Changes and improvements of lead-acid battery industry as a sustainable development – Where do they go from here

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Introduction

In 1859, Gaston Planté invented lead-acid battery. The lead-acid battery or so called 'secondary cell" is rechargeable and usually consists of six cells connected together in series. Each cell consists of a lead plate as a negative electrode, and a lead oxide plate as a positive electrode, both immersed in dilute sulfuric acid electrolyte solution. However, over the past one hundred and thirty eight years, there has not been any significant change in terms of its design, and lead-acid battery is still widely used in cars, trucks, ships, and airplanes. Today, the lead-acid battery manufacturing industry is at the crossroads under many threats including stringent environmental and occupational healthy regulations as well as other competitions such as advanced battery technology, etc. In order to solve environmental-induced smog problems, the California Air Resources Board (ARB) and some organizations in other states have mandated that ten percent of the new car sold in the year be zero-emission vehicles (ZEVs) without allowance for tailpipe emissions. At this time, only the electric vehicles (EVs) can meet those requirements. ARB even announced that the EVs manufacturers should develop advanced batteries that do not contain lead. In 1991, The U.S. Advanced Battery Consortium (USABC) worked out a 12 years plan costing US $1.2 billion aimed at speeding development of advanced storage batteries that could replace the existing lead-acid battery. And the International Lead Zinc Research Organization (ILZRO) set up the Advanced Lead-Acid Battery Consortium (ALABC) in 1992. Their goal was to promote electric vehicles as a reality by the end of the decade. As a result, the lead-acid battery industry has to seek for new ways to make a stand against various challenges originated from regulations and economics.

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Environment Impact

It is often inevitable to completely prevent lead emission to the environment in smelting operations, battery manufacturing and recycling industries. Lead-acid battery itself can produce certain amount of airborne lead and acid mist during operation and recharging stages. In operation, the negative lead electrode dissociates into free electrons and positive lead ions. The electrons travel through the external electric circuit, and the positive lead ions combine with the sulfate ions in the electrolyte to form lead sulfate. When the electrons re-enter the cell at the positive lead-dioxide electrode, another chemical reaction occurs. A lead-acid storage cell runs down as the sulfuric acid gradually is converted into water and the electrodes are converted into lead sulfate. When the cell is being recharged, the chemical reactions described above are reversed until the chemicals have been restored to their original conditions. Because lead is slightly soluble in sulfuric acid and the chemical reactions are violent, some sulfuric acid aerosols with lead are continually released to the environment.

Airborne lead and sulfuric acid aerosols can cause environmental and health related problems in working areas. Statistic shows that many employers of those fields have paid a great deal of money in workers' compensation claims and lawsuits. The Clean Air Act of 1967 as amended in 1970, 1977, and 1990 is the legal basis for air-pollution control. The primary and secondary standards for lead is 1.5 μ/m^3 in three month. In April 24, 1997 ARB identified inorganic lead as the 19th toxic air contaminant. In addition, many countries have set a limit on lead in its occupational air and biological exposure. Sulfuric acid aerosols though have not been officially regulated as a pollutant, but it is known to cause of asthma, and even cancer. Therefore, the priority should be to reduce the emissions of airborne lead and acid mist in our living environments. The following are two examples of such efforts:

- Reduction of lead emission during primary and secondary lead smelting production; and
- Recycling of used lead acid battery or the enhancement of recycle rate.

Occupational Health

In the United States, numerous laws are directed at protecting both occupational and environmental health. Most have been passed since 1960, including the Occupational Safety and Health Act (OSHA) of 1970 and the Resource Conservation and

Recovery Act (RCRA) of 1979. Means for the rapid cleanup of toxic lead dumps were provided in the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980.

Some Battery Council International (BCI) members are finalizing the Lowest Feasible Level (LFL) Agreements with the Occupational Safety and Health Administration (OSHA). Recently, BCI has required a voluntary blood lead reduction initiative for the battery industry from the currently required level of 50 µg/100 g to 40µg/100g.

