LEAD INDUSTRIES ASSOCIATION
60 EAST 42ND STREET
NEW YORK 17, N.Y.

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SUBJECT: DEVELOPMENTS IN STORAGE BATTERIES

To Members of the Lead Industries Association:

We believe that most of the members will be interested in the attached paper which describes developments in lead-acid storage batteries in recent years. It appears effectively to answer occasional criticism leveled at the battery industry by pointing out the really important improvements in batteries which have been accomplished by battery manufacturers and their suppliers.

Additional copies are available as long as our supply lasts.

Very truly yours,

Robert L. [illegible]

Secretary.

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DEVELOPMENTS IN STORAGE BATTERIES*

By

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The lead-acid storage battery has been the subject of continuing technical development. There is scarcely any component part that has not recently been improved by this evolutionary process. Few people have been aware of this since a battery is difficult to glamorize. It still remains the silent black box, mysterious and unpredictable.

Whereas other components of the car are said to "wear-out", the battery is always referred to as having "failed". Unfortunately, no one has developed a satisfactory device to warn the driver of the impending exhaustion of the storage battery so that when it has faithfully delivered its last watt-second of energy, the owner regards it as a sort of betrayal and mentally holds to the feeling that the manufacturer is entirely responsible. He forgets that the battery is not the true source of electrical energy on the car, but that the generator is and that the battery only stores a part of the energy which has been given to it and, being an electromechanical device, will slowly lose that over a period of time.

The battery's quiet faithfulness and its willingness to deliver its power until exhausted is therefore both its strength and its weakness. The electrical engineers regard the battery as an outlaw in the electrical system because it is sensitive to temperature changes and its voltage varies over a wide range when on charge and discharge. They have learned to live with it amazingly well, however, and it seldom fails them.

The battery industry and its suppliers have spent, and are yet committed to spend, millions of dollars to enable the lead-acid battery to meet the new demands which are constantly being made upon it for greater wattage output per pound of weight, for greater reliability over a wider temperature range and for greater service per dollar of cost. Had this development effort not succeeded, our batteries would be five times as large, five times as heavy and cost four times as much as they do today.

12-Volt Batteries

The recent shift from 6 to 12 volt electrical systems has had a tremendous impact on the battery industry. It has brought into being, 15 new SAE battery group sizes with capacity ratings ranging from 45 to 70 ampere-hours in 5 ampere-hour increments, with four different terminal arrangements.

The automotive body engineers have found it necessary, because of styling demands, increases in engine sizes, and the installation under the hood of power brake, air conditioning and other control equipment, to specify batteries of a variety of configurations and terminal locations. So, that instead of 6 batteries or less, which might have been made to cover the industry's requirements, we already have 15 with probably more to come. This is quite understandable from the viewpoint of the automotive engineer, but it has placed a heavy burden on the battery manufac-

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turers and will place a heavy burden on all battery merchandizers of replacement batteries who must now add to their stocks the new 12-volt sizes in addition to the long list of 6-volt sizes accumulated over the years.

This situation of increased battery inventory of a multiplicity of types, many of which are slow moving, has emphasized the need for a battery construction which can be stored for long periods of time without deterioration. Such a battery is known as a "Dry-charged" battery. The industry has built such a battery for military vehicle applications for many years but it was considered too costly for general automotive use or replacement sale.

Dry-Charged Batteries

The dry-charged construction requires that the battery plates be electro-formed in sulfuric acid, then water-washed and dried. The negative plates must be dried in such a way that the water be withdrawn from the spongy lead of the plates without exposing them for any appreciable time to the oxygen of the air. Oxygen combines rapidly with moist sponge lead and this oxidation, with great evolution of heat energy, results in the total loss of the chemical charge in the plates. The withdrawal of moisture from the negative plates must therefore be accomplished by the use of vacuum driers, or by means of ovens with controlled inert gas atmospheres. Positive plates may be dried in atmospheric air ovens at controlled temperature below 250° F. The bone-dry plates must then be assembled with bone-dry separators.

Wood veneer separators, chemically treated to remove the resins, were formerly the standard of the industry. Port Orford Cedar and Douglas Fir species of wood were once universally used in the separators for wet battery construction but these could not be dried for use in dry-charged batteries because they would shrink and crack. The only separator available for dry-charged construction was, for many years, the very satisfactory but expensive porous rubber type.

