indiana
Iowa
Louisiana
Montana
Nevada
New Hampshire
New York
North Carolina
Ohio[a]
Oklahoma
Oregon
Pennsylvania
Puerto Rico
South Carolina
Texas
Virginia
West Virginia

[a] In Ohio this requirement applies when commodities are sold by weight, liquid measure, or count.

2. Jurisdictions that require, in general, only that all packages containing *foods* (f), *drugs* (d), or *cosmetics* (c) be marked with statements of net content:

Connecticut (f, d, c)
Delaware (f)
District of Columbia (f)
Georgia (f)
Hawaii (f, d, c)
Maine (f)
Maryland (f)
Massachusetts (f)
Michigan (f)
Minnesota (f)
Missouri (f, d, c)
Nebraska (f)
New Jersey (f)
North Dakota (f, d, c)
Rhode Island (f)
South Dakota (f)
Tennessee (f, d, c)
United States—interstate shipments (f, d, c)
Utah (f)
Vermont (f)
Wisconsin (f)
Wyoming (f, d)

3. Jurisdictions which require that if packages of *food* carry a content declaration, this declaration must be accurate:

Arizona[a]
Arkansas
Colorado
Idaho
Kansas
Kentucky
Mississippi
Ohio

[a] In addition, a considerable number of specific food commodities, when in package form, are required to be marked with statements of net content.

NOTE.—These laws sometimes exempt a few specific commodities. A provision frequently incorporated is the exemption of "small" packages, sometimes defined as packages containing less than ½ ounce avoirdupois, ½ fluid ounce, or a "count" of six or less. Permissible variations from declared contents are occasionally stated in the law, but in the majority of instances are authorized to be set up by regulations issued by the enforcing officials.

Tabulation of Requirements

For net-content marking of packages of "all commodities" and of packages of foods, drugs, and cosmetics. (The existence of a requirement or provision is indicated by X—in the case of "all commodities"—or by x—in the case of packages of foods, drugs, or cosmetics—placed in the appropriate column.)

Name of jurisdiction	Scope				Marking is mandatory	If marked, statement must be accurate	Specific commodity exemptions included	Exemptions for "small" packages		Tolerances	
	All commodities	Foods	Drugs	Cosmetics				Fixed	Authorized	Fixed	Authorized
Alabama	X				X						X
Do				x	x				x		x
Alaska											
Arizona		x [a]			x					x	
Do		x				x					
Arkansas		x				x					
California	X				X		X	X			
Do		x	x		x				x		x
Colorado		x				x					
Connecticut		x	x	x	x				x		x
Delaware		x			x						
District of Columbia		x			x				x		x
Florida	X				X				X		X
Do		x			x		x		x		x
Georgia		x			x				x	x	x [b]
Hawaii		x	x	x	x				x		x
Idaho		x				x					
Illinois	X				X				X		X
Indiana	X				X						
Do		x	x	x	x				x		x
Iowa	X				X				X		X
Kansas		x				x					
Kentucky		x				x					
Louisiana	X				X				X		X
Do		x			x		x		x		x
Maine		x			x						x
Maryland		x			x				x		x
Massachusetts		x			x		x		x		x
Michigan		x			x		x		x		x
Minnesota		x			x				x		x
Mississippi		x				x					

[a] Arizona. A considerable number of specific food commodities in package form are required to be marked with statements of net content.

[b] Georgia. It appears that tolerances in excess may be established by regulation in addition to the tolerances in deficiency which are fixed by the statute.

Tabulation of Requirements—Continued

Name of jurisdiction	Scope				Marking is mandatory	If marked, statement must be accurate	Specific commodity exemptions included	Exemptions for "small" packages		Tolerances	
	All commodities	Foods	Drugs	Cosmetics				Fixed	Authorized	Fixed	Authorized
Missouri	----	----	x	x	x	----	----	----	x	----	x
Do	----	x	----	----	x	----	x	----	x	----	x
Montana	X	----	----	----	X	----	X	----	----	X	----
Do	----	x	----	----	----	x	----	----	----	----	----
Nebraska	----	x	----	----	x	----	x	----	----	----	----
Nevada	X	----	----	----	X	----	X	----	----	----	----
Do	----	x	x	x	x	----	----	----	x	----	x
New Hampshire	X	----	----	----	X	----	----	----	X	----	X
New Jersey	----	x	----	----	x	----	----	----	x	----	x
New Mexico	----	----	----	----	----	----	----	----	----	----	----
New York	X	----	----	----	X	----	X	X	----	----	X
North Carolina	X	----	----	----	X	----	----	----	X	----	X
North Dakota	----	x	x	x	x	----	----	----	----	----	----
Ohio	X	----	----	----	X [c]	----	----	----	X	----	X
Do	----	x	----	----	----	x	----	----	----	----	----
Oklahoma	X	----	----	----	X	----	X	----	X	----	X
Oregon	X	----	----	----	X	----	----	----	----	----	X
Do	----	x	----	----	x	----	----	----	x	----	x
Pennsylvania	X	----	----	----	X	----	X	----	----	----	X
Puerto Rico	X	----	----	----	X	----	----	----	X	----	X
Rhode Island	----	x	----	----	x	----	----	----	x	----	x
South Carolina	X	----	----	----	X	----	X	X	----	----	----
South Dakota	----	x	----	----	x	----	----	----	x	----	x
Tennessee	----	x	x	x	x	----	----	----	x	----	x
Texas	X	----	----	----	X	----	X	----	X	----	X
Do	----	x	----	----	----	x	----	----	----	----	----
United States—interstate shipments	----	x	x	x	x	----	----	----	x	----	x
Utah	----	x	----	----	x	----	----	----	x	----	x
Vermont	----	x	----	----	x	----	----	----	x	----	x
Virgin Islands	----	----	----	----	----	----	----	----	----	----	----
Virginia	X	----	----	----	X	----	----	----	X	----	X
West Virginia	X	----	----	----	X	----	X	----	X	----	X
Wisconsin	----	x	----	----	x	----	x	x	----	----	x
Wyoming	----	x	x	----	x	----	----	----	x	----	x

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[c] Ohio. Applies when commodities are sold by weight, liquid measure, or count.

Recommendations

The advantages and desirability of a requirement that, in general, "packages of all commodities" bear declarations of net content should be fairly obvious. From the preceding summary and tabulation it is seen that the principle of net-content marking has been almost universally applied in the case of packages of foods. It is just as logical and necessary that a net-content declaration appear on a package of a nonfood commodity as it is that it appear on a package of food, and 20 jurisdictions have already enacted laws requiring this. Those jurisdictions which are without such a law are benefiting to a considerable extent, with respect to packages distributed on a national scale, from the requirements of the 20 jurisdictions which have in effect the broad requirement in question, but are without protection in the case of packages originating within and sold in their jurisdictions.

Each jurisdiction in which the net-content marking of packages is permissive instead of mandatory or in which mandatory marking of net content is limited to only one or several categories of packaged commodities, is urged to give early consideration to the enactment of a comprehensive package-marking law. A suggestion for the substantive portion of such a law is as follows:

> That it shall be unlawful to keep for the purpose of sale, offer or expose for sale, or sell, any commodity in package form unless (1) the net quantity of the contents in terms of weight, measure, or numerical count, and (2) the name and place of business of the manufacturer, packer, or distributor, be plainly and conspicuously marked on the outside of the package: *Provided, however,* That reasonable variations or tolerances shall be permitted, and that these reasonable variations or tolerances and also exemptions as to small packages shall be established by rules and regulations made by the Commissioner. It shall be unlawful to keep for the purpose of sale, offer or expose for sale, or sell any commodity in package form (1) if its container is so made, formed, or filled, or if it is so packaged or wrapped, as to mislead the purchaser as to the quantity of the contents, or (2) if the contents of its container fall below the standard of fill prescribed by regulations promulgated as provided in this section. For the effectuation of the purposes of this section the Commissioner is hereby authorized to promulgate regulations fixing and establishing for any commodity in package form a reasonable standard of fill of container.
>
> The words "commodity in package form" as used in this Act shall mean commodity put up or packaged in any manner, in advance of sale, so as to constitute a unit quantity of the commodity for either wholesale or retail sale, but this definition shall not include an auxiliary shipping container enclosing packages which are individually marked as required by this section. For purposes of this Act, an individual item or lot of any commodity on which there is marked a selling price based on an established price per unit of weight or measure, shall be construed to be commodity in package form.

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DEPARTMENT OF COMMERCE
UNITED STATES OF AMERICA

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NBS CIRCULAR 504

Battery Additives

UNITED STATES DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

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Battery Additives

by

Paul L. Howard and George W. Vinal

National Bureau of Standards Circular 504
Issued January 10, 1951

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C. - Price 15 cents

PREFACE

The National Bureau of Standards has issued several leaflets during the past 25 years on the subject of battery additives. Many of these additives have been exploited as panaceas for lead-acid storage-battery failures. These leaflets were an expedient means of answering many hundreds of inquiries about such materials. The leaflets were revised as occasion required, and the present is an opportune time to issue a more extended statement based on recent tests. This Circular shows by a comprehensive series of comparative tests that these materials are not effective. This Bureau does not make tests of storage batteries or battery materials for the public, but has had frequent occasion in the past to make tests for Federal agencies needing such information.

This Circular is intended for the average automobile owner and storage battery user.

E. U. Condon, *Director*.

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Battery Additives

Paul L. Howard and George W. Vinal

Various preparations of liquids and solids have been sold to the public as means of rejuvenating worn out or so-called "dead" batteries. The majority of these materials are composed of varying proportions of magnesium sulfate and sodium sulfate. Extensive laboratory and field tests have been made covering various proportions of magnesium and sodium sulfates. The results show no difference between the batteries treated with these mixtures and similar untreated batteries used as control.

