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SEPARATOR TECHNOLOGY FOR LEAD/ACID BATTERIES

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Introduction

The separator in a battery fulfills two basic functions. Firstly, a battery separator is an electrical insulator preventing a short circuit between each adjoining positive and negative plate. Secondly, the separator is a mechanical spacer that holds the plates in the prescribed position and helps to retain the active mass in contact with the grid.

To serve these functions, the separator must be porous and wettable to allow acid to permeate through it, as the battery is charged or discharged. Ideally, the separator will not impede or impose a restriction on the ionic flow. The separator must be constructed from materials that are resistant to the acidic and oxidative environment. It must be of sufficient strength to withstand the assembly operations and perform its functions as a mechanical spacer under thermal and vibration conditions existing during the life of the battery. Ideally, the separator should displace as little acid as possible since this is the fuel or reserve capacity for the battery itself.

Separator categories

There are several methods by which we can categorize battery separators. Some separators are made from naturally occurring materials, others are synthetic. Separators can be produced from various polymeric resins or the materials can be fibrous in nature and again either natural or man made. Because the separator must be porous, there are several techniques for formation of the pores. Some materials used in the past (such as Port Orford cedar) are naturally occurring and inherently porous. The products in principal use today are fibrous in nature and are made using a traditional paper-making process. Because the fibres align randomly rather than perfectly, a porous structure results and there is no need for special pore-forming ingredients. Conversely, most resinous or polymeric separators in use today utilize a purified, precipitated silica as the carrier for a liquid pore-forming agent. The precipitated silica, which remains in the product, has a skeletal structure and is highly absorptive and naturally acid-resistant. Because it is hydrophilic or water absorbing, it adds the very desirable trait of being easily wetted and thereby contributes to a low electrical (ionic)

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resistance. Some current products use a naturally occurring silica such as diatomaceous earth. These are generally less porous and can contribute to contamination of the electrolyte.

Alternatively, the sintered polyvinyl chloride (PVC) separator is simply the light fusion of spherical particles of resin. Without being compressed, the void space between the tiny particles provides the porosity, which is limited by the geometrical relationship of a circle and a sphere. Frequently, a surfactant is added to improve wetting and to lower the electrical resistance.

At present, there are four major groups of separators being utilized in the construction of SLI batteries. These are

(i) Wood or cotton fibre paper protected and stiffened with a phenol–formaldehyde resin binder.

(ii) Sintered PVC.

(iii) Glass microfibre paper possibly blended with synthetic fibres, and stiffened with a latex binder.

(iv) Polyethylene containing a purified precipitated silica.

All of these types can be utilized as leaf separators in battery construction. PVC and polyethylene can be used also as enveloped separators around either the positive or the negative plate.

It is appropriate to note that any type of SLI grid alloy can be used with enveloped separators. This is not true, however, of leaf separators. Present thinking and practice is that if the battery is constructed with either a calcium or a calcium–aluminum positive plate, then enveloped separators must be utilized. The reasons for this are primarily dendrite growth, positive-plate expansion, and poor adhesion of paste to calcium or calcium–aluminum grids. Calcium positive plates exhibit a high rate of dendrite growth, and without an envelope separator, shorting around the sides of the separator will, in all probability, occur. This type of grid construction will not perform properly in a leaf separator environment. One type of cell construction that is meeting with increased popularity is a low-antimony positive with a calcium–aluminum negative. This "hybrid" cell is suitable for either leaf separators or envelope separators.

Comparison of separator technologies

Factors such as market battery requirements and demands, separator cost, and total manufacturing cost play a major role in deciding which separator technology to use for a given product. Since these factors may vary greatly from manufacturer to manufacturer, however, it is appropriate to acknowledge their importance, but not to elaborate on them.

In regard to the physical and chemical merits of the different battery separator types, key points for the battery manufacturer's consideration can be offered. Cellulosic fibre separators, which have been commercially available since the early 1950s, do offer satisfactory battery performance and typically are low in cost. They exhibit higher electrical resistance than the other types, however, and, because of their brittleness, can account for higher separator scrap rates and potential battery failure Also, their greater susceptibility to electrolytic attack can result in shorter battery life — particularly in semi-tropical or tropical climates when higher acid temperatures destroy the wood or cotton fibre more quickly.

PVC separators are, without question, the most widely available of the four separator types. PVC is chemically clean and offers a reasonable pore size in defence of dendrite growth. PVC separators exhibit a high corrosive puncture resistance. Additionally, they can be designed to offer lower electrical resistance than cellulose separators Separators constructed from PVC are extremely brittle and this can cause the same type of results as noted in respect of cellulosic separators. On exposure to high temperature, PVC separators will release chlorine gas and once this phenomenon starts it continues This release of chlorine gas can have dramatically adverse effects on battery life

Glass-fibre separators, which were first introduced by Evanite in 1980, offer·

(i) extremely low electrical resistance — 60% less than cellulose — resulting in more cold-cranking amps (CCAs),

(ii) low acid displacement — 50% less than cellulose — resulting in more reserve capacity,

(iii) extreme chemical cleanliness,

(iv) high oxidation resistance

In addition, glass-fibre separators are much less vulnerable to breakage or cracking than cellulosic or PVC separators. In excess of 80% of the SLI leaf-separator market in the U.S.A is now glass fibre.

