Rubber Separators For Tomorrow: Performance Characteristics And Selection Guide

Syng L. Paik[a], Giovanni Terzaghi[b]
[a]Amerace Microporous Products, Inc.,
596 Industrial Park Rd.,
Piney Flats, TN 37686, USA

[b]Termar S.R.L., Via Anfossi 14, 20135 Milan, Italy

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Abstract

A brief description is given of the basic differences in manufacturing processes and composition of the three types of rubber separator, namely: (I) sulfur-cured, hard rubber, Ace-Sil® separator (II) electron-beam crosslinked, Flex-Sil® rubber separator; (III) coated glass-mat Micropor-Sil® separator containing rubber. The physical, chemical, electrical and electrochemical properties of the three types of rubber separator are considered and the primary differences are explained. The beneficial performance characteristics found with rubber separators are presented, such as on-charge voltage characteristics, electrochemical compatibility for float-charging systems, retardation of antimony transfer, prevention of dendrite growth, and good wettability. Based on analysis of separator properties and battery requirements, a selection guide for rubber separators applicable to various types of lead/acid battery is compiled.

Keywords: Battery separator; Microporous rubber separator; Lead/acid batteries; Electrochemical compatibility, Electron beam crosslinked rubber.

1. Introduction

The performance of hard-rubber separators, such as Ace-Sil, has been known for many ears in the lead/acid battery industry. In recent years, Flex-Sil electron beam crosslinked, flexible, rubber separators have proved very successful in deep-cycling lead/acid batteries. Yet another type of rubber separator, Micropor-Sil, has been introduced recently. Each of these three types of rubber separator has unique physical, chemical and electrochemical properties, as well as distinct performance characteristics [1-3]. The availability of he new types of rubber separator has greatly expanded their range of applications and has enhanced battery performance. Understanding the various properties of these separators has become increasingly important in selecting a suitable type for a given battery design or specific application.

2. Function Of Separators

The primary function of separators, placed between the positive and negative plates of a battery, is to prevent electrical short-circuiting, while allowing the free transportation of electrolyte and electrical current. In order to accomplish this relatively simple task, a separator must have, amount other things: high porosity, small mean pore diameter, mechanical strength, and chemical resistance to corrosive electrolyte. Many types of separators presently used in lead/acid batteries fulfill these functions. A good separator is much more than just a fine insulating mechanical filter. There are other importance properties essential to battery performance that are mostly electrochemical in nature and closely related to the material composition of a separator, such as its base polymer or main organic material constituents. For these reasons, rubber separators exhibit different performance characteristics from those of plastic, glass fiber or cellulose separators.

3. Lead/acid batteries and their separators

For convenience, lead/acid batteries can be classified into two major types, namely, automotive and industrial. In addition, there are many special batteries that cannon be easily categorized as either of the two types. As these types of batteries are constructed with different materials and design to meet the requirements of their intended end-uses, each requires a particular separator with specific material composition, mechanical design, and physical, chemical and electrochemical properties that are tailored for the battery. These batteries are available in flooded electrolyte or valve-regulated (sealed) versions.

Separators currently used in lead/acid batteries can be classified by their materials of construction into four major types: plastic separators, cellulose separators glass separators and rubber separators, as shown in Table 1.

Table 1: Types of Separators Classified by the Material of Construction

Plastic Separators	Polyethylene/silica
	PVC (polyvinyl chloride)/silica
	Phenolic resorcinol/silica
	Sintered PVC (polyvinyl chloride)
Paper Separators	Phenolic resin-coated cellulose
Glass Separators	Glass fiber mat
	Absorptive microfiber glass mat
Rubber Separators	Sulfur-cured, hard rubber (Ace-Sil, Mipor B)
	electron beam cured, flexible rubber (Flex-Sil)
	coated, glass mat, rubber (Micropor-Sil)

