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LEAD INDUSTRIES ASSOCIATION, INC.

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SOME PROCESS AND ASSEMBLY INNOVATIONS *
IN THE LEAD-ACID BATTERY
BY

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The lead-acid storage battery, a 100-year-old product, has had an economic growth coinciding with that of the automobile. Today, close to 35 million S. L. I. batteries are produced annually in this country by an industry with an annual dollar volume greater than 300 million dollars.

Contrary to the opinion of many who only think of a battery when their car doesn't start on a cold winter morning, there has been continuous technological growth in this industry. For example, in the early 1920's, lead was 6 cents a pound, labor was 50 cents an hour, and a battery for a Ford or Chevrolet cost the consumer about $40.00. Today, forty years later, lead costs 10 cents a pound, labor $2.50 an hour, and yet the cost to the consumer is less than half that of 1920.

Further, the electrical load demands of the modern car have increased approximately 200% in the last decade. At the same time, trends in styling have posed constantly greater physical limitations on the design of the battery.

The quality of today's batteries is decidedly better than those made forty years ago. For example, the average service life of a battery has increased (as shown in Figure 1.)

In addition, today's battery is only slightly larger than it was twenty-five years ago, yet it is capable of delivering twice as much electrical energy. Performance data representing gains by the industry are shown in Figure 2.

In spite of greater service demands and higher material and labor costs, the cost to the consumer has been reduced. And he's getting a better product. This is the result of continued engineering effort to improve material efficiency and develop more efficient manufacturing processes and equipment. The gain in material efficiency over the years is shown by the data presented in Figures 3 and 4.

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Look Ahead with Lead

Figure 3 gives a comparison of the number of 100 ampere-hour automotive batteries that have been obtained from 100 pounds of lead oxide. In the 1920's, only 6 batteries were produced per 100 lbs. of lead oxide while today an average of 11.1 batteries are produced — an 80% improvement in material efficiency. In Figure 4, comparable data are shown for the amount of lead grid metal used in batteries. In this case, a 162% improvement in material efficiency has been realised over the 40-year span. The data in Figures 3 and 4 are just one method of expressing the improvements made over the years.

These significant improvements could also be expressed in terms of watt-hours per unit of weight, volume, and cost which, together with cycle life, are actually the basic criteria for evaluating all energy storage devices. This method, using the change in amount of lead per battery over the years, was selected to illustrate to you, members of the Lead Industries, the trend in our industry necessitated by customer demands and the usual competitive pressures. It is only correct to point out that these improvements have been the result of not only the efforts of the battery industry, but also the efforts of the lead and other suppliers.

Obviously, it is not possible to relate what the whole industry is doing to further improve the quality of the lead-acid batteries, but in this paper some of the engineering programs actively being pursued within the Battery Division of Globe-Union, Inc. will be described.

To find out what are the causes of failure of batteries in actual field service, we have a continuous and extensive product performance evaluation program underway. We call it the STAT Survey System.

Working with our customers, each year we pick up from the field many thousands of junk batteries of both our own and competitors make. These batteries are completely analyzed. Causes of failure are determined and registered in a controlled tabulating card system. Equating cause and frequency of failure to the volume of batteries produced in a given area and time, the weaknesses of the battery materials and design can be determined. This information is of great value in directing our engineering programs. During the last year and a half, for example, it resulted in the extension of the national average service life of Globe's batteries by two months.

One of the major causes of battery failure is the corrosion or breakage of the positive grid. Others are mechanical defects such as container or post breakage, failure of negative plates, shedding of the positive plate, and separator failure. We at Globe have extensive development programs underway to correct or retard all these causes of failure, the size of the effort determined by the magnitude of the failure.

For example, we are devoting considerable effort to reducing positive grid corrosion. We believe we have found the major causes of grid failure, and are developing methods of eliminating these defects. Our preliminary experimental data show that it should be possible to double the life of the grid. Results of this study, together with other material studies which will be released in approximately a year, will point the way to further reduction in the weight of the lead in a battery and still allow greater energy output per unit of weight and volume.

In this paper, two new developments which result in improved processes and products will be reviewed. The first of these is the cast-on-strap process and the second, the intercell connector design, resulting in a product known as Globe's H-V (high voltage) battery.

CAST-ON-STRAP PROCESS

Since the introduction of the lead-acid automotive battery the construction of the cells has been much the same. Each cell consisted of multiple flat plate elements with lugs on each plate. In one standard method of assembly, the stack of plates with separators interspersed is placed in a jig and a pre-cast comb is placed on the plate lugs in the stack, as illustrated in Figures 5, 6, and 7. The lugs and comb are fused together by means of a gas flame torch which is either operated by hand as in Figure 5 or fixed and the assembly moved through the flame as in Figures 6 and 7. This method of assembly has been satisfactory, but there are shortcomings, particularly in the human variables which are necessarily present in the lead melting and fusion operation.

This method allows occasional lead rundowns between the plates, causing cell shorts which cannot easily be detected. Secondly, it is difficult to get perfect alignment of the lead cell terminal posts, making it difficult to assemble the covers on the battery. In addition, this conventional method of assembly does not enable the operator to make a cell with a tight stack of separators and plates, - a feature important for the battery to withstand severe vibration conditions in service.

Since 1890, many attempts have been made to eliminate this method of assembly and in place of the comb and lead burning process to cast a lead strap and fuse directly onto the plates.

To our knowledge, the Globe-Union cast-on-strap process is the first and only practical method developed for this purpose.