Polyethylene separators, which have been commercially available since the mid 1970s, offer the battery manufacturer low electrical resistance, improved reserve capacity, high resistance to oxidation, high resistance to dendrite growth, high corrosive puncture strength, along with flexibility and sealability

The first consideration of many battery manufacturers is CCAs It has already been noted that the electrical resistance of a glass fibre or polyethylene separator with a 0.25 mm backweb for enveloping is significantly lower than either cellulose or PVC. This can result in a 5 - 10% increase in CCAs from a given battery design. The voltage drop at 25 °C and −18 °C in cells using various types of separators is given in Table 1 If the battery manufacturer is already producing a battery at acceptable CCA performance, and has no need to increase CCAs, then it may be appropriate to consider the cost savings of eliminating a plate and a separator and producing a battery of equivalent performance.

The next major consideration of the battery manufacturer is reserve capacity The displacement of acid by separator material will affect reserve capacity Acid displacement for a given type of separator at an overall thickness of 1 04 mm is given in Table 1, along with the acid displacement per cell for a separator of dimensions 133 mm × 148 mm. Each ml of acid in a cell

TABLE 1

Properties of various separator materials

Separator	Electrical resistance (ohm cm^2)		Voltage drop −18 °C (V/cell)*	Acid displacement		Mean pore diameter (μm)	Puncture (g)	
	25 °C	−18 °C		ml cm^{-2}	ml/cell		Dry	Corrosive
Cellulose	0 22	0 67	0 137	0 02	39 10	25	350	100
PVC	0 16	0 49	0 098	0 03	58 65	13	500	450
Glass	0 08	0 24	0 049	0 01	19 55	24	320	300
Polyethylene	0 08	0 24	0 049	0 01	19 55	<0 1	—	—

*400 A, 11-plate SLI battery with 10 separators per cell and 1 280 specific gravity acid at 1.260 specific gravity can contribute about 7 s of reserve capacity at 25 A, assuming that the specific gravity is at 1.120 at the end of the discharge. Consequently, in this example, a glass fibre separator would yield about 2 3 more minutes of reserve capacity when compared with cellulose and about 4.6 more minutes when compared with PVC.

The third possible separator consideration for the battery manufacturer can be the separator's ability to resist dendrite growth. This may first be addressed by an evaluation of separator mean pore diameter. The data presented in Table 1 illustrate the fact that cellulose and glass separators are less resistant to dendrite growth than PVC or polyethylene, and that polyethylene is extremely resistant because of its dramatically smaller mean pore diameter.

The puncture strength of the separator (Table 1) also reflects the separator's ability to resist dendrite penetration. Polyethylene material stretches, but does not puncture The corrosive puncture is of greater significance than the dry, since this is indicative of the separator's strength in the electrolyte environment. It should also be noted that a separator, when enveloped, strongly reduces the potential for side shorts.

In summation, the newer, more technologically advanced, battery separator options of glass or polyethylene offer the battery manufacturer higher CCAs and lower electrical resistance. Additionally, polyethylene separators are extremely resistant to dendrite growth. Furthermore, polyethylene and glass separators are extremely clean chemically, and typically yield longer life than either cellulose or PVC

Battery assembly with different separator materials

To complete this examination of the strengths and weaknesses of the major separator types available to the battery manufacturer, it is appropriate to examine battery assembly processes briefly as a means of further assessing the separator decision The battery manufacturer has three basic options available. These are: hand-stacking with leaf separators, machine-stacking with leaf separators, or machine operation with envelope separators.

With hand stacking, there is no capital equipment expense, nor does the battery manufacturer run the risk of lost production due to equipment breakdown This method of battery assembly typically yields higher separator scrap, a higher percentage of batteries being reworked, and higher field failures due to mis-aligned or missing separators.

Alternatively, the battery manufacturer may elect to machine-stack leaf separators with equipment such as that produced by Eberle Engineering Company, or Tekmax, Inc. In both cases, the equipment has been designed around the glass-fibre separator. A production rate, utilizing two employees, of about 900 batteries per shift may be expected. This rate holds true whether 9- or 19-plate batteries are manufactured Naturally, this type of manufacturing means a major initial capital expense; but in all probability it will yield lower separator scrap, a lower percentage of batteries being reworked, lower field failures due to mis-aligned or missing separators, and consistent production rates

The final option of enveloping with a machine such as the ones produced by Tekmax or Elbak also represents a significant initial capital investment With two employees, however, about 900 batteries, based on 11 plates per cell per shift, can be produced The major advantages of enveloping are low separator scrap, a low percentage of batteries being reworked, no mis-aligned or missing separators, consistent production rates, and no shorting caused by side mossing of the positive plate

To summarize, the major advantages of automated stacking are higher production rates, fewer defective assemblies, and greater product quality and consistency

Separator market in U.S.A.