4. Rubber Separators

Rubber separators have some intrinsic properties that may not be found in other types of separators. For example, rubber separators have good voltage characteristics, an ability to retard antimony transfer, properties to prevent dendrite growth, and good electrochemical compatibility (4). All these attributes are very importance aspects of lead/acid battery performance and life. Rubber separators do not require additives such as VCA (voltage-controlled additives) to enhance on-charge voltage characteristics, chemicals to augment retardation of antimony transfer, nor a surface-active agent to improve wettability of separators. Rubber separators impart these properties naturally. Due to the hydrophilic properties of the rubber composition, the separators are highly wattle and repeatable because of the hydophobic properties of the plastics that are being used, particularly when they contain mineral oil.

4.1. Physical, chemical, and electrochemical properties of rubber separators

All three types of rubber separators have an ultra-fine pore structure, with mean pore diameters of less than 0.3 µm. Porosity (determined by the mercury intrusion method and electrical resistance (determined by the preboil test method) for the latest samples are listed in Table 2. Also shown are electrochemical compatibility (BCI Battery Technical Manual Section 3-044, Test Procedure 12D) and analytical test results including metal and chloride ion contents. A well-established specification for electrochemical compatibility of a separator for a float-charged stationary battery requires that the shift in cathodic polarization in the hydrogen evolution region with separator-leached sulfuric acid compared with pure acid should not exceed ±50 mV and ±25 mV in anodic polarization in the oxygen evolution region. Figs 1-3 show the pre-size distribution of Ace-Sil, Flex-Sil and Micropor-Sil, respectively.

4.2. Ace-Sil Separator (sulfur-cured, microporous, hard-rubber separator)

The Ace-Sil separator is the longest continuously serving product among the rubber separators. The manufacturing process starts by mixing natural rubber, rehydrated precipitated silica and sulfur in an internal mixer. The rubber compound stock is then extruded and calendered, vulcanized under water, and dried. A flow chart of the manufacturing process for Ace-Sil, along with that for Flex-Sil and Micropor-Sil is presented in Fig. 4. There has been a continuous effort to find the manufacturing process and product design; this has resulted in products with finer ore diameter (averaging 0.2 µm), increased mechanical strength, lower electrical resistance (through the reduction of backweb thickness), and reduced acid-displacement volume. The new Ace-Sil also provides versatility in rib configuration that includes diamond-shaped interrupted alternating diagonal ribs for the positive plate and mini-ribs (cannelure ribs) to be faced against the negative plate.

Ace-Sil imparts a higher end-of-charge voltage than plastic separators. This prevents overcharging when a voltage-limiting charging system is used, and, thereby increases the life of the battery. It exhibits favorable Tafel curves and very good float-charging characteristics for stand-by system. Ace-Sil has excellent resistance against oxidation from both the battery acid and the lead oxide of the plate. It retards antimony transfer and, thus, reduces self-discharge and gas evolution.

For these reasons, Ace-Sil separators are recommended for stationary batteries for telecommunications, UPS (uninterruptible power supply), motive power, submarine, locomotive duties, as well as for batteries to be used in load-leveling/peak-shaving applications.

Table 2: Physical, Chemical and Electrochemical Test Results of Rubber Separators

	Ace-Sil®	Flex-Sil®	Micropor-Sil®
Mercury Intrusion Porosimeter Test			
Total Porosity (ml/g)	0.87	0.47	1.22
Mean Pore Diameter (µm)	0.25	0.06	0.17
Pore Size Over 20 µm (%)	4.40	7.0	6.2
Volume Porosity (%)	58	49	69
Electrical Resistance			
Ω cm^2 (mΩ in^2)	0.226 (35)	0.258 (40)	0.071 (11)
Backweb Thickness, mm (inch)	0.71 (0.028)	0.38 (0.015)	0.28 (0.011)
Electrochemical Compatibility			
Cathodic Shift (mV)	–1	+2	+39
Anodic Shift (mV)	–12	–20	–7