I. General description of lead-acid storage battery

Figure 1 shows a cutaway view of an ordinary automobile battery. Three cells are housed in a hard-rubber or composition container and covered with tops of similar material containing filler wells,

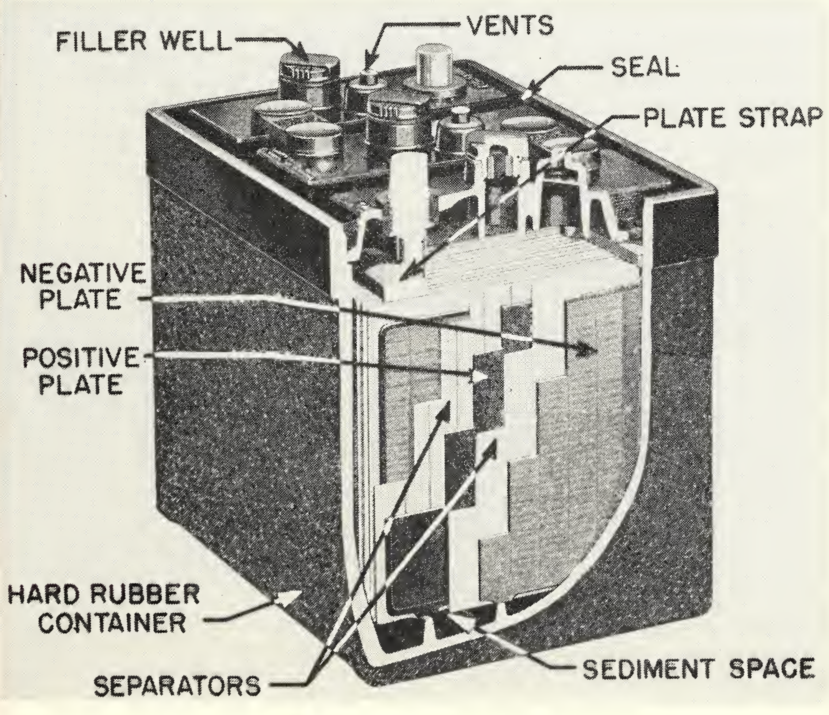

Figure 1. *Cross-sectional view of standard automotive battery.*

vents,[1] and terminals. The top is sealed with a bituminous material to complete the battery enclosure. Each cell is composed of several positive and negative plates separated by a wood or microporous separator. Raised partitions in the bottom of the container leave a space under the plates for sediment to collect during the useful life of the battery.

The positive plate is composed of a lead-alloy grid into which lead oxides are pasted and the whole formed electrolytically so that the oxides are converted to lead dioxide. Similarly, the negative plate consists of an alloy grid into which lead oxides are pasted and the whole formed electrolytically so that the oxides are converted to sponge lead. The electrolyte consists of a water solution of sulfuric acid that has a specific gravity in the charged state of about 1.28 when used as an automobile battery.

Figure 1 gives a general picture of a battery at the beginning of its normal life. Figure 2 shows the condition of a battery at the end of its useful life. At that time the positive plates are corroded and the outer grid frame ruptured. Similarly, the negative plates have lost

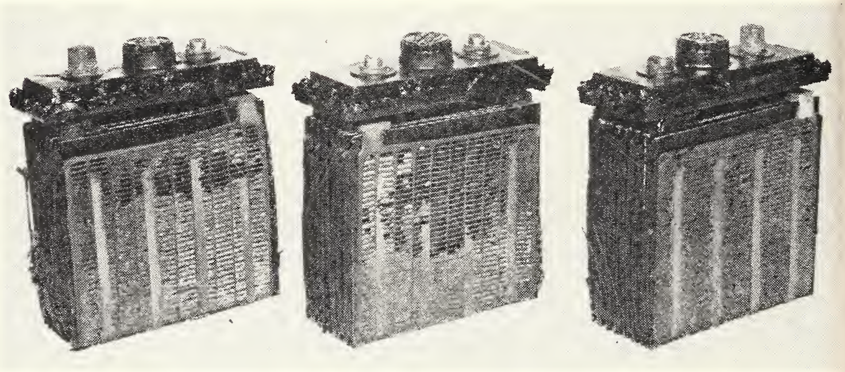

Figure 2. *Cell groups from standard automotive battery at end of life.*

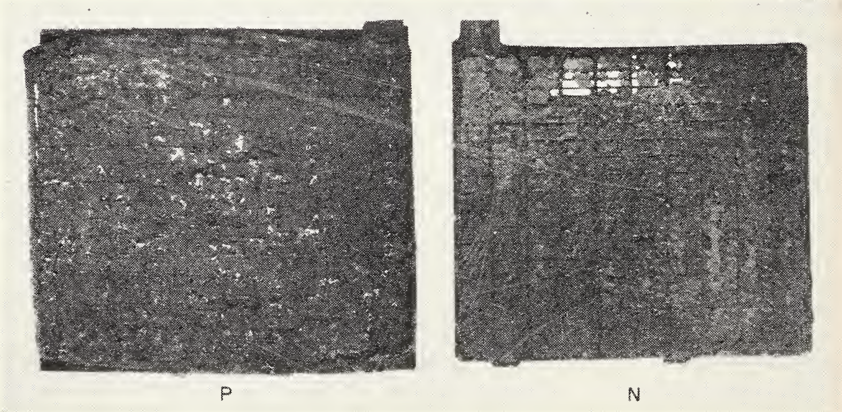

Figure 3. *Positive and negative plates from storage battery at end of useful life.*
P=positive, N=negative.

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[1] Sometimes the vents are in the filter caps.

some of their active material and are badly sulfated. The wood separators are charred by the sulfuric acid, and active material is deposited on their surfaces. Figure 3 shows the condition of the positive plates and negative plates. The positive grid frame is corroded to such an extent that the plate is disintegrated. The negative plate has lost some of its active material in the sulfated area.

II. Fundamental facts about storage batteries

A storage battery may be considered as an electrochemical apparatus in which electric energy is stored as chemical energy.

When a storage battery is discharged the chemical energy is transformed into electric energy as the lead dioxide and sponge lead react with the sulfuric acid to form lead sulfate at both the positive and negative plates. The current flows from the positive to the negative plate externally and from the negative to the positive plate internally to complete the cycle of transformation of chemical energy into electric energy.

The lead sulfate formed during the discharge forms a surface coating over most of the surface of each particle of finely divided sponge lead or lead dioxide. The center of the particle, being nonporous, is not converted to lead sulfate. Each particle is in intimate contact with the next particle so that electrically continuous flow of current is maintained. Thus this normal deposit of lead sulfate forms a relatively thin film over the particles of active material and is easily reconverted to the corresponding lead or lead dioxide during subsequent recharge. The relative size of these particles determines the amount of electrolyte that may be in the pores of the plate at any given time.

If a battery is subjected to a high rate of discharge, the reaction of the lead and lead dioxide with sulfuric acid will be very rapid. This tends to weaken the layer of acid close to the surface of each particle, thus limiting the continuous discharge capacity. However, if the discharge is stopped for a short period and then repeated, the battery will give additional performance. Thus it may appear to the layman as if it has automatically charged itself. This may be repeated a number of times with each succeeding discharge, giving poorer performance until the battery is effectively completely discharged. This phenomenon, which has been known for 70 years, is inherent in all storage batteries and is known as the recuperative power of the lead-acid battery. Each time the battery is rested the acid diffuses into the pores of the plate and replenishes the supply of acid at the surface of the particles of active material.

After the battery has been discharged it is charged by forcing an electric current in the opposite direction so that the lead sulfate is converted back to lead dioxide and sponge lead according to its original condition. This completes the cycle in which chemical energy furnishes electric energy and electric energy is again stored as chemical energy.

The word "charge" as applied to storage batteries is defined as follows in the Standards for Storage Batteries adopted by the American Institute of Electrical Engineers, dated June 22, 1922 (Definition No. 36–250):

"Charge.—The conversion of electric energy into chemical energy within the cell or battery. This consists of the restoration of the active material by passing a unidirectional current through the cell or battery in the opposite direction to that of the discharge. A cell or battery which is said to be "charged" is understood to be *fully* charged."

All the processes described above follow the fundamental electrochemical laws of Faraday, which may be stated as follows:

1. The quantity of a substance set free at an electrode is directly proportional to the quantity of electricity that passes through the solution.
2. The same quantity of electricity sets free the same number of equivalents of substances at the electrodes.

These laws govern the fundamental reactions within the storage battery, regardless of minor changes in electrolyte brought about by the addition of foreign matter.

III. Sulfation

The term "sulfation" has been used in several senses, and this has lead to some confusion. In general, it means the formation of lead sulfate on the surface and in the pores of the active material of the plates. This may be formed as a result of (1) normal discharge, (2) self-discharge, and (3) neglect or abuse.

Sulfation occurring during a normal discharge results in a fine crystalline coating over the particles of active materials. This product is easily reconverted by the charging current. This type of sulfation is a necessary part of the operation of a battery and is not a source of trouble.

The self-discharge type of sulfation is caused by parasitic currents or by the action of the acid on the substances present. The rate at which this sulfation proceeds depends upon the temperature and concentration of the electrolyte. The formation of lead sulfate in this manner is much slower than by the normal discharge process. This allows larger crystals to form. However, if the battery is not neglected, these also will be easily reconverted to active material by the charging current. For an ordinary automobile battery the average loss in charge (as indicated by specific-gravity change) for different temperatures may be given as 0.003 drop per day at 100° F, 0.002 drop per day at 80° F, 0.0005 drop per day at 50° F.

Thus if an 0.075 drop is allowed, the battery would need recharging as a result of local action at the following intervals: At 100° F recharge at 25 days, at 80° F recharge at 37 days, and at 50° F recharge at 5 months. Certain impurities in the electrolyte will increase the local action and hence the rate of sulfation in the plates.

The third and popular use of the word sulfation applies to excessive amounts of lead sulfate that may form in or on the plates as a result of neglect or abuse, as

1. Allowing the battery to stand in a discharged condition for a long time.
2. Neglecting to make repairs when evidence of trouble within the cells becomes apparent.
3. Filling cells with electrolyte when water should have been used.
4. Operating battery at excessive temperatures.
5. Persistent undercharging.
6. Presence of certain impurities in the electrolyte.
7. Operation for long periods in a partially charged condition.

This type of sulfation is more difficult to reduce and may injure the plates. Excessive sulfation can be avoided with reasonable care. It is doubtless true that the liability to troublesome sulfation of lead batteries has been exaggerated by those exploiting so-called cures.

When a battery stands in a discharged condition for some time the lead sulfate crystals tend to grow. In doing this they harden and become larger and may break away from the surface. Also, the growth of the sulfate crystals tends to block the pores of the plate. As these crystals occupy more space than the original active material, their expansion may eventually either fracture the grid frame or loosen the active material.

Lead sulfate is very slightly soluble in sulfuric acid electrolyte at normal temperatures. However, the solubility increases with rise in temperature. One cause of crystal growth depends on a rise in temperature to dissolve the lead sulfate and a drop in temperature to recrystallize it. Thus the larger crystals grow at the expense of the smaller. Another cause is the removal of acid from the electrolyte in the pores as lead sulfate is formed, causing a greater solubility of the lead sulfate in the low gravity acid and a recrystallization as more acid diffuses into the pores or as the amount of electrolyte in the pores is reduced due to growth of the crystals. Both of these causes contribute to troublesome sulfation.