Advanced Battery Technologies

Improved versions of conventional storage batteries called valve-regulated lead acid battery (VRLA) has been used for EV1 by GM. But they still suffer various drawbacks such as quick discharge, high expenses, bulkiness, or environmental problems. The U.S. Advanced Battery Consortium (USABC), a consortium that includes the U.S. Department of Energy and the three major American automakers, was set up in 1991 to speed up development of advanced storage batteries. Such batteries are expected to cause very few environmental problems and to occupy less space.

Lead-acid battery can deliver a strong current of electricity for starting an engine, but it runs down quickly. An ordinary lead-acid battery has a useful life of about four years. It produces about 2.1 V per cell. Recently, lead-acid batteries with useful lives of 5 to 7 years have been developed for special applications. In response to the needs of electric vehicles, many types of batteries in various designs are being tested including the followings: nickel-cadmium, nickel-iron, nickel-metal hydride, sodium-sulfur, sodium-nickel chloride, lithium-iron disulfide, lithium-ion, lithium polymer, zinc-air, zinc-bromine, and fuel cell, etc. Since most of these new batteries are very costly, and they are technically immature. For those reasons, GM's EV1 is still using valve-regulated lead acid battery (VRLA). But Honda and Toyota will start using nickel-metal hydride battery in their next generation EVs; meanwhile Nissan is also planning to employ lithium ion batteries. Unless lead acid manufacturing industry is willing to start new production line, all of those EVs battery candidates might soon become its potential competitors.

Modification of lead-acid battery

In order not to make too much changes in the manufacturing process for the purpose of sustainable development of lead-acid battery manufacturing industry, one of the approaches would be to change the battery components for example, the polyethylene separators can be modified. Another method would be to employ other electrolytes such as silica or polymeric gel that could give many advantages over conventional lead-acid battery. Gel electrolyte battery can make fewer pollutants emission, has longer life cycle, causes less corrosion, requires less maintenance upkeep, and can also have good recharging abilities.

Case study – gel electrolyte battery

U.S. patent No. 5202196 for gel electrolyte battery was issued in 1993. This invention uses colloidal type of silica gel electrolyte instead of sulfuric acid in lead-acid battery's cell. That gel is more resistant to hydration and it also does not crack. Based on the test results (Table 1), airborne lead and sulfuric acid aerosols emissions in that kind of battery were much lower than sulfuric acid electrolyte battery. The battery also ahs good recharge ability and 50% longer life cycle, and can function at different temperatures. Therefore; it can fit most EPA and OSHA requirements.

Conclusions

As the environmental and occupational health regulations get more strict, along with the rising new battery technology. The lead-acid battery industry should update its quality standard with the related sources such as auto and ship manufactures, electric utilities producers, environmental and occupational health related groups, and the government to adjust to the worldwide trend. It also needs to advance its technology to lower life cycle costs, to reduce lead emission, to eliminate sulfuric acid aerosols emission, and to increase both its recyclability and performance. For instance, ZEVs are slowly becoming an alternative to replace conventional gasoline vehicles. In regard to marketing, even though electric vehicle brings uncertainties, lead acid battery has is its well established recycle system. Other batteries seem to come short in certain aspects in compare to lead acid battery. For example, lithium-polymer batteries were rated very well for performance but poorly for recyclability and nickel-metal hydride batteries were rated with moderately high marks for both performance and recyclability. Reduction of air lead emission in all smelting process is another essential step to fit the requirements set by EPA and OSHA.

Table 1. Airborne lead and sulfate aerosols emission from two different storage batteries in the durations of eight hours.

PARAMETER	Sulfuric acid electrolyte (S.G. 1.28)	Gel electrolyte	Permissible Limit
Sulfate Aerosols (mg/m^3)	2571.43	44.38	Not regulated (SO2 only)
Airborne Lead (Pb) (mg/m^3)	6670.00	<0.01	50 mg/m3 in 8 hr (OSHA) 1.5 mg/m3 in 3 mo (EPA)

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