Chemical Analysis (%)

Ash	28.87	56.63	64.60
Iron, Fe	0.017	0.031	0.016
Sodium, Na	0.021	0.200	0.194
Magnesium, Mg	0.006	0.011	0.006
Manganese, Mn	<0.0001	<0.0001	<0.0001
Aluminum, Al	0.064	0.109	0.046
Calcium, Ca	0.007	0.008	0.010
Copper, Cu	<0.001	<0.0001	<0.0001
Chloride, Cl^-	0.0003	0.0007	0.0004

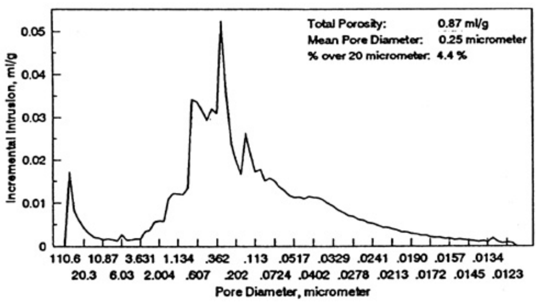

Fig. 1. Pore-size distribution of ACE-SIL® rubber separator.

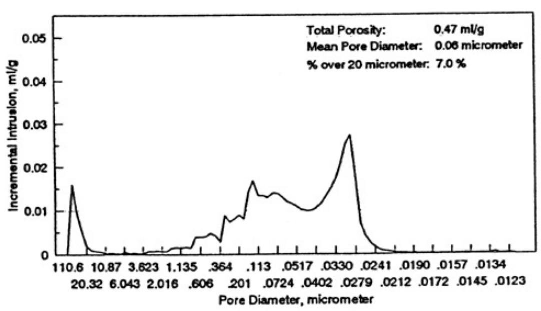

Fig. 2. Pore-size distribution of FLEX-SIL® rubber separator.

against oxidation from both the battery acid and the lead oxide of the plate. It retards antimony transfer and, thus, reduces self-discharge and gas evolution.

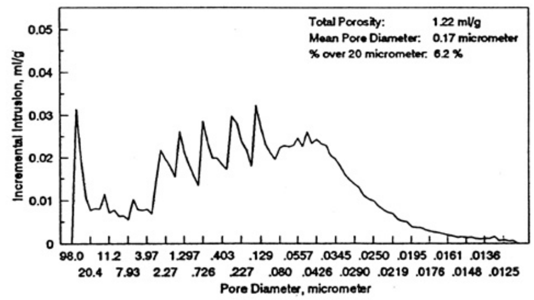

Fig. 3. Pore-size distribution of MICROPOR-SIL® rubber separator.

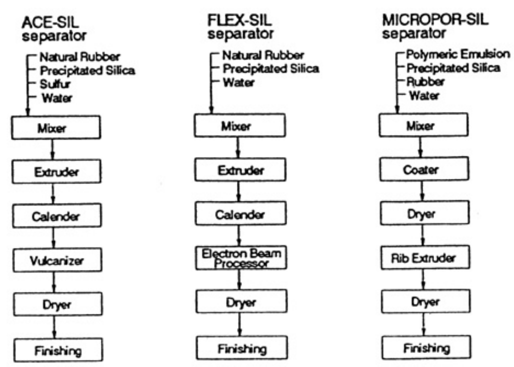

Fig. 4. Flow charts for the ACE-SIL®, FLEX-SIL® and MICROPOR-SIL® separator manufacturing process.

4.3. Flex-Sil Separator (electron-beam-cured, microporous, flexible rubber separator)

Even though Flex-Sil is a relatively new product that has been marketed since 1982, it is currently supplied to more than 90% of the golf-card battery market in the United States. The manufacturing process consists of mixing natural rubber and rehydrated precipitated silica in the internal mixer, and then extruding and calendering the compound. The calendered sheet is irradiated with an ionizing electron beam and dried (see Fig. 4). As a result of a state-of-the-art, electron beam crosslinking process, the separator is flexible and has the finest ore structure, with a mere 0.06 µm mean pore diameter. Its ultra-fine pore structure and ability to retard the transfer of the negative plate makes the Flex-Sil separator perform best in deep-cycling applications by reducing overcharging, gassing, water addition, and charge-current demand.