Plastic Separators

During World War II, the scarcity of natural rubber stimulated research to perfect a plastic equivalent of the porous rubber separator. The resulting bone-dry plastic separators, after a long period of development and a heavy investment in automatic processing equipment, have now become commercially plentiful at a competitive price with wood and have practically completely replaced wood as a separator material. These plastic separators are made of a sheet of felted cellulose fibers impregnated with acid-resisting, thermo-setting phenolic resins. This saturated and partially dried web is then embossed with ribbing on one face and is heat-cured into semi-rigid sheets which are cut to separator size. In some cases the ribs alone, or the entire ribbed face of the separator, which must rest in contact with the corrosive positive plate, is coated with additional reinforcing and protective resin.

The separators are also impregnated with an organic chemical wetting agent to facilitate rapid penetration of the acid into, and the displacement of air from, the pores of the separator when the battery is converted from the dry to the wet state. This makes possible the instant activation of the dry-charged battery upon the addition of acid.

Compared to wood, the plastic separators are more porous, have a lower ohmic resistance, and are more acid-and oxidation-resistant. They are also more uniform in texture than wood. All this adds up to better cold temperature cranking ability and higher heat resistance for the batteries, whether wet or dry-charged.

The plastic separators are sometimes provided with resin-bonded glass fiber mats adhered to their ribbed faces to help prevent the lead dioxide active material of the positive plates from shedding away from the plate and becoming detached and inactive.

Another type of separator which has had successful development, consists of a thin sheet of diatomaceous earth bonded with rubber latex and laminated with a mat of glass fibers.

Batteries constructed with the new types of plastic separators have been in large scale production for sufficient time now to demonstrate their superiority and their versatility in both wet and dry battery construction.

After assembly, dry-charged batteries must be protected from the entrance of moisture since moisture catalyzes the oxidation of the sponge lead on the negative plates with resulting loss of charge. Temporary vent plug seals are therefore used to keep moisture out of the cells so as to prolong the retention of charge.

In the dry-charging process, battery plates will retain about 90% of their rated 20-hour discharge capacity. During prolonged storage they may slowly lose some of their charge, depending upon conditions of storage. Under conditions encountered in normal distribution, a relatively dry atmosphere and an even temperature are conducive to good charge retention.

Acid Electrolyte Supply

The dry-charged battery requires that a supply of very pure battery-grade sulfuric acid electrolyte of accurate specific gravity be available at the time the battery is made wet. This has led to the development of ingenious plastic containers and unit packages of sulfuric acid electrolyte for filling the dry batteries at the time of sale. This is, of course, not without its penalty of extra cost. The convenience of not having to maintain wet batteries in a charged conditon seems to warrant the expense, however, as judged by the growing popularity of the dry-charged construction.

The question of how long dry-charged batteries may be stored is often asked but is difficult to answer with certainty. It will depend on the original processing of the plates, the care used to insure dryness of separaters and plates in assembly and will depend upon the ambient atmosphere provided for storage. Slow loss of charge of the negative plates is the principal deterioration likely to occur, but if it should occur this will not reduce the battery's life expectancy after it is made wet but will affect only the initial capacity obtainable from the battery when it is filled with acid. Dry-charged batteries stored under optimum conditions have been known to retain a high percentage of their charge for several years. However, it is not safe to depend upon this.

When making the dry-charged battery wet, there are several important conditions which should be observed. First, both battery and acid should be above 60°F when combined. Table I shows the typical effect of combining temperature on the discharge performance of a 6-volt, 100 A.H. battery at 300 amperes to 3-volts, 15 minutes after the battery is filled with acid. This simulates the conditon experienced at the point of sale when a dry-charged battery is "brought to life" by the addition of acid to the cells.

Taking the performance at the 80° F combining temperature as 100%, we see that the relative performance at the lower temperatures to be as indicated.

TABLE I

Effect of Filling Temperature on Performance of Dry-charged Batteries

Temperature of Battery and Acid When Combined	Relative Performance When Discharged at 300 Amperes to 3-Volts, 15 Minutes After Filling.			
	5-Sec. Volts	% of 80°F Performance	Minutes Capacity	% of 80°F Performance
80°F	4.9 Volts	100%	4.75 Min.	100%
50°F	4.65	95	3.2	67
30°F	4.4	90	2.1	44
0°F	3.5	71	0.4	8.4

It will be noted that very useful capacity is obtained when both battery and acid are at 80° F when combined. At lower temperatures the 5-second engine-cranking voltage is not too adversely affected until temperatures below 50° F are reached, but capacity falls off rapidly below 80°F.

