Technical Bulletin

Topic: DARAK Separator for Flooded Industrial Batteries

1. Industrial Separators

The choice of a separator for an industrial application is a decisive factor with significant impact on the battery performance. The performance of an industrial cell is often directly defined by the separator.

2. Separator Key Properties

The pores of battery separators should be small enough to prevent lead particles from penetrating and causing short circuits, yet as high as possible to minimize electrical resistance and acid displacement. Electrical resistance and acid displacement are also dependent on backweb thickness and profile design.

Table 1 shows the key parameters of separators used in flooded industrial batteries. Looking at those figures, it becomes obvious that it is challenging to combine all optimal parameters in one separator.

Attributes	DARAK 5005	DARAK 5000	DARAK 9000	Poly-ethylene	Micro PVC	Sinter PVC	Rubber
Overall Thickness (mm)	2.0	2.0	2.9	2.0	2.0	2.0	2.0
BackwebThickness (mm)	0.5*	0.6*	0.9*	0.5	0.7	0.5	0.8
Porosity (%)	70	70	68	58	70	35	52
Average Pore Size μ(m)	0.5	0.5	0.6	0.15	0.4	15	0.8
Maximum Pore Size μ(m)	< 1	< 1	< 1	< 1	5	25	1.7
Acid Displacement (ml/m²)	220	240	370	350	250	350	400
Electrical Resistance** (Ωcm²)	0