Because of the closing of the pores in the active material by the crystal growth of the lead sulfate it becomes increasingly difficult for the electrolyte to penetrate into the plates. If a battery which has stood for a long time is filled with water and placed on charge with a direct-current source it is found that the initial closed-circuit voltage is much in excess of its normal value. As the electrolyte penetrates into the active material and reconversion begins the voltage will gradually drop to that of a normal cell. If the applied voltage is low and the cell resistance is high, the indications might be that the cell is dead. However, if sufficient time is allowed, there would be a gradual break down of active material and current would begin to flow. This condition is true, regardless of whether or not a battery has been treated with additives, provided it has been in a sulfated condition for a long period.

IV. Types of additives

More than 100 additives have been brought to the Bureau's attention during the past 30 years. A statement entitled "Solutions do not charge storage batteries" was issued in the Bureau's Technical News Bulletin 94, February 10, 1925. Since that time many additional tests on solutions and compounds, the latter in the form of salts to be added to the battery electrolyte, have been made. Bureau Letter Circular 302 was issued in 1931 and has been revised to meet new demands.

Various types of additives have been marketed over the period of years. Analysis of these preparations shows their composition falls into the following categories:

Solids:

(1) Preparations of varying proportions of magnesium sulfate and sodium sulfate in various states of hydration.

(2) Preparations including potassium, aluminum, calcium, or ammonium sulfates, or the corresponding phosphate salts.

(3) In addition to the compounds in (1) and (2), nitrates, chlorides, iron, copper, or mercury may be present. All these are definitely harmful to the battery.

Liquids:

(1) Solutions of sulfuric acid of various specific gravities, with or without some coloring matter.

(2) Solutions of sulfuric acid of various specific gravities, with additions of significant amounts of materials containing some or all the following metal ions: Sodium, magnesium, potassium, aluminum, and other common materials.

(3) Tap water with a little organic dye and traces of metal salts.

(4) Tap water with significant amounts of organic acids or metallic salts of these acids.

(5) Glycerin or alcohol in water solution with or without metal sulfates added.

In general, the directions for using additives specify that each cell of the battery be treated with the contents of a package, filled with water and charged by means of the automobile generator for a certain length of time. Then a specified test is usually given in which the starter motor drains the battery until it will no longer turn the motor. Then after a rest period the ignition is turned on and the starter will usually turn the motor over long enough to start it.

Such tests are not indicative of the condition of the battery or whether the additive improved the characteristics of the battery, but are calculated to give the unwary purchaser a false idea that an improvement has been caused by the additive. Preliminary tests are essential in order to determine any improvement in performance resulting from the treatment.

In order to make a comprehensive and complete study of the effect of various additives on a battery, a complete check on the characteristics of the battery must be made before and after treating to establish a valid comparison. Referring back to the types of additives listed above, certain conclusions may be drawn from earlier work.

1. In all cases where sulfuric-acid solutions are concerned it is known that no long-term advantage is to be gained through increasing the specific gravity of the electrolyte. Momentarily there may be an increase in capacity, but the increased local action associated with the higher specific gravity will soon overcome this advantage.

2. Use of water with traces of other materials shows no advantage over using plain tap water to fill the battery. If glycerin or alcohols are present, these are considered harmful as they are converted to harmful organic acids that may remain in the electrolyte and shorten the life of the positive plate.

3. The use of materials containing copper, mercury, iron, nitrates or chlorides is definitely harmful, as shown in the work of Vinal and Schramm [2] and others.

4. Of all the types listed, the most commonly used materials are magnesium sulfate and sodium sulfate. Combinations of these substances are most commonly used in present-day additives.

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[2] Trans. Am. Inst. Elec. Engrs. **44,** 288 (1925).

V. Experimental Procedure

In order to study these combinations it was necessary to devise a test procedure that would cover the main characteristics of the battery and the claims most often used by the manufacturers for their additive. A series of tests was set up to cover the following points:

1. Change in specific gravity of solution produced by the additive.
2. Effect on capacity at normal discharge rates, such as the 5-hour rate, to determine whether there was a decrease in sulfation.
3. Effect on self-discharge or local action as an indication of improvement in retention of charge.
4. Effect on temperature of cells during charge as a means of prolonging life.
5. Effect on water consumption as an indication of whether the battery was taking the charge better with or without the treatment.
6. Simulation of an operational test where the batteries remained just under full charge for a long period but never on a complete discharge cycle to determine whether the treated cells would recharge more completely than untreated cells.
7. High-rate discharges starting at 300 amp then reducing to 200 amp and 100 amp successively to determine whether there is any change in cell performance under these conditions by treating the battery with additives.
8. Determination of the recuperative power of a cell when subjected to 300-amp load for a short interval followed by a rest period and repetition of the cycle. This is to indicate whether any improvement was made by the treatment.
9. Effect of several complete cycles to see if there was an increase in capacity and specific gravity.

In order to make such a series of tests it was first necessary to obtain mechanically sound batteries that were permanently sulfated. Various so-called sulfated batteries were obtained and given a charge for an extended period until there was no further change in gravity. A battery made in 1920 that had been allowed to stand from then until 1949 was dismantled and the negative plates charged in 1.050 specific gravity sulfuric acid against sheet-lead positives. These plates were completely converted to sponge lead. It has been the experience here that most of the so-called sulfated batteries filled with low-gravity sulfuric acid or water will respond to normal charging procedures, provided the charge is slow and over an extended period. However, if the cells are filled with high-gravity acid, the response to charge is very poor.

Six batteries of Army 6-volt type 2H that had stood for 4 years in a charged and damp condition were filled with 1.050 acid and given a 388 amp-hr charge. The results of this charge are shown in table 1. Here the specific gravity did not rise equally in all cells and the capacity was low except in battery 5. This battery recovered all its rated capacity but was high in local action.

Capacity and stand loss were measured on these batteries to establish their characteristics prior to treating. A series of combinations of anhydrous magnesium and sodium sulfates were set up as shown in table 2. Mixtures A and C are commercial products, while mixtures B, D, and E were prepared and included in the group in order to extend the range of compositions studied.

TABLE 1. *Unused 2H batteries stored damp for 4 years, filled with sulfuric acid of specific gravity 1.050 and charged at 5-amp for 388 amp-hr*

Battery No.	Final specific gravity at 28° C of cell—		
	1	2	3
1	1. 268	1. 248	1. 243
2	1. 268	1. 268	1. 243
3	1. 253	1. 253	1. 268
4	1. 258	1. 258	1. 268
6	1. 273	1. 263	1. 253
5	1. 288	1. 288	1. 288

TABLE 2. *After preliminary tests, 2 cells in batteries 1, 2, 3, 4, and 6 of table 1 treated with various mixtures of magnesium sulfate and sodium sulfate*

Percentages are of the anhydrous salts. Differences from 100% indicate the percentage of water of hydration.

Treatment mixture	Battery	Cells treated	Sodium sulfate (Na_2SO_4)	Magnesium sulfate ($MgSO_4$)	Weight of dry mixture
			%	%	g
A	1	1 and 3	[1] 68	[1] 15	9. 7
B	2	2 and 3	50	30	17
C	3	2 and 3	[1] 42	[1] 45	21
D	4	1 and 2	20	60	18
E	6	2 and 3	10	80	20

[1] (Approx.).

Batteries were treated as indicated in table 2. In all cases one cell in each battery was used as standard, and the other two were treated. The results of these tests are given in tables 4 to 38.

A number of statements have been made over the years to the effect that there is little or no change in gravity when these materials are added to the electrolyte. In order to show the effect on specific gravity, the test mixtures in table 2 were dissolved in 200 ml of water, and the specific gravity of each was determined. The results are given in table 3. This volume is approximately 50 percent of the free electrolyte per cell in an automobile storage battery, so the immediate rise in specific gravity approximates 0.015 for every 10 g of additive. However, this rise in gravity is much smaller at the end of a full charge due to complete mixing of the electrolyte.

Tables 4, 5, 6, 7, and 8 show the capacity variations at the 20-amp rate when discharged immediately after charge and after a 16-hour stand before and after treatment. In practically every case the capacity decreased after treatment more than average. This definitely shows that there is no improvement of cell performance obtained by the use of such additives and further confirms the fact that such additives do not remove the products of sulfation. If the sulfate was removed from the plates, there would have been a marked increase in the capacity of the treated cells. This is not the case. In all cases it is seen that there is no significant difference between treated and untreated cells.

TABLE 3. *Specific gravity of solutions of the treatment mixtures listed in table 2 in 200 ml of water at 24° C*

Treatment mixture	Dry weight	Specific gravity
	g	
A	9.7	1.036
B	17	1.066
C	21	1.063
D	18	1.062
E	20	1.054

TABLE 4. *Ampere-hour capacity at the 20-amp rate before and after treating battery 1 with mixture A*

Cell	Treatment	Temperature	Time	Ampere-hour capacity	
				Freshly charged	After 16-hr stand
		°*C*			
1	Untreated	33	Initial	56	--------
	do	28		--------	33
	Treated	33	4 cycle	36.6	--------
	do	28		--------	28.6
	do	33	6 months	5.0	--------
2	Untreated	33	Initial	72.6	--------
	do	28		--------	46.6
	do	33	4 cycle	66.4	--------
	do	28			53.0
	do	33	6 months	12.6	--------
3	Untreated	33	Initial	50	--------
	do	28			36
	Treated	33	4 cycle	46	--------
	do	28		--------	37.6
	do	33	6 months	11.6	--------

TABLE 5. *Ampere-hour capacity at the 20-amp rate before and after treating cells 2 and 3 of battery 2 with mixture B*

Cell	Treatment	Temperature	Time	Ampere-hour capacity	
				Freshly charged	After 16-hr stand
		°*C*			
1	Untreated	33	Initial	98.4	--------
	do	28		--------	95.6
	do	33	4 cycle	83.6	--------
	do	28		--------	82.0
	do	33	6 months	19	--------
2	Untreated	33	Initial	76.6	--------
	do	28		--------	57.2
	Treated	33	4 cycle	63.9	--------
	do	28		--------	52.6
	do	33	6 months	8.0	--------
3	Untreated	33	Initial	84.4	--------
	do	28		--------	66.6
	Treated	33	4 cycle	95.6	--------
	do	28		--------	83.4
	do	33	6 months	69.6	--------