A new dry-charged battery, activated at the 80° F temperature simply by filling it with acid of proper specific gravity, will usually crank an engine at temperatures above freezing. However, it has been found that as dry-charged batteries stand in stock under a variety of uncontrolled atmospheric conditions, they may not all respond in the same way when filled with acid. It has been found by experience that the activation of batteries of any age can be greatly accelerated, the initial performance substantially increased and the subsequent charge acceptance on the vehicle improved, if a short activation charge is given the battery at a 25 ampere rate for 12-volt batteries or at a 50 ampere rate for 6-volt batteries. For example, the effect of such a 10 minute activation charge on the initial high-rate discharge 5-second voltage and capacity of a 100 A.H., 6-volt battery is shown in Table II.

TABLE II

Effect of 10 Minute Activation Charge at 50 Amperes on Performance of 6-Volt, 100 A.H. Dry-charged Batteries Filled at Various Temperatures and discharged at 300 Amperes to 3-Volts

Temperature of Battery and Acid When Combined	Performance 15 Minutes After Filling, Including Charging 10 Minutes at 50 Amperes					
	5-Second Volts			Minutes Capacity to 3-Volts		
	Without a 10 Minute Charge	With a 10 Min. Charge	% Gain	Without a 10 Minute Charge	With a 10 Min. Charge	% Gain
80° F	4.9	4.46	1%	4.75	5.5	16%
50° F	4.65	4.9	5	3.2	5.0	56
30° F	4.4	4.9	11	2.1	4.65	122
0° F	3.5	4.5	28	0.4	3.25	713

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It will be noted that very substantial gains in capacity are obtained at temperatures of 50°F and below by the 10 minute activation charge.

If the cells of correctly processed dry-charged batteries were hermetically sealed and moisture kept out, their charge could be retained indefinitely. This could be accomplished at comparatively little cost by proper design of cover and vent.

Pulse-Charging of Wet Batteries

Much of the popularity of the dry-charged battery stems from the difficulty of maintaining wet batteries in a charged condition. In addition to the periodic low-rate charging and the continuous trickle charging methods commonly used, a recent attempt to overcome this loss of charge has resulted in the development of a system of "pulse-charging" which, by means of an electric program clock, automatically connects a low-rate charger to the wet batteries, one at a time, for intermittent charging. This system maintains the batteries in a fully charged condition without subjecting them to excessive overcharging which is known to be detrimental to positive grids.

Whereas the trend has been strongly toward the dry-charged battery for domestic replacement and export batteries, there are those in the industry who believe that the loss of charge, in wet-charged batteries, can be reduced to a point where there would be less need for the more expensive dry-charged battery with its separately packaged acid.

Much of the loss of charge in a wet-charged battery is attributable to the antimony which dissolves from the positive grids during the electroformation process of plate manufacture. The antimony transfers electrolytically to the negative plates where it sets up a local self-discharge of the plates. An alloy less likely to release antimony in harmful amounts would decrease the self-discharge on standing. Much research has resulted from this concept of improvement of charge retention by improving the corrosion resistance of the positive grid metal.

This leads us to another important development in battery construction, the use of corrosion-resistant alloys in the positive plate grids.

Corrosion Resistant Grid Alloys

The positive plate grids support the chemically active and corrosive lead dioxide. Whenever the battery is charged, high concentrations of sulfuric acid are formed at these electrodes and nascent oxygen is also generated there from the decomposition of water by electrolysis. This is an environment extremely conducive to oxidation and corrosion of the positive grid wires.

Surveys which have been made of batteries after failure in service have indicated positive plate grid corrosion as a dominant factor in the termination of battery life. This has been the subject of considerable research over the years and there have come into use today several alloys of basic antimony-lead-tin composition to which other alloying elements have been added. These added elements impart marked corrosion resistance to the grids when subjected to excessive charging. Two additional elements found to be highly effective are arsenic or silver when used alone, or in combination with the basic antimony-lead-tin alloy. Tellurium in combination with silver is also effective with the basic alloy.

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The S.A.E Overcharge Test is a test which has been devised to provide a measure of the ability of a battery's positive plate grids to withstand excessive charging. On this test, batteries constructed with the new corrosion-resistant alloys may show more than a 100% improvement in resisting the corrosive effects of overcharging. Whereas batteries normally operate under conditions where the voltage regulator protects the battery from excessive overcharge, the presence of one of these corrosion resistant alloys in the positive grids provides an added measure of protection in the event of failure or maladjustment of the regulator.

