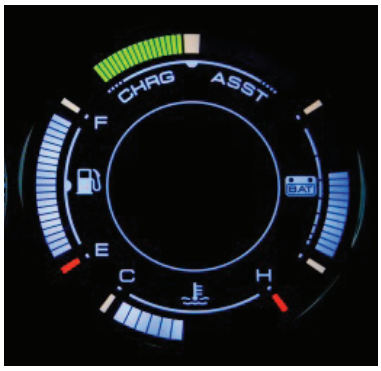

The Advanced Lead-Acid Battery
Bipolar Designs – A Commercial Reality

The Bi-Polar Advantage

More Powerful ▶
Higher Specific Energy (Wh/kg) and higher Energy Density (Wh/L)

Smaller ▶
40% Volume Reduction compared to equivalent monopolar batteries

Attractive Cost Profile ▶
Bi-polar lead-acid batteries use low-cost materials

Even current distribution through the battery gives **high utilization and a long life-cycle with high energy turn over**

Recyclable materials available for all lead-acid applications are used in bi-polar batteries.

The Commercialization of Bipolar Technology

Just as the lead-acid industry continues its breakthrough work on incorporating carbon and supercapacitors in batteries to improve their performance, significant progress is also being made in another key area: the commercialization of bipolar technology.

Scientists have long known that bipolar technology can help produce batteries that will achieve the twin goals of more power and a smaller footprint, something very important in the effort to make hybrid electric vehicles more affordable for consumers.

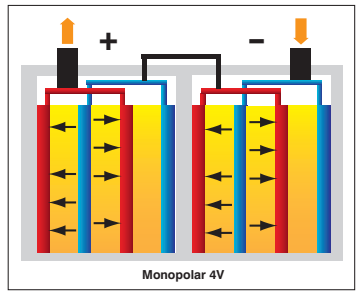

Figure 1

For years most batteries have been made with conventional 'monopolar' technology that uses two plates per cell and then connects those cells in a series of metallic connectors outside of the cells or through a wall. (Figure 1) This design results in ohmic losses within the plates leading to unsymmetrical distribution of the current density during operation. Furthermore, these grid and cell connectors increase the total weight of the battery.

While bipolar and monopolar designs share the same lead-acid chemistry, they differ in that in bipolar batteries, the cells are stacked in a sandwich construction so that the negative plate of one cell becomes the positive plate of the next cell. The cells are separated from each other by the bipolar plate* which allows each cell to operate in isolation from its neighbor.

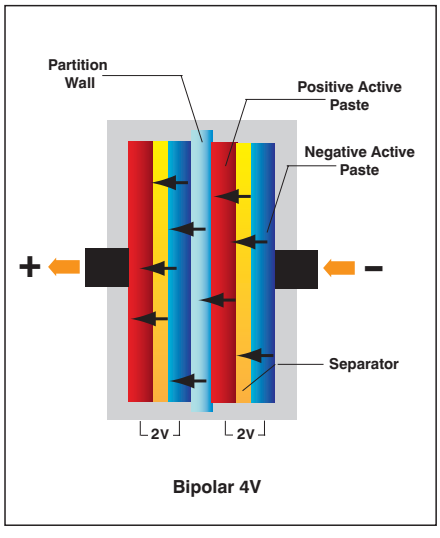

Figure 2

Stacking these cells next to one another (Figure 2) allows the potential of the battery to be built up in 2 volt increments.

Since the cell wall becomes the connection element between cells, bipolar plates have a shorter current path and a larger surface area compared to connections in conventional cells. This construction reduces the power loss that is normally caused by the internal resistance of the cells. At each end of the stack, single plates act as the final anode and cathode. This simpler construction leads to reduced weight since there are fewer plates and bus bars are not needed to join cells together. The net result is a battery design with higher power than conventional monopolar lead-acid batteries.

Until recently, the main problem limiting the commercialization of bipolar lead-acid batteries was the availability of a lightweight, inexpensive and corrosion resistant material for the bipolar plate, and the technology to properly seal each cell against electrolyte leakage. ALABC members **Atraverda** and **Effpower**, however, have each developed technology to overcome these challenges and are bringing their bipolar innovations to the marketplace.

- **Atraverda**, based in the United Kingdom, has developed an electrically conductive ceramic, Ebonex® technology, a titanium suboxide material that has a unique combination of metallic-like electrical conductivity along with the characteristic high corrosion resistance of ceramics. The Ebonex® technology is currently being evaluated by a number of major battery manufacturers.

- **Effpower**, founded in 1999 by Volvo and Gylling Optima Batteries AB, also has achieved breakthroughs in the development of ceramic materials and production technology to create new lead-infiltrated ceramic (LIC™) plates. These plates act as portioning walls between cells in its own bipolar battery, the Effpower, that currently is undergoing tests in Sweden.

In both instances, the distance between electrodes is shorter and electrical current is more evenly distributed throughout the battery itself. The result is greater energy density within a smaller, lighter-weight container.

*The bipolar plate is a solid structure which conducts electrons, allowing the potential of the positive plate to be transmitted to the negative of the adjacent cell but it does not take part in the cell chemistry.

ALABC

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