Table 6. *Ampere-hour capacity at the 20-amp rate before and after treating cells 2 and 3 of battery 3 with mixture C*

Cell	Treatment	Temperature	Time	Ampere-hour capacity	
				Freshly charged	After 16-hr stand
		°C			
1	Untreated	33	Initial	70.4	
	do	28			57.6
	do	33	4 cycle	71.4	
	do	28			61.0
	do	33	6 months	22.6	
2	Untreated	33	Initial	52.4	
	do	28			45.4
	Treated	33	4 cycle	47.0	
	do	28			40.00
	do	33	6 months	9.4	
3	Untreated	33	Initial	14.4	
	do	28			15.2
	Treated	33	4 cycle	14.4	
	do	28			11.0
	do	33	6 months	6.0	

Table 7. *Ampere-hour capacity at the 20-amp rate before and after treating cells 1 and 2 of battery 4 with mixture D*

Cell	Treatment	Temperature	Time	Ampere-hour capacity	
				Freshly charged	After 16-hr stand
		°C			
1	Untreated	33	Initial	53.6	
	do	28			46.0
	Treated	33	4 cycle	46.4	
	do	28			40.6
	do	33	6 months	13.4	
2	Untreated	33	Initial	90.00	
	do	28			78.4
	Treated	33	4 cycle	71.6	
	do	28			66.4
	do	33	6 months	10	
3	Untreated	33	Initial	97.0	
	do	28			97.2
	do	33	4 cycle	89.0	
	do	28			86.4
	do	33	6 months	8.6	

Tables 9, 10, 11, 12, and 13 summarize the 3- and 4-day stand on open circuit before and after treatment. The stand loss is directly related to retention of charge and is usually a measure of local action. There is no significant difference between treated and untreated cells.

Tables 14, 15, 16, 17, and 18 summarize tests of successive discharges made by starting at 300 amp and reducing the current to 200 and then to 100 amp to determine any benefits of treating. It is shown that there is no significant difference in performance of the treated and untreated cells.

Tables 19, 20, 21, 22, and 23 give a record of final cell temperatures for eight charges spread over a 3-month period. It might be noted that cell 2 is a center cell, which, because of its protected position normally runs 0.5 to 1 deg C higher. There is no significant difference in temperature between treated cells during this period.

Table 8. *Ampere-hour capacity at the 20-amp. rate before and after treating cells 2 and 3 of battery 6 with mixture E*

Cell	Treatment	Temperature	Time	Ampere-hour capacity	
				Freshly charged	After 16-hr stand
		° *C*			
1	Untreated	33	Initial	85.4	
	do	28			75.6
	do	33	4 cycle	68.0	
	do	28			60.0
	do	33	6 months	4.0	
2	Untreated	33	Initial	31.4	
	do	28			30.0
	Treated	33	4 cycles	27.4	
	do	28			22.4
	do	33	6 months	5.0	
3	Untreated	33	Initial	30.6	
	do	28			30.0
	Treated	33	4 cycles	27.6	
	do	28			22.0
	do	33	6 months	6.0	

Tables 24, 25, 26, 27, and 28 summarize the water consumption over a 6-month period. The first part covered cycle operation during tests of cell characteristics. The remaining period covered a simulated life test. There is no significant difference in water consumption between treated and untreated cells. An over-all average per week shows a loss of 59 ml of water for the treated and 58 ml of water for the untreated cells for the 27-week period.

Tables 29, 30, 31, 32, and 33 give the variations in specific gravity over a 26-week period of simulated life test where the battery is maintained just under full charge. In this case the loss in charge was due to excessive local action. The variation is about the same order, whether the cells are treated or untreated. After the 26 weeks, a freshening charge was given to determine the ability of the batteries to return to initial conditions. Here again, the untreated cells performed as well as the treated cells.

Table 9. *Drop in specific gravity during 3- and 4-day stands before and after treating cells 1 and 3 of battery 1 with mixture A*

Cell	Treatment	Following cycle—	Total drop in specific gravity at 28° C		
			Time	3-day stand	4-day stand
1	Untreated	1		0.028	
	do	2			0.044
	Treated	3		.043	
	do	4			.049
	do		6 months		.049
2	Untreated	1		.033	
	do	2			.042
	do	3		.033	
	do	4			.059
	do		6 months		.044
3	Untreated	1		.033	
	do	2			.042
	Treated	3		.038	
	do	4			.059
	do		6 months		.039

Table 10. *Drop in specific gravity during 3- and 4-day stands before and after treating cells 2 and 3 of battery 2 with mixture B*

Cell	Treatment	Following cycle—	Total drop in specific gravity at 28° C		
			Time	3-day stand	4-day stand
1	Untreated	1		0.023	
	do	2			0.042
	do	3		.038	
	do	4			.054
	do		6 months		.019
2	Untreated	1		.028	
	do	2			.047
	Treated	3		.043	
	do	4			.049
	do		6 months		.039
3	Untreated	1		.033	
	do	2			.042
	Treated	3		.038	
	do	4			.049
	do		6 months		.039

Table 11.—*Drop in specific gravity during 3- and 4-day stands before and after treating cells 2 and 3 of battery 3 with mixture C*

Cell	Treatment	Following cycle—	Total drop in specific gravity at 28° C		
			Time	3-day stand	4-day stand
1	Untreated	1		0.033	
	do	2			0.037
	do	3		.028	
	do	4			.044
	do		6 months		.044
2	Untreated	1		.028	
	do	2			.042
	Treated	3		.043	
	do	4			.044
	do		6 months		.044
3	Untreated	1		.033	
	do	2			.042
	Treated	3		.043	
	do	4			.039
	do		6 months		.039

Table 12. *Drop in specific gravity during 3- and 4-day stands before and after treating cells 1 and 2 of battery 4 with mixture D*

Cell	Treatment	Following cycle—	Total drop in specific gravity at 28° C		
			Time	3-day stand	4-day stand
1	Untreated	1		0.043	
	do	2			0.042
	Treated	3		.053	
	do	4			.044
	do		6 months		.039
2	Untreated	1		.038	
	do	2			.042
	Treated	3		.038	
	do	4			.029
	do		6 months		.049
3	Untreated	1		.028	
	do	2			.027
	do	3		.033	
	do	4			.029
	do		6 months		.039

Table 13. *Drop in specific gravity during 3- and 4-day stands before and after treating cells 2 and 3 of battery 6 with mixture E*

Cell	Treatment	Following cycle—	Total drop in specific gravity at 28° C		
			Time	3-day stand	4-day stand
1	Untreated	1		0.038	
	do	2			0.037
	do	3		.023	
	do	4			.034
	do		6 months		.034
2	Untreated	1		.038	
	do	2			.047
	Treated	3		.033	
	do	4			.044
	do		6 months		.039
3	Untreated	1		.038	
	do	2			.047
	Treated	3		.038	
	do	4			.039
	do		6 months		.039

Table 14. *300, 200, 100 amp successive constant-current discharge of battery 1 after treating cells 1 and 3 with mixture A*

Current	Time of discharge	Cell 1, treated	Cell 2, untreated	Cell 3, treated
amp	*min*	*v*	*v*	*v*
300	0.5	1.14	1.37	1.27
	1.0	0.95	1.29	1.18
	1.5	.55	1.17	1.03
	2.0	0	1.02	0.85
	2.5	−.8	0.87	.62
	3.0	−.125	.65	.3
200	3.0			
	[a] 3.5	−.96	.80	.5

[a] After the 3.5-minute reading, cell 1 began to smoke so discharge was discontinued.

Table 15. *300-, 200-, 100-amp successive constant-current discharge of battery 2 after treating cells 2 and 3 with mixture B*

Current	Time of discharge	Cell 1, untreated	Cell 2, treated	Cell 3, treated
amp	*min*	*v*	*v*	*v*
300	Start	1.60	1.50	1.68
	1.0	1.60	1.46	1.67
	2.0	1.54	1.27	1.65
	3.0	1.49	1.04	1.62
200	3.0			
	3.5	1.62	1.24	1.72
	5.0	1.60	1.15	1.71
	7.0	1.52	0.60	1.68
	7.5	1.49	.40	1.67
100	7.5			
	8.0	1.69	1.00	1.78
	10.0	1.69	0.88	1.78
	15.0	1.63	.32	1.76
	20.0	1.48	−.45	1.69

Table 16. *300-, 200-, 100-amp successive constant-current discharge of battery 3 after treating cells 2 and 3 with mixture C*

Current	Time of discharge	Cell 1, untreated	Cell 2, treated	Cell 3, treated
amp	*min*	*v*	*v*	*v*
300	Start	1.53	1.29	0.96
	0.5	1.48	1.21	.40
	1.0	1.46	1.10	−1.05
200	1.0			
	1.25	1.61	1.33	−1.00
	2.00	1.58	1.23	−1.40
100	2.3			
	2.4	1.78	1.62	0
	2.5	1.77	1.57	−0.65

Table 17. *300-, 200-, 100-amp successive constant-current discharge of battery 4 after treating cells 1 and 2 with mixture D*

Current	Time of discharge	Cell 1, treated	Cell 2, treated	Cell 3, untreated
amp	*min*	*v*	*v*	*v*
300	Start	1.4	1.47	1.59
	0.5	1.29	1.44	1.58
	1.0	1.18	1.37	1.56
	2.0	0.70	1.20	1.51
	2.5	.35	1.07	1.49
200	2.5			
	2.75	.68	1.32	1.64
	3.0	.60	1.29	1.62
	3.5	.32	1.25	1.62
	4.0	0	1.21	1.61
100	4.0			
	4.25	.85	1.56	1.77
	5.0	.83	1.565	1.78
	10.0	.13	1.44	1.74
	11.0	−.02	1.41	1.74

Table 18. *300-, 200-, 100-amp successive constant-current discharge of battery 6 after treating cells 2 and 3 with mixture E*

Current	Time of discharge	Cell 1, untreated	Cell 2, treated	Cell 3, treated
amp	*min*	*v*	*v*	*v*
300	Start	1.49	1.21	1.13
	0.5	1.43	1.03	0.98
	1.0	1.36	0.64	.60
	1.25	1.33	0	0
200	1.25			
	1.5	1.50	.67	.72
	2.0	1.47	.34	.43
	2.33	1.47	0	.13
100	2.33			
	2.5	1.68	.76	.90
	3.0	1.69	.69	.84
	5.0	1.65	.16	.38
	7.0	1.60	−.40	−.18
	8.0	1.57	−.57	−.38