To illustrate the impact of glass-fibre and polyethylene separators on SLI battery technology, it is interesting to examine the battery separator market in the U.S A As recently as twelve years ago, the market was almost entirely cellulosic fibre with minimal usage of PVC, rubber and diatomaceous earth composing the balance of the market Today, 33 million batteries are made that employ glass-fibre separators, 32 million with polyethylene, and 7 million with other types of separator

This dramatic shift in the market has been stimulated by a variety of reasons, primarily the desire of the consumer for increased CCAs and increased reserve capacity The electrical demands of the U S automobile are tremendous and the battery must be able to meet these demands under great extremes of climate. Naturally, the requirements for enveloped separators necessitated by calcium positive-grid technology have further influenced this shift Many people are of the opinion that before the end of this decade, the U S market will be limited to glass and polyethylene separators Cellulose, PVC, etc , will no longer be utilized by SLI battery manufacturers in the U S A

The area of industrial battery separators, like SLI battery separators, has been, and is presently, undergoing dramatic changes This is both in traction and in stationary applications The introduction of polyethylene battery separators in the 1970s is primarily responsible for this change Currently, the industrial battery manufacturer utilizes microporous rubber or polyethylene separators in industrial batteries Microporous rubber separators offer to the battery manufacturer an industrial separator that yields moderate performance The separator, however, is extremely prone to breakage which, if it occurs, would naturally lead to shorter battery life Additionally, microporous rubber separators are limited (to some extent) in minimum backweb thickness, and typically have a higher electrical resistance when compared with polyethylene On the other hand, polyethylene industrial battery separators made using very pure precipitated silica offer the industrial battery manufacturer an extremely clean and an extremely durable battery separator. The separator will not break or crack and is very resistant to dendrite growth. Also, unlike rubber separators, the backweb thickness of a polyethylene separator can be made thinner for a specific battery application, thus allowing for reduced electrical resistance and acid displacement This will result in greatly improved battery performance.

In excess of 99% of the motive power batteries in the U.S.A. are made with polyethylene battery separators Stationary batteries are currently made with either polyethylene or microporous rubber. Manufacturers of stationary batteries are now in the process of testing polyethylene in applications that are still currently utilizing rubber separators In general, the thinking of the battery manufacturers is that it is only a matter of time before polyethylene entirely replaces microporous rubber in the industrial battery market

Separators for sealed lead/acid batteries

It is appropriate to offer a few comments regarding sealed lead/acid batteries. Manufacturers of these batteries have two basic options available to them· they can gel the electrolyte or they can utilize an absorptive-glass-mat (AGM) battery separator. The AGM separator is extremely hydrophilic and will readily absorb and hold the electrolyte This will allow the battery to be fully sealed and allow recombination of the gases as they are generated during the charge cycle Throughout the battery's life, AGM will continue to hold the electrolyte and totally prevent acid leakage or spillage. Sealed lead/acid batteries with AGM type material are being tried daily, it seems, in new applications.

The AGM separator is used extensively in small UPS and stationary battery applications In addition, various manufacturers are utilizing sealed lead/acid (AGM) batteries in such diverse applications as SLI and motive power. The full potential of the technology has not yet been reached, and it is viewed as being extremely diversified with a bright future

Conclusion

Of the various battery separator technologies available to the SLI battery manufacturer, glass fibre and polyethylene are the standards by which all others are judged, because they offer superior battery performance and battery life In the U.S A , the SLI market will, in all probability, be using only glass fibre and polyethylene separators before the end of this decade. Polyethylene battery separators offer significant advantages in industrial batteries when compared with microporous rubber Dramatically stronger and significantly more adaptable to various industrial battery applications, polyethylene battery separators are continually growing in use and have proved to be the industrial battery separator of choice.

Ever increasing applications for sealed lead/acid batteries are being developed. The majority of batteries already being produced in this category utilize absorptive glass mat (AGM) separator material There is every indication that this utilization will not only continue, but will increase.

It is impossible to forecast accurately what types of battery separators will be used by lead/acid battery manufacturers in the future. It is safe to say, however, that new and more exotic separators will become available Since the 1930s, each decade has given us a new type of separator What new separator will be developed for the 1990s is open to speculation, but if history is any predictor of the future, then there will indeed be a new battery separator in the 1990s