Flex-Sil separators are recommended for golf-cart, floor-sweeper/scrubber, marine, wheelchair, electric-vehicle, and other traction batteries.

Table 3: Rubber Separator Selection Guide*

	Ace-Sil®	Flex-Sil®	Micropor-Sil®
Industrial Stationary Batteries			
Telecommunications	xxx		xx
UPS	xx		xxx
Load Levelling	xxx		xx
Industrial Traction Batteries			
Forklift Truck	xxx	xx	xxx
Mining Equipment	xxx	xx	xxx
Automatic Guided Vehicle	xxx	xx	xxx
Automotive Batteries			
SLI	x		
Other Batteries			
Submarine	xx		xx
Golf Cart	x	xxx	xx
Marine	x	xxx	xxx
Electric Vehicle	xx	xxx	xxx
Diesel Starting	xx	x	xx
Gel Batteries of All Types			
	xx	xx	xxx

* xxx: Highly Recommended; xx: Recommended; x: Conditionally Recommended

4.4. Micropor-Sil Separator (coated, glass mat, microporous, rubber separator)

The Micropor-Sil separator is the latest development by Amerace, Microporous Products, Inc. The leaf separator is produced by mixing polymeric emulsion, precipitated silica, and rubber in a mixer; this compound is then coated on a fiberglass mat and finally cured and dried (see Fig. 4). The average pore diameter is less than 0.2 μm and the material has a very high total porosity. Because of its thin backweb design and high porosity, it has a very low electrical resistance and a low electrolyte-displacement volume. This makes the separator suitable for high-rate discharging and cold-cranking applications. Since Micropor-Sil is made with a rigid and chemically-inert glass-mat substrate, it shows excellent thermal dimensional stability under unusual conditions. It is therefore appropriate for the dry-charging process. The separator, which has a physical affinity to silica gel, is well suited for gelled-electrolyte battery applications. Because Micropor-Sil contains rubber, it imparts many of he characteristics unique to rubber separators.

Micropor-Sil is recommended for UPS, starting/trolling marine, motive power (traction), automotive SIL (starting, lighting and ignition), miners cap-lamp, and various types of gelled-electrolyte batteries.

5. Rubber separator selection guide

There are several factors that link the design and properties of separators to the performance requirements of batteries for specific applications. The art of choosing the correct separator for a given battery begins with understanding various features and properties of separators. Table 3 is provided to help select the proper rubber separator for a particular battery type.

6. Conclusions

The three types of rubber separators, Ace-Sil, Flex-Sil and Micropor-Sil, have unique electrochemical properties that may not be found in other types of separator. They show high on-charge voltage, which prevents overcharging of cells under a voltage-limited charging system, desirable Tafel behavior, and electrochemical compatibility for float-charging systems. They also retard the transfer of antimony and prevent dendrite growth. All of these features given rise to a long battery life with reduced battery maintenance. These separators are available with mini-ribs (cannelure) to be faced against the negative plates, or glass retainer mats attached to regular ribs to prevent the shedding of active material from the positive plate. The rubber separators are highly wettable and do not contain mineral oil, residual organic solvent or voltage-control additives (organic surface active compound) that and leach out to the electrolyte.

Ace-Sil separators perform best in industrial stationary or traction batteries, Flex-Sil separators are ideally suited for deep-cycling batteries, and Micropor-Sil separators are an excellent choice for high-rate discharging or cranking applications and all types of gel cells. The battery separators for tomorrow will demand more than just god insulators and mechanical filters; they will require unique electrochemical properties already found in rubber separators today.

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