Table 19. *Cell temperatures at end of charge before and after treating cells 1 and 3 of battery 1 with mixture A*

Charge	Input	Finishing rate	Temperature of cell— 1				
			1		2, untreated	3	
			Untreated	Treated		Untreated	Treated
	amp-hr	*amp*	° *C*	° *C*	° *C*	° *C*	° *C*
1	388	5	32.5	------	33.5	32.5	------
2	248	5	31.5	------	32	32	------
3	339	5	31	------	32	31	------
4	194	5	--------	35	35	--------	35
5	130	10	--------	38.5	39	--------	38.5
6	145	10	--------	34	35	--------	35
7	135	5	--------	31	31	--------	31
8	120	5	--------	37	37.5	--------	37

Table 20. *Cell temperatures at end of charge before and after treating cells 2 and 3 of battery 2 with mixture B*

Charge	Input	Finishing rate	Temperature of cell—				
			1, Untreated	2		3	
				Untreated	Treated	Untreated	Treated
	amp-hr	*amp*	° *C*	° *C*	° *C*	° *C*	° *C*
1	388	5	33	33.5	------	33.5	------
2	248	5	32	32.5	------	32	------
3	339	5	31	32	------	31.5	------
4	194	5	33.5	------	34	--------	33.5
5	130	10	36	------	36.5	--------	36
6	145	10	34	------	34.5	--------	35
7	135	5	31	------	31	--------	31
8	120	5	38.5	------	39	--------	39

Table 21. *Cell temperatures at end of charge before and after treating cells 2 and 3 of battery 3 with mixture C*

Charge	Input	Finishing rate	Temperature of cell—				
			1, Untreated	2		3	
				Untreated	Treated	Untreated	Treated
	amp-hr	*amp*	° *C*	° *C*	° *C*	° *C*	° *C*
1	388	5	33	33.5	------	33	----------
2	248	5	32	32.5	------	32	----------
3	339	5	31	31.5	------	31	----------
4	194	5	33.5	--------	34	--------	33.5
5	130	10	38.5	--------	39	--------	38.5
6	145	10	34.5	--------	35.5	--------	35.5
7	135	5	32.5	--------	32	--------	32
8	120	5	39	--------	39	--------	39

TABLE 22. *Cell temperature at end of charge before and after treating cells 1 and 2 of battery 4 with mixture D*

Charge	Input	Finishing Rate	Temperature of cell—				
			1		2		3, Untreated
			Untreated	Treated	Untreated	Treated	
	amp-hr	*amp*	° *C*	° *C*	° *C*	° *C*	° *C*
1	388	5	32. 5	------	33. 5	------	33. 5
2	248	5	32. 0	------	32. 5	------	32. 5
3	339	5	31. 0	------	32. 0	------	31. 0
4	194	5	--------	33. 0	--------	34. 0	33. 5
5	130	10	--------	38. 0	--------	39. 0	38. 0
6	145	10	--------	34. 0	--------	35. 0	35. 0
7	135	5	--------	31. 5	--------	32. 0	31. 5
8	120	5	--------	39. 0	--------	39. 0	39. 0

TABLE 23. *Cell temperature at end of charge before and after treating cells 2 and 3 of battery 6 with mixture E*

Charge	Input	Finishing rate	Temperature of cell—				
			1		2		3, Untreated
			Untreated	Treated	Untreated	Treated	
	amp-hr	*amp*	° *C*	° *C*	° *C*	° *C*	° *C*
1	388	5	33. 5	33. 5	--------	33. 0	------
2	248	5	32. 5	32. 5	--------	32. 0	------
3	339	5	31. 5	32. 0	--------	31. 5	------
4	194	5	33. 5	------	34. 5	------	33. 5
5	130	10	38. 5	------	40. 5	------	39. 5
6	145	10	35. 0	------	35. 0	------	34. 0
7	135	5	32. 0	------	31. 0	------	31. 0
8	120	5	39. 0	------	38. 0	------	38. 0

TABLE 24. *Water consumption of battery 1 over a 27-week period after treating cells 1 and 3 with mixture A*

Time	Cycle condition	Water consumption by—		
		Cell 1, treated	Cell 2, untreated	Cell 3, treated
Weeks	*Daily*	*ml*	*ml*	*ml*
Start	Cycled	144	90	75
3	do	150	218	220
9	4-hr charge, 20-hr stand	350	317	327
16	do	522	497	475
22	do	320	242	275
27	do	240	214	224
Total, ml		1, 726	1, 573	1, 521
Average water per week, ml		64	58	56

Table 25. *Water consumption of battery 2 over a 27-week period after treating cells 2 and 3 with mixture B*

Time	Cycle condition	Water consumption by—		
		Cell 1, untreated	Cell 2, treated	Cell 3, treated
Weeks	*Daily*	*ml*	*ml*	*ml*
Start	Cycled	95	75	95
3	do	171	174	162
9	4-hr charge, 20-hr stand	312	330	296
16	do	440	459	392
22	do	324	303	261
27	do	211	230	214
Total, ml		1, 553	1, 571	1, 420
Average water per week, ml		57	58	53

Table 26. *Water consumption of battery 3 over a 27-week period after treating cells 2 and 3 with mixture C*

Time	Cycle condition	Water consumption by—		
		Cell 1, untreated	Cell 2, treated	Cell 3, treated
Weeks	*Daily*	*ml*	*ml*	*ml*
Start	Cycled	145	70	80
3	do	139	213	228
9	4-hr charge, 20-hr stand	329	329	336
16	do	493	477	483
22	do	301	303	296
27	do	228	226	260
Total, ml		1, 635	1, 618	1, 683
Average water per week, ml		60	60	62

Table 27. *Water consumption of battery 4 over a 27-month period after treating cells 1 and 2 with mixture D*

Time	Cycle condition	Water consumption by—		
		Cell 1, treated	Cell 2, treated	Cell 3, untreated
Weeks	*Daily*	*ml*	*ml*	*ml*
Start	Cycled	80	90	90
3	do	220	191	209
9	4-hr charge, 20-hr stand	327	340	272
16	do	502	483	488
22	do	308	305	276
27	do	243	250	232
Total, ml		1, 660	1, 659	1, 567
Average water per week, ml		61	61	58

TABLE 28. *Water consumption of battery 6 over a 27-week period after treating cells 2 and 3 with mixture E*

Time	Cycle condition	Water consumption by—		
		Cell 1, untreated	Cell 2, treated	Cell 3, treated
Weeks	*Daily*	*ml*	*ml*	*ml*
Start	Cycled	85	70	60
3	do	207	233	228
9	4-hr charge, 20-hr stand	306	324	318
16	do	453	450	482
22	do	302	283	297
27	do	231	204	238
Total, ml		1, 584	1, 564	1, 623
Average water per week, ml		58	58	60

TABLE 29. *Specific gravity of battery 1 after treating cells 1 and 3 with mixture A, placed on a cycle of 4-hour charge at 5 amp and 20-hour stand per day, 7 days per week for 26 weeks*

Time	Specific gravity at 28° C					
	Cell 1, treated		Cell 2, untreated		Cell 3, treated	
	Cycle	Full charge	Cycle	Full charge	Cycle	Full charge
Weeks						
Start	-------	1. 253	-------	1. 243	-------	1. 248
6	1. 242	1. 250	1. 227	1. 250	1. 217	1. 245
12	1. 232	-------	1. 217	-------	1. 202	-------
20	1. 212	1. 228	1. 202	1. 223	1. 192	1. 218
26	1. 202	1. 224	1. 192	1. 219	1. 177	1. 204
Loss Cycle	0. 040	-------	0. 035	-------	0. 040	-------
Loss Full charge	-------	0. 029	-------	0. 024	-------	0. 044

TABLE 30. *Specific gravity of battery 2 after treating cells 2 and 3 with mixture B, placed on a cycle of 4-hour charge at 5 amp and 20-hour stand per day, 7 days per week for 26 weeks*

Time	Specific gravity at 28° C					
	Cell 1, untreated		Cell 2, treated		Cell 3, treated	
	Cycle	Full charge	Cycle	Full charge	Cycle	Full charge
Weeks						
Start	-------	1. 258	-------	1. 272	-------	1. 253
6	1. 242	1. 255	1. 272	1. 280	1. 242	1. 255
12	1. 222	-------	1. 262	-------	1. 232	-------
20	1. 207	1. 229	1. 252	1. 264	1. 222	1. 234
26	1. 197	1. 224	1. 247	1. 264	1. 222	1. 234
Loss Cycle	0. 045	-------	0. 025	-------	0. 020	-------
Loss Full charge	-------	0. 034	-------	0. 008	-------	0. 019

Table 31. *Specific gravity of battery 3 after treating cells 2 and 3 with mixture C, placed on a cycle of 4-hour charge at 5 amp and 20-hour stand per day, 7 days per week for 26 weeks*

Time	Specific gravity at 28° C					
	Cell 1, untreated		Cell 2, treated		Cell 3, treated	
	Cycle	Full charge	Cycle	Full charge	Cycle	Full charge
Weeks						
Start	-------	1.253	-------	1.258	-------	1.268
6	1.247	-------	1.237	-------	1.242	-------
	-------	1.260	-------	1.255	-------	1.260
12	1.232	-------	1.222	-------	1.227	-------
20	1.212	-------	1.212	-------	1.222	-------
	-------	1.234	-------	1.239	-------	1.234
26	1.212	-------	1.207	-------	1.212	-------
	-------	1.234	-------	1.229	-------	1.234
Loss Cycle	0.035	-------	0 030	-------	0.030	-------
Loss Full charge	-------	0.019	-------	0.029	-------	0.034

Table 32. *Specific gravity of battery 4 after treating cells 1 and 2 with mixture D, placed on a cycle of 4-hour charge at 5 amp and 20-hour stand per day, 7 days per week for 26 weeks*

Time	Specific gravity at 28° C					
	Cell 1, treated		Cell 2, treated		Cell 3, untreated	
	Cycle	Full charge	Cycle	Full charge	Cycle	Full charge
Weeks						
Start	-------	1.255	-------	1.265	-------	1.260
6	1.242	-------	1.252	-------	1.272	-------
	-------	1.260	-------	1.265	-------	1.275
12	1.222	-------	1.232	-------	1.262	-------
20	1.217	-------	1.222	-------	1.250	-------
	-------	1.234	-------	1.239	-------	1.259
26	1.207	-------	1.222	-------	1.232	-------
	-------	1.234	-------	1.239	-------	1.254
Loss Cycle	0.035	-------	0.030	-------	0.040	-------
Loss Full charge	-------	0.021	-------	0.026	-------	0.006