It also affords a measure of protection against overcharge in the event a battery should become overheated and its counter-electromotive force falls off to a value where it could not actuate the voltage regulator to gain the protection against overcharging which the regulator would ordinarily provide.

Batteries containing the corrosion-resistant grid metal in the positive plates do not exhibit an appreciable increase in cycle life when tested by the S.A.E Cycle Life Test since this cycling test is more of a test of plate active materials than of grids.

These corrosion resistant alloys usually employ a reduced percentage of antimony in the basic metal which results in a lower rate of antimony transfer from positive to negative plates. This has the beneficial effect of reducing self-discharge and capacity loss on standing on open circuit resulting in less sulfation and better shelf-life. This development tends to minimize the former disadvantage of the wet battery when stored for prolonged periods.

These alloys have enabled battery manufacturers to reduce the number and cross section of grid wires resulting in a substantial grid weight and cost reduction and a small increase in volume of plate active materials.

Plate Pasting Machines

Automatic plate pasting machines have been developed which are capable of applying active material pastes to the grids to a thickness greater than the grid thickness. This permits the use of grids as much as 10 to 15% thinner than the desired overall thickness of the pasted plate. This resulting increased ratio of active material weight to its supporting grid permits an increase in battery capacity and performance as well as the economy resulting from the use of lighter weight alloy grids.

Plate Active Materials

Battery plate active materials have been the subject of a great deal of research. Such materials are essentially mixtures of lead oxides and sulfuric acid, in pastes of controlled densities, and are applied to the open mesh of cast alloy grids. The plates are then dried under carefully controlled conditions of humidity and temperature so as to maintain the desired porosity of pastes and to form a well-cemented structure of the oxide material for good retention in the grid mesh during manufacture and service life.

The pastes for the positive and negative plate are of different composition and density but consist basically of partially sulfated lead oxide, often associated with substantial percentages of free lead. Red lead, a higher oxidation form of lead oxide, is sometimes used in the positive plates to help speed the electroformation.

Cellulose fibers are often blended with the oxides to form a reinforcement of the pastes when dried, and to prevent dislodgment of the dried pastes during handling in manufacture.

Organic compounds of lignin, together with barium sulfate and carbon black are usually included with the pastes for the negative plates. These materials, called "expanders", are not "extenders" or "fillers" but are used to prevent the sponge lead from gradually contracting and reverting to a denser, less porous material with attendant loss of cold discharge capacity during service life. The lignin compounds impart to the negative plates, a greatly improved performance at low temperatures and high rates of discharge which gives to the batteries greatly improved cold cranking ability. However, these organic expanders also cause the battery to have a higher counter electromotive force (C.E.M.F.) or opposing voltage when they are charged. This is a disadvantage in cold weather since a battery's opposing voltage steadily increases as it becomes colder. In fact, the voltage can rise so high that the generator's available voltage is so limited by the voltage regulator that little, if any, current can be forced through the battery to charge it.

Control of Charge Voltage

To overcome this disadvantage, nickel salts in small amounts can be added to the negative pastes. The nickel ion has a depressant effect on the charge voltage of the negative plates, allowing the battery to accept a higher charge, at low temperatures, than would otherwise be the case. A similar, and additive effect can also be obtained by the use of a cobalt salt in the positive plates where the cobalt ion has a depressing effect on the charge voltage. The cobalt ion, however, is highly oxidizing to wood separators so it must be used, if used at all, with the more oxidation-resistant plastic or rubber separators. When cobalt salts are used, a considerable measure of corrosion resistance to overcharge is also said to be imparted to positive grids.

The charge-voltage of batteries and the cold weather charge acceptance of batteries has been the subject of a great deal of research. It is of great importance to the automotive electrical engineer and is now a project for study by the S/E Storage Battery Subcommittee.

Battery charge-voltage is affected by a number of factors such as charge rate, state of charge, plate area, density of separators, electrolyte temperature, type of expander in negative plates, presence of metallic additives and amount of antimony transferred from the positive to the negative plates.

Since the battery regulates the charging system by its changes in counter-voltage, it is important to be able to determine the charge characteristic of the battery and if possible control it to desired values. This is desirable for several reasons:

1. To permit better regulation of system voltage.
2. To cooperate with generators of increasing output.
3. To improve battery charge acceptance in cold weather.
4. To prevent battery damage when batteries become overheated from any cause.