We begin with the same stack of separators and plates, but the lead post is cast and fused to the element in one operation. The equipment, designed for this process and now in operation in 14 of our 16 plants, has four stations as shown in Figure 8 and illustrated in detail in Figure 9. In the first position, the stacks are loaded with the lugs in the downward position and are held rigidly in clamps. In the second position, the lugs are cleaned and conditioned, and at the third station the strap and post are cast. At the fourth station, the elements or cells are unloaded onto a conveyor from which they are assembled into containers. A typical element assembly obtained from this equipment is shown in Figure 10.

The advantages of this process and equipment over the conventional method of burning are:

1. No lead rundowns between plates as the strap and post are cast in the upside-down position.

2. Improved post to plate alignment. The posts are parallel to each other and, also, parallel to both edges and the faces of the plates (Figure 10).

3. Improved separator alignment.

4. Elimination of charred separators.

5. Consistent element tightness.

6. Improved vibration characteristics. A tight stack results in less pelleting. Vibration resistance improvements of 400% are achieved.

7. Consistent plate to strap fusion.

8. Clean lead posts resulting in improved link burning and the elimination of the high resistance link connections.

9. Reduction in labor and process variables associated with the operator.

10. Step to automation.

INTERCELL CONNECTOR — HV (Higher Voltage) Battery.

In the standard battery assembly, the posts of each cell or element protrude through the container cover and are connected above the cover with precast lead link as shown in Figure 11. This construction, while used for the last fifty years, has had some obvious disadvantages.

The lead links on the top of the battery (particularly 12-volt batteries) were subject to corrosion from acid creeping up through the rubber or lead bushings around the posts and from spillage through the vent caps. There was also a production problem in covering the links with a compound that would resist acids and wide temperature changes, yet could be painted to give an attractive appearance.

As previously shown in this paper, there has been a marked increase in demand on the battery. The industry has met these requirements to some extent by increasing the surface area of the plates, using more and thinner plates, and lower resistance separators. One aspect which has been overlooked, however, is the internal resistance associated with the long posts, links, and link-post connections. The obvious solution would be to bring the cell connector directly through the partition, thereby reducing the length of the path for the flow of current.

The idea of an intercell connection is not new. Like the cast-on-strap process, many attempts have been made over the years to make a connection of this type. The methods which have been tried include the use of rubber grommets, lead bolts with crimping devices, and other radical means. To our knowledge, none are being used in automotive production or have been found practical.

With the development of the cast-on-strap process and resulting improved alignment of the post, strap, plates, and separators, it became possible to develop a practical process for making a liquid-tight connection directly through the partition of the container. This has been accomplished by punching a hole in the partition, constructing a male and female button on the positive and negative posts on the cells and compression and resistance welding the lead buttons through the partition to adjacent cells. Such a construction is shown in Figure 11. By careful alignment and control a rigid, electrolyte-tight seal is easily obtained. Twelve thousand batteries of this construction have been made and field tested with satisfactory results. An illustration of the production equipment which is in operation now is shown in Figure 12. This is a fully automatic machine consisting of three stations: aligning, welding, and testing of intercell welded connections.

In addition to the obvious material and labor savings associated with this intercell connector process, there is a decided improvement in product performance. This is a result of the lower internal resistance of the battery. In Figure 13 are shown discharge data obtained on 60 ampere-hour batteries with conventional elements and flat back mechanical separators with resistances ranging between 0.030 and 0.035 ohms/sq. in. The data were gathered at a discharge rate of 300 amperes at 0° F. representing the cranking conditions of an automobile in the winter. The RPM data equated to battery voltage were obtained from one of the large car manufacturer's laboratories. It can be seen that, after 10 seconds of discharge, the H-V battery gives better than 50% greater RPM's (or cranking power) than the conventional battery. Furthermore, the new battery gives the same cranking power at the end of 30 seconds of discharge that the conventional battery gives at 10 seconds. These are important features to the car owner who is faced with starting his car on a cold winter morning.

Figure 14 gives 5-second voltage data obtained on High Voltage and conventional batteries discharged at varying rates at 0° F. and -20° F. These batteries are the 24S-60 type. They consist of plates 5-11/16" wide by 4-3/4" high and separators with 0.030 ohms/sq. in. resistance. The advantages of the new high voltage connector batteries in terms of increased power at low temperatures are obvious.

Additional data important for the design of future batteries are given in Figure 15, showing the savings that could be realized in the ampere-hour capacity and, in turn, lead oxide if a battery were designed to deliver a specified voltage at a discharge rate of 300 amperes at 0° F. Comparable gains at other discharge rates and temperatures can also be realized.

Summing up, the advantages of the new intercell connector as utilized in the new H-V battery are:

PRODUCT IMPROVEMENTS

1. Higher starting voltage.
2. Greater power at high loads.
3. Improved cover design — more space for product identification.
4. Elimination of link corrosion.
5. Elimination of resin compound.

6. Less weight.

7. Potentialities of the design of smaller batteries with same power output at high drains and low temperatures.

PROCESS AND EQUIPMENT IMPROVEMENTS

1. Reduction of parts and handling.

2. Elimination of link burning.

3. Elimination of process problems associated with bubbles and blisters in the resin compound.

4. Less process steps and variables associated with human element.

5. A more consistent quality level because of the automatic equipment used to carry out the process.

The cast-on-strap and the intercell connector are examples of what is being done in the working of lead in the battery industry to provide a higher quality product with an improved performance through advances in product design and manufacturing innovations. Undoubtedly there are other important engineering developments which will further improve the efficiency of the lead-acid power source. As the product is improved through the continued collaborative effort of your industry and ours, new applications for the lead-acid battery will be developed which will result in a continued economic growth for us all.

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