Table 33.—*Specific gravity of battery 6 after treating cells 2 and 3 with mixture E, placed on a cycle of 4-hour charge at 5 amp. and 20-hour stand per day, 7 days per week for 26 weeks*

Time	Specific gravity at 28° C					
	Cell 1, untreated		Cell 2, treated		Cell 3, treated	
	Cycle	Full charge	Cycle	Full charge	Cycle	Full charge
Weeks						
Start	-------	1.272	-------	1.259	-------	1.259
6	1.277	-------	1.242	-------	1.242	-------
	-------	1.285	-------	1.260	-------	1.260
12	1.267	-------	1.227	-------	1.227	-------
20	1.252	-------	1.212	-------	1.212	-------
	-------	1.259	-------	1.229	-------	1.229
26	1.242	-------	1.202	-------	1.202	-------
	-------	1.254	-------	1.224	-------	1.224
Loss Cycle	0.035	-------	0.040	-------	0.040	-------
Loss Full charge	-------	0.018	-------	0.035	-------	0.035

Tables 34, 35, 36, 37, and 38 show the results of short high rate discharges with rest periods in between. It must be pointed out that open-circuit voltages are essentially normal after each cycle. Particular attention is called to the last cycle where the immediate open-circuit voltages are given showing the recuperative power of the battery. The results again show no significant difference between treated and untreated cells. The tests outlined above were on unused batteries sulfated from long wet shelf life.

An additional test was carried out on a used 6-v, 100-amp-hr automobile battery which would not hold its charge. Characteristics of this battery were determined before treatment and again after treating cells 2 and 3 with mixture C of table 2. Table 39 summarizes the 300-, 200-, 100-, and 50-amp constant-current successive discharge before and after treatment. The battery then stood 16 hours, and the same discharge was repeated. It was found that 200 amp was the highest current that could be maintained. A careful survey of this table shows there is a voltage rise each time the current is reduced. This shows the remarkable recuperative power of a battery regardless of its condition, provided it is mechanically sound. As seen here, there is no significant improvement in the treated cells. For a good battery the voltage should be near 2.00 v and not reversed. Table 40 summarizes the stand characteristics of the same battery. Again, there was no improvement shown in its ability to retain a charge.

Table 34. *Test on recuperative power of battery 1 after cells 1 and 3 were treated with mixture A when subjected to a 300-amp constant-current load for 1 minute followed by 15 minutes on open circuit and the cycle repeated*

Cycle	Discharge time	Cell 1, treated		Cell 2, untreated		Cell 3, treated	
		Open circuit	Closed circuit	Open circuit	Closed circuit	Open circuit	Closed circuit
	min	*v*	*v*	*v*	*v*	*v*	*v*
1	----	2.08	----	2.08	----	2.08	----
	Start	----	1.05	----	1.30	----	1.20
	0.5	----	0.6	----	1.14	----	1.05
	1.0	----	−.2	----	1.00	----	0.88
2	----	2.03	----	2.03	----	2.02	----
	Start	----	.5	----	1.10	----	.9
	0.5	----	Reversed	----	1.06	----	1.02
3	----	2.03	----	2.03	----	2.02	----
	Start	----	0	----	1.00	----	1.00
Final open circuit	----	2.03	----	2.02	----	2.02	----

Table 35. *Test on recuperative power of battery 2 after cells 2 and 3 were treated with mixture B when subjected to a 300-amp constant-current load for 2 minutes followed by 15 minutes on open circuit and the cycle repeated*

Cycle	Time	Cell 1, untreated		Cell 2, treated		Cell 3, treated	
		Open circuit	Closed circuit	Open circuit	Closed circuit	Open circuit	Closed circuit
	min	*v*	*v*	*v*	*v*	*v*	*v*
1	------	2.08	------	2.08	------	2.08	------
	Start	------	1.50	------	1.34	------	1.65
	0.5	------	1.44	------	1.23	------	1.64
	1.0	------	1.40	------	1.04	------	1.62
	1.5	------	1.32	------	0.66	------	1.61
	2.0	------	1.23	------	.20	------	1.60
2	------	2.03	------	2.06	------	2.04	------
	Start	------	1.36	------	.94	------	1.63
	0.5	------	1.20	------	−.60	------	1.6
	1.0	------	1.06	------	−1.00	------	1.56
3	------	2.03	------	2.06	------	2.04	------
	Start	------	1.30	------	0.40	------	1.60
	0.5	------	1.03	------	−1.09	------	1.56
Immediate	------	1.96	------	1.68	------	2.0	------
15 min	------	2.03	------	2.05	------	2.03	------

Table 36. *Test on recuperative power of battery 3 after cells 2 and 3 were treated with mixture C when subjected to a 300-amp constant-current load followed by 15 minutes on open circuit with cycle repeated*

Cycle	Time	Cell 1, untreated		Cell 2, treated		Cell 3, treated	
		Open circuit	Closed circuit	Open circuit	Closed circuit	Open circuit	Closed circuit
	min	*v*	*v*	*v*	*v*	*v*	*v*
1	-----	2.08	------	2.08	------	2.08	------
	Start	------	1.44	------	1.06	------	0.72
	0.5	------	1.30	------	0.74	------	−.2
2	------	2.05	------	2.04	------	2.03	------
	Start	------	1.34	------	.80	------	0
	0.3	------	1.28	------	.50	------	−.8
3	------	2.05	------	2.03	------	2.03	------
	0.1	------	1.3	------	.2	------	−1.10
Immediate	------	2.01	------	2.0	------	1.90	------
15 min	------	2.04	------	2.03	------	2.03	------

Table 37. *Test on recuperative power of battery 4 after cells 1 and 2 were treated with mixture D when subjected to a 300-amp constant-current load followed by 15 minutes on open circuit with cycle repeated*

Cycle	Time	Cell 1, treated		Cell 2, treated		Cell 3, untreated	
		Open circuit	Closed circuit	Open circuit	Closed circuit	Open circuit	Closed circuit
	min	*v*	*v*	*v*	*v*	*v*	*v*
1	------	2.08	------	2.08	------	2.08	------
	Start	------	1.26	------	1.22	------	1.43
	0.5	------	1.08	------	1.02	------	1.39
	1.0	------	0.82	------	0.72	------	1.32
2	------	2.03	------	2.05	------	2.07	------
	Start	------	1.04	------	.84	------	1.36
	0.5	------	0.54	------	−.10	------	1.26
3	------	2.03	------	2.05	------	2.07	------
	Start	------	.82	------	.40	------	1.30
	0.5	------	.20	------	−.24	------	1.24
Immediate	------	1.86	------	1.78	------	2.03	------
15 min	------	2.02	------	2.03	------	2.06	------

Table 38. *Test on recuperative power of battery 6 after cells 2 and 3 were treated with mixture E when subjected to a 300-amp constant-current load followed by 15 minutes on open circuit with cycle repeated*

Cycle	Time	Cell 1, untreated		Cell 2, treated		Cell 3, treated	
		Open circuit	Closed circuit	Open circuit	Closed circuit	Open circuit	Closed circuit
	min	*v*	*v*	*v*	*v*	*v*	*v*
1	------	2.08	------	2.08	------	2.08	------
	Start	------	1.24	------	1.24	------	0.92
	0.5	------	1.04	------	0.66	------	.62
	.75	------	0.86	------	.30	------	.30
2	------	2.07	------	2.03	------	2.03	------
	Start	------	1.05	------	.50	------	.40
3	------	2.07	------	2.03	------	2.03	------
	Start	------	1.00	------	.32	------	.32
	0.5	------	0.86	------	0	------	.10
Immediate	------	1.94	------	1.84	------	1.86	------
15 min	------	2.07	------	2.03	------	2.03	------

Table 39. *Results of 300-, 200-, 100-, and 50-amp successive discharges on a discarded 6-v automobile battery that would not hold its charge, before treatment and after treating cells 2 and 3 with mixture C*

Current	Time of discharge	Cell 1, untreated		Cell 2		Cell 3	
		Before	After	Before treatment	After treatment	Before treatment	After treatment
amp	*min*	*v*	*v*	*v*	*v*	*v*	*v*
300	Start	1.63	------	1.60	------	1.63	------
	0.5	1.61	1.56	1.55	1.58	1.61	1.58
	1.5	1.55	1.48	1.45	1.50	1.55	1.40
	2.0	1.51	1.40	------	------	------	------
	2.5	------	------	1.22	1.29	1.45	1.34
	3.0	1.40	1.33	1.00	1.20	1.25	1.19
200	3.5	------	------	------	------	------	------
	3.75	1.60	1.50	1.24	1.27	1.59	1.40
	4.0	------	1.50	0.6	0.6	------	1.35
100	4.25	------	------	------	------	------	------
	4.5	1.74	1.70	1.18	.4	1.74	1.62
	5.0	------	1.69	−0.2	Reversed	------	1.62
50	5.0	------	------	------	------	------	------
	5.1	1.90	1.81	1.44	1.24	1.90	1.79
	6.0	1.82	1.80	0.55	−0.1	1.82	1.76
	10.0	1.81	1.78	−.47	−.5	1.81	1.74
	16	1.77	------	−.41	------	1.77	------
Repeat discharge after overnight stand							
200	0.25	1.52	1.48	−1.05	−1.00	1.44	1.43
100	.25	------	------	------	------	------	------
	.75	------	1.66	------	−0.6	------	1.58
50	.75	------	------	------	------	------	------
	1.00	------	1.77	------	−.45	------	1.72
	2.00	------	1.76	------	−.45	------	1.71

Table 40. *Results of stand test on a discarded 6-v automobile battery before and after treating cells 2 and 3 with mixture C*

Time	Drop in specific gravity at 28° C					
	Cell 1, untreated		Cell 2		Cell 3	
	Initial	Final	Before treatment	After treatment	Before treatment	After treatment
Days						
3	0.024	0.050	0.194	0.209	0.030	0.060
7	.049	.084	.194	.219	.060	.094

As a further study of the possible effect of various mixtures of magnesium and sodium sulfates on self-discharge, tests were made on negative plates taken from a discarded battery. These plates were charged in sulfuric acid of specific gravity 1.050 against pure-lead positives. After charge they were placed horizontally in tanks of sulfuric acid of specific gravity 1.350 and inverted glass tubes closed at the top and initially completely filled with acid were placed over portions of the plates to collect the gas given off in a 24-hour period. Then the plates were taken out and recharged in sulfuric acid of specific gravity 1.275 with the various mixtures of magnesium and sodium sulfates outlined in table 41 and the test repeated. The amount of gas collected is an indication of the local action on the plate. Table 41 gives a summary of the results. There is no significant reduction in local action due to treatment with magnesium or sodium sulfates.