The trend to the use of engines of higher horsepower with higher compression ratios has placed a greater demand on the battery for increased cranking power. This demand is being partially met by building the battery elements with a greater number of thinner plates to provide greater plate area and better access of electrolyte to the available active materials for better maintenance of voltage during discharge at high rates. Plates as thin as 0.060 in. have proved to be quite satisfactory in passenger car service and have been in use in aircraft and ordnance batteries for tactical vehicles for a number of years.

S.A.E. standards for 12-volt batteries of less than 80 A.H. capacity, have been based on the discharge performance at 150 amperes at 0°F to 6-volts terminal voltage. Whereas the 150 ampere discharge rate is a satisfactory basis for comparative 12-volt battery ratings, it is not a realistic basis for selection of a battery for a new engine. Most car manufacturers are interested in the battery performance at temperatures lower than 0° F and most experimental cold starting work is done at -20°F. At such a low temperature, the power requirements for the newer high compression engines greatly increase so that discharge rates in the range of 300 to 600 amperes are frequently experienced with the 12-volt batteries of less than 80 A.H. capacity. Under such conditions, data on the battery voltage 10-seconds after the start of discharge is preferred rather than the conventional 5-second voltage rating, as an indication of available battery power. An end-point of 5.0 volts instead of 6.0 volts is used in determining capacity at -20°F.

It is obvious, with larger engines and the additions of other added electrically operated equipment and power assists, that batteries, starting motors and generators may have to become larger. It will be especially important to provide generators with lower cut-in speeds to make better use of the available driving time to maintain the battery charge, especially in metropolitan areas where traffic is slowed and stops are frequent. During such stops, with automatic transmissions, the low engine idle speed is often not high enough to bring the generator voltage up to charging voltage and this allows the battery to be discharged by a high connected load. Unless generator speed is maintained to correspond to a driving speed of about 18 miles an hour or better, the battery can gradually be discharged if lights, heater, radio and stop lights are operating. Such connected loads will discharge the battery to a greater extent than cranking the engine. For example, an engine start at 360 amperes for 5 seconds will consume only 1/2 ampere-hour battery capacity, but a connected load of 30 amperes at traffic lights will consume this ampere-hour battery capacity in only 60 seconds. Unless driving time is sufficient to overcome these capacity losses, a discharged battery may result.

Battery Containers

Containers have, for many years, been molded either of hard rubber or bituminous base composition. These materials served the industry relatively well, especially the hard rubber. However, as with most molded products, plastics began to make inroads on these materials and new types of materials have appeared in containers made of rubber and resin blends and of modified polystyrene. The walls and partitions of such containers can be made thinner which make possible in the same overall dimension a higher internal volume for greater element capacity or acid volume. Or, it makes possible a smaller overall volume and weight for a fixed element size.

This gives the battery engineer a degree of freedom which aids in design for higher power-to-weight ratios and greater compactness for the already crowded under-the-hood locations.

Most batteries are limited in ampere-hour capacity by the amount of electrolyte which can be contained in them. The battery engineer can therefore either take advantage of the extra acid volume made available, by the thinner wall containers which enables the ampere-hour capacity to be increased or, he can reduce the specific gravity of the electrolyte and keep the ampere-hour rating the same. In the case of overcharged batteries and high operating temperatures, the milder strength of acid is somewhat less detrimental to the battery's component parts.

Cover Constructions

Cover designs for the new 12-volt batteries are of the individual cell, lead-bushing post seal type. To minimize battery top corrosion and electrical leakage, as well shorten the electrical circuit, cell connectors are lowered and embedded in sealing compound.

The cell dimensions of the 12-volt batteries are so small that the self-levelling filling devices developed for controlling water levels of 6-volt batteries cannot readily be employed in the 12-volt constructions. No satisfactory 12-volt equivalents have yet made their appearance. There is little need for these where water levels can be observed while filling.

Battery Sealing Compounds

Battery sealing materials have been improved. Bituminous-base sealing compounds have long been used to make acid-tight the space between the container walls and the individual flanged cell covers. This acid-resisting material has been improved in quality so as to retain its adhesive and cohesive properties over a wide range of temperatures without flowing at high temperature or cracking at low temperatures. Such improved materials can better withstand prolonged heating in production dispensing equipment without deterioration of physical properties, or clogging the supply lines in production.

One-Piece Cover Constructions

Some premium types of 6-volt replacement batteries have been offered with one-piece covers sealed with permanent cement. These present a smooth top appearance which is easily cleaned of acid spray. The cements may be of the solvent type in the case of polystyrene covers and containers, or in the case of rubber covers sealed to rubber containers one of the heat-cured casting-type resins or epoxy base resins with hardeners may be used. Such cemented covers cannot be removed which prevents any attempt at battery repair but does guarantee a leak-proof seal under conditions of extremely rugged service.