Table 41. *Measurement of gas evolution from negative plates on 24-hour stand in sulfuric acid of specific gravity 1.350 before and after treating with mixtures of sodium sulfate and magnesium sulfate*

Plate [a]	Anhydrous material in 30 g of material		Milliliters of gas from portions of plates—			
			Upper		Lower	
	Sodium sulfate	Magnesium sulfate	Before treatment	After treatment	Before treatment	After treatment
	%	%				
1	None	None	75.6	74.9	14.4	20.2
2	None	None	27.2	30.0	29.0	34.9
3	80	20	79.1	82.0	10.4	15.4
4	80	20	30	69	20.8	22.9
5	60	40	70.3	45.5	20.0	16.3
6	60	40	26.0	39.0	12.8	18.6
7	40	60	50.5	35.0	20.3	18.4
8	40	60	71.8	54.2	20.0	31.9
9	20	80	77.7	88.0	41.8	55.8
10	20	80	51.0	51.5	24.2	27.4
11	None	100	45.4	45.5	21.1	20.6
12	100	None	71.2	73.0	23.7	30.6

[a] Plates 5, 7, 8, upper sections badly sulfated. Did not recharge during treatment.

Another series of tests was carried out by storing batteries for a period of 1 year and then reservicing them. These batteries were reserviced as follows: Filled with sulfuric acid of specific gravity 1.280, treated with a commercial preparation of magnesium and sodium sulfate, treated with a saturated water solution of sodium sulfate, and treated with a saturated water solution of magnesium sulfate. A summary of the results is given in figures 4, 5, and 6.

Figure 4 gives variation in capacity at the 5-hour rate. This shows the standard procedure of filling with acid is superior. Similarly, figure 5 shows the 5-minute rate, and figure 6 the cycle life. In all cases there is no improvement shown by the use of combinations of magnesium and/or sodium sulfate.

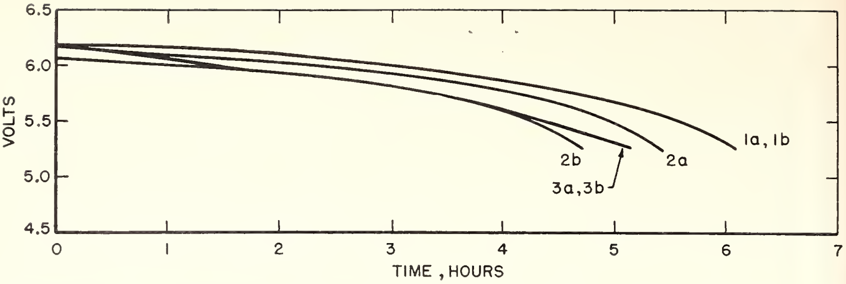

FIGURE 4. *Capacities of batteries stored 1 year reserviced, both treated and untreated, discharged at the 5-hour rate*

Cell	Composition of additive			Time of treatment
	Na_2SO_4	$MgSO_4$	H_2O	
	Percent	*Percent*	*Percent*	
1a	--------	--------	----	Not treated.
1b	--------	--------	----	Do.
2a	44. 2	29. 3	25. 8	Before storage.
2b	44. 2	29. 3	25. 8	After storage.
3a	(1)	--------	----	Do.
3b	--------	(1)	----	Do.

[1] Saturated solution.

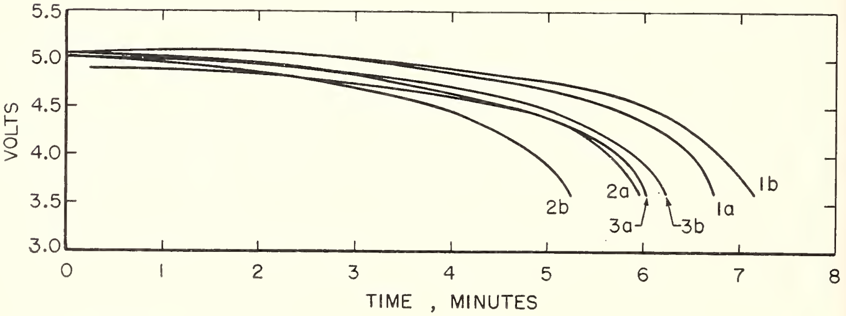

FIGURE 5. *Capacities of batteries stored 1 year reserviced, both treated and untreated, discharged at the 5-minute rate*

Cell	Composition of additive			Time of treatment
	Na_2SO_4	$MgSO_4$	H_2O	
	Percent	*Percent*	*Percent*	
1a	--------	--------	----	Not treated.
1b	--------	--------	----	Do.
2a	44. 2	29. 3	25. 8	Before storage.
2b	44. 2	29. 3	25. 8	After storage.
3a	(1)	--------	----	Do.
3b	--------	(1)	----	Do.

[1] Saturated solution.

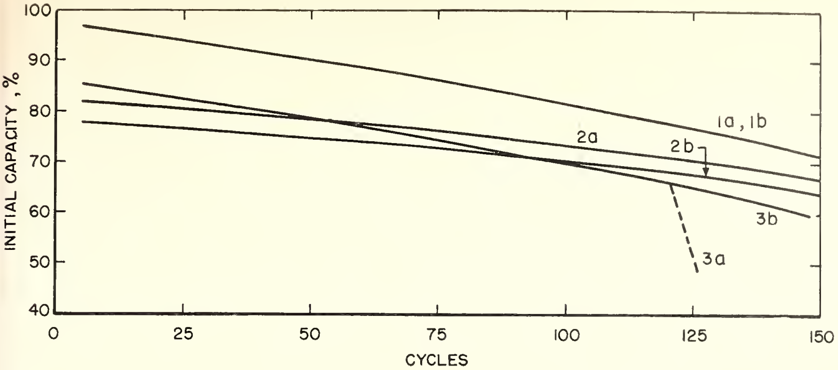

FIGURE 6. *Capacities of batteries stored 1 year reserviced, both treated and untreated, during cycle life discharged at 5-hour rate*

Cell	Composition of additive			Time of treatment
	Na_2SO_4	$MgSO_4$	H_2O	
	Percent	*Percent*	*Percent*	
1a	--------	--------	----	Not treated.
1b	--------	--------	----	Do.
2a	44.2	29.3	25.8	Before storage.
2b	44.2	29.3	25.8	After storage.
3a	(1)	--------	----	Do.
3b	--------	(1)	----	Do.

[1] Saturated solution.

VI. Discussion of Results

In the past the various commercially prepared additives containing magnesium and sodium sulfates were referred to simply as a mixture of Epsom salt and Glauber's salt. However, as noted in Letter Circulars and various statements issued by the Bureau covering these materials, the present commercially prepared solid additives usually contain anhydrous or partially hydrated magnesium and sodium sulfates, so that strictly speaking they could not be described as containing Epsom salt or Glauber's salt. However, these materials in water solution will behave the same as Epsom salt or Glauber's salt, except for the quantity of the corresponding anhydrous salt.

Tests have been made with hydrated and dehydrated magnesium and sodium sulfates, and the results show that no improvement is obtained when these additives are used. Several commercial preparations have been analyzed and used to fill in the percentage range covered. In no case has there been any improvement in battery performance.

The investigation has covered the following subjects, which are usually set up as claims for additives:

1. *Change in specific gravity.* There is an increase in specific gravity proportional to the amount of increase in sulfate ion.

2. *Reduction or elimination of troublesome sulfation.* True indication of this would be found in a marked improvement in capacity at normal discharge rates. Increases in specific gravity after charge

must be greater than the increase which is directly ascribable to addition of the additive itself. Tests have now shown neither of these to be increased.

3. *Retention of charge.* For a battery to show an improvement in retention of charge there must be a reduction in self-discharge and/or local action. Tests show no evidence of such a reduction.

4. *Reduced operating temperatures.* In order to lower the operating temperature of a sulfated battery there must be a reduction of sulfate in the plates. There has been no significant difference in temperature between treated and untreated cells.

5. *Reduction in water consumption.* This is based upon the assumption that the sulfate will be reconverted and the batteries will operate at a lower temperature. Test results on a number of batteries showed no difference between water consumption of treated and untreated batteries.

6. *Capability of recharge after being maintained for long periods in a partially charged condition.* This is a condition conducive to sulfation. Tests showed that there is no difference between treated and untreated batteries in their ability to recharge.

7. *High-rate capacity improved.* An impression of such an improvement is given by tests made by turning the motor with a battery-operated starter after the battery has been treated and given some charge. Then, after a rest period, the performance may be repeated. The layman is always astounded at the battery giving several supposedly full discharges with short intervals of rest in between. Tests have been made that show there is no improvement in high rate capacity with treated cells. In addition, it is shown that repeated high rate discharges are normal to a storage battery, and this is not changed by the additive.

8. *Effect of cycle.* Some proponents of the additives claim no effect will be shown by cycling a battery, whereas others say it takes a number of cycles to show an improvement. Tests showed that there is no improvement by cycling over that normally obtained in untreated batteries. Tests on a schedule simulating car operation have been made, and the results show no difference between treated and untreated batteries.

9. *Prolonged battery life.* This is rather vague as battery life depends largely on conditions of use. Many batteries are discarded or replaced prematurely. If batteries are checked and any mechanical defects corrected as required by the manufacturers of the additives, they will give additional life without the use of additives. In other cases the discarded batteries may show conditions as indicated in figures II and III. It is obvious that such batteries cannot be helped or the life prolonged by the use of additives.

10. *Prevention of freezing.* This is often used as a claim. Any change in freezing point of the electrolyte must be due to a change in specific gravity. At any temperature where the battery will operate the starter the specific gravity will be high enough to prevent freezing whether or not an additive is used.

11. The statements regarding making lights brighter and spark hotter are misleading. It is well known that the lights will become brighter at high engine speeds and after the car has been running a while, even though the battery is not fully charged. The voltage and current furnished to both the lights and ignition system come primarily from the generator and not the battery while the car is in operation.