Extra Electrolyte Constructions

In many 6-volt batteries of premium grade, where slightly additional battery height and cost can be tolerated, extra water space has been provided above the elements to reduce the frequency of adding water to cells. Under normal service conditions water need be added to such batteries only two or three times a year.

Vent Plugs

The increase from 6 to 12-volt batteries meant increasing the battery cells from 3 to 6. This imposed an extra burden in the watering of such batteries to unscrew and screw back in place six vent plugs. This has been alleviated on one car

manufacturer's batteries by the use of semi-soft rubber vent plugs which can be quickly snapped out and in for a rapid inspection of the liquid level of each of the six cells. Colorful polystyrene vent plugs have replaced hard rubber vents in most batteries.

Battery Life Extension

Now it must be apparent that a great deal of technological development and manufacturing skill has been built into the modern automotive storage battery. The service life which is obtained from such a fine product is largely within the control of the car owner.

Battery life is largely determined by the amount of charging the battery receives. Either too much or too little charging is detrimental to battery life. Longest life is obtained when the battery is maintained in the upper quarter of the charged state, and water consumption is at a minimum. Excessive need for water in a normal battery is indicative of excessive charging and is a signal to have the voltage regulator adjusted to a lower voltage setting. This is especially true in extremely warm climates or in cases of drivers running very high mileage. Factory settings of voltage regulators are for driving conditions normally experienced. Departure from this norm may require individual voltage regulator settings to maintain charge in extremely cold climates or prevent overcharge and excessive water loss in hot climates. Battery life can be greatly extended by closer attention by the car owner to his voltage regulator settings and observation of water consumption.

Automation in Battery Manufacture

Along with the improvements in battery component parts, there has concurrently been carried forward a program of improvement in manufacturing methods and production equipment resulting in a high degree of automation.

In a typical 9-plate, 60 ampere-hour, 12-volt battery there are 102 fragile plates and separators, the manual assembly of which is consuming of such labor and productive of both scrap and deteriorated plate quality. This situation has been relieved, costs have been reduced and quality improved by the application of automation in one of the newest and largest storage battery plants to be built.

Here parts are automatically collated and welded together on a conveyor of moving fixtures. Assembled elements are automatically electroformed and washed in a 160 foot long, conveyorized, processing machine. All of the elements are next dry-charged in a continuous dryer in inert gas atmosphere. The elements are then inserted in containers which are placed on an indexing conveyor above which a variety of specially devised work stations are mounted under which batteries pause for the exact time needed for each assembly or electronic inspection operation. All these stations are electrically interlocked by a maze of "memory circuits" which master-mind the operation of the entire assembly process.

Upon entering the continuous flow conveyor, the unfinished battery enters the cover alignment station where cell covers are fed from overhead supply stations and placement is automatically checked. From there the battery is moved rapidly through the remaining 16 work stations, emerging as a completed, tested battery.

Four of the stations are devoted to automatic inspection procedures. These check electric resistance of cells, test for internal short-circuits, search for acid leaks and probe for correct electrolyte level. If a defect is found at any of

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the automatic inspection stations, information is instantly relayed to a "memory circuits" drum and the defective or suspected battery is locked out from all subsequent operations along the line.

After cover alignment is checked, lead cell connectors are automatically fused on, the positive and negative terminal posts are molded into place, the ends of the posts properly shaped and the cell connector shields and terminal post molds removed.

The tops of the battery covers are next pre-heated to the correct temperature for best adhesion and the sealing compound is flowed into the seal channels.

At the next indexed position the battery is code stamped and both terminals are coated with a corrosion preventive compound.

The machine provides a station for filling each battery with sulfuric acid electrolyte if wet batteries are desired. The electrolyte level is then checked automatically.

The last station on the continuous flow line automatically screws vent caps into each cell cover.

Batteries move off onto conveyors for paint high-lighting and then to the shipping department.

The entire plant is air-conditioned to ± 5° F which is maintained with a 700 ton air conditioning system with an air capacity of over a million cubic feet per minute.

Such advanced methods for manufacturing lead-acid storage batteries are both a challenge and a reassurance to the over 200 manufacturers of lead-acid batteries. Such an investment is a vote of confidence in the future of the lead-acid storage battery as a preferred electro-chemical system for automotive applications.