The layman is told his battery is "dead" when it fails to perform. No real definition has been established for this term. Some mechanics use a hydrometer reading, others a cell tester and still others resort to a quick charge for a short interval and then use either the hydrometer or cell tester to determine the condition of the battery.

Without a full knowledge of battery principles, either the hydrometer readings or cell tester may lead to erroneous conclusions. Let us consider two conditions that may be present, i. e., (1) a battery with sufficient electrolyte to measure, (2) a battery with the electrolyte level below the tops of plates.

In the first case, the battery is in a discharged condition but has sufficient electrolyte to obtain hydrometer readings. If this battery is placed on charge at a high rate for approximately 30 minutes, there will be very little change in hydrometer readings. This condition is common in storage-battery operation and should not be construed to mean that the battery is not taking the charge. When a discharged battery is first placed on charge most of the electric energy is used to convert the lead sulfate to active material and sulfuric acid. As there is practically no gas evolution there is no stirring action present to mix the sulfuric acid formed at the surface of the plates with the rest of the electrolyte of lower specific gravity. Consequently, the sulfuric acid streams down the surface of the plate and settles to the bottom, because it is heavier than the remainder of the electrolyte. It may take some time for sufficient gas to be developed to stir the electrolyte enough to form a homogenous solution. Hydrometer readings are made on samples of electrolyte at the top of the cell. It is easily seen that such a reading does not show a true picture of the condition of the battery until the electrolyte is thoroughly mixed.

In the second case, water is added to the cell before charging. The mixing of the water with the electrolyte is not complete until the charging period is almost completed, at which time gas evolution is sufficiently strong to thoroughly mix the solution. Thus any readings taken early in the charge would lead to an erroneous conclusion.

Figure 7 shows the voltage, specific gravity, and high-rate charging current on a normal 108-amp-hr battery that was discharged at the 6-hour rate to 1.70 v per cell and then given a quick charge.

Placing a battery on charge at a constant current, approximating the 20-hour rate, and periodically measuring the voltage with an accurate 1,000-ohm/v voltmeter is the best method of determining whether a battery is "dead." If there is a continuous voltage rise during the charge, the battery is not considered dead.

After a battery or cell has been charged, its ability to retain this charge rests upon its mechanical and chemical condition. If there is an internal short, the cell will lose its charge rapidly. If there is high local action, the same thing will be true. In either case the use of additives has shown no beneficial effects.

In a large percentage of the procedures used in adding additives to discarded batteries two conditions are included, i. e.

1. The battery is nearly dry and needs a large amount of water to bring the level over the top of the plates.
2. There are mechanical defects that must be repaired by dismantling the battery and either replacing separator or plates and generally disturbing the equilibrium of the system.

As discussed earlier, the water treatment is the procedure long recognized as best adapted to the removal of substantial portions of the

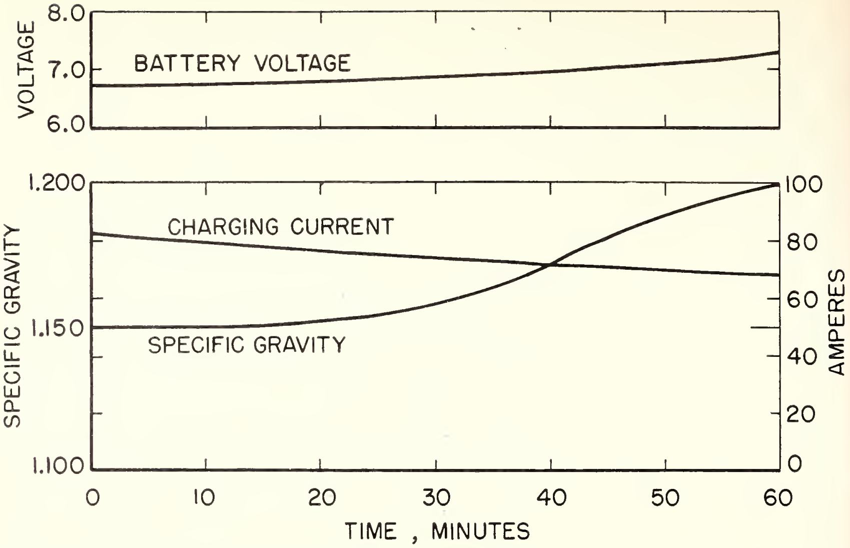

Figure 7. *Voltage, specific gravity, and charging current during the first hour of a high-rate charge on a discharged battery.*

sulfate from the plates. In the first case, this essentially resolves itself into such a treatment. The end result will be the same with or without the additive.

In both cases, air has had an opportunity to play a part in the overall reaction. In item (2), particularly, the plates are exposed to air. In such cases some oxidation is taking place that changes the composition of the plate to a mixture of lead oxides and sulfate. In general, after a repair operation the plates are more easily converted to lead and lead dioxide. The addition of water or low-gravity sulfuric acid is normal procedure. Thus the battery responds equally well with or without any additives. In such a procedure the battery is charged at the 20-hour rate for approximately 50 hours.

VII. Field Tests

The above results and discussion are based on simulated tests made in the laboratory. As a further check on the correctness of these tests, actual field tests were carried out by the Ordnance Corps, Department of the Army, on 200 automotive batteries at various depots throughout the country. These four groups of batteries were all mechanically sound and in various stages of life, as follows: (1) 50 batteries ready for salvage, (2) 50 batteries still in service, (3) 50 batteries new but never put in service, and (4) 50 batteries new but never put in service.

The batteries in groups (1), (2), and (3) were treated with mixture C, and those in group (4) were tested as controls. Monthly checks were made to determine the condition of the batteries. The results of these checks are given in tables 42, 43, and 44. Table 42 summarizes the failures, table 43 gives variation in specific gravity, and table 44 summarizes the results as to satisfactory performance. From these tests it was concluded that there were no beneficial effects gained by using mixture C.

Table 42. *Number of failures out of 50 batteries in each group when treated with mixture C and field tested for 6 months*

Battery condition	Months						Total percentage of failure
	1	2	3	4	5	6	
							%
Mechanically sound, but ready for salvage (treated)	4	12	3	2	2	0	46
Mechanically sound and still in service (treated)	2	4	3	0	0	4	26
New batteries never prepared for service (treated)	0	1	1	1	1	0	8
New batteries never prepared for service (untreated)	0	0	0	0	1	0	2

Table 43. *Percentage variation in specific gravity at end of 6-month period on batteries treated with mixture C*

	Group 1, treated	Group 2, treated	Group 3, treated	Group 4, untreated
	%	%	%	%
Increase	34	32	35	40
Same	24	23	21	19
Lower	42	45	44	41

Table 44. *Percentage of satisfactory and unsatisfactory batteries after inspection at 6-month period on batteries still in service*

Condition	Group 1, treated	Group 2, treated	Group 3, treated	Group 4, untreated
	%	%	%	%
Satisfactory	47	45	64	75
Unsatisfactory	53	55	36	25

VIII. Conclusions

In the course of this investigation five batteries comprising 15 cells were subjected to an extended series of laboratory tests to determine the effect of adding specified amounts of sodium and magnesium sulfates in varying proportions. These batteries were in sound mechanical condition but were sulfated to the extent that their initial capacity after prolonged charging was about two-thirds of their rated capacity. Ten cells were treated with additives, and the remaining five were not treated.

Tables 4 to 31 show no significant differences in the operating characteristics of the cells that were treated as compared with those not treated. Obviously, the condition of a group of batteries in a sulfated state is not uniform, but the average results of 15 cells covering all tests show a remarkable uniformity in the behavior of treated and untreated cells. The averages are given in table 45.

It appears from table 45 that both sodium and magnesium sulfates are ineffective in improving the condition of the batteries or in prolonging their life.

TABLE 45. *Average results of all tests, tables 4 to 31*

	Untreated cells	Treated cells
Capacity rating	120 amp-hr	120 amp-hr
Initial capacity, all cells	64 amp-hr	
Initial capacity of treated cells:		
Before treatment	54 amp-hr	
After treatment		48 amp-hr.
Final capacity after 6 months:		
Untreated cells	13 amp-hr	
Treated cells		14 amp-hr.
Voltage at 1 minute, per cell, 300-amp load	1.45v	1.12 v.
Recuperative voltage per cell, 1 minute after 300-amp load	2.04 v	2.03 v.
Water consumption during 27-week test, per cell	58 ml/week	59 ml/week.
Decrease in specific gravity during 4-day stand	0.006	0.007.
Points lost at full charge during cycle test, 26 weeks	0.020	0.028.
Cell temperature at end of 8th charge	39.0°C	38.4°C.

From the extensive laboratory and field tests covered in this investigation the fact remains that there has been no improvement found in the use of a series of commercial and specially prepared additives composed of magnesium and sodium sulfates either hydrated, partially hydrated or anhydrous.

The indiscriminate addition of these solutions and compounds to a battery is not advisable, although in some cases no particular harm may be done. It is a well-recognized principle in battery operation that acid should be added only to replace that which has been spilled or, in rare instances, to adjust the specific gravity to the required standard after the completion of a full charge. Materials containing iron, copper, mercury, nitrates, chlorides, glycerine, or alcohols should never be added to batteries as they will cause permanent damage to the battery.

The findings reported here are not confined to the Bureau's experience. Investigations by other laboratories, both Government and industrial, have arrived at similar conclusions on the various points discussed in this publication.

IX. References

T. Tiku, Behavior of the discharged plates in the lead storage battery. Residual capacity of positive plates. J. Electrochem. Assoc. Japan **8,** 16–20 (1940).

Hoehne, Additions to sulfuric acid of lead storage batteries, Chem. Fabrick. p. 259 (1936).

Hoehne, Das Verhalten gepasteter Bleisammler wahrend u. nach langerer, Nichthenutzung Archiv fur Metallkunde, p. 185–191 (May 1949).

B. N. Kabanov, Crystallization of lead sulphate and the thickness of the passive layer on lead. Acad. Sci. U. S. S. R. Compt. rend. **31,** 581–4 (1941).

A. C. Zacklin, Effect of temperature on the rate of self discharge of lead acid storage batteries. Trans. Electrochem. Soc. **82,** 365–71 (1942).

G. W. Vinal and D. N. Craig, Solubility of lead sulphate in solutions of sulfuric acid, determined by dithizone with photronic cell, J. Research NBS **22,** 55 (1939) RP1165.

G. W. Vinal and G. N. Schramm, Storage battery electrolytes, Trans. Am. Institute of Elect. Eng. **44,** p. 228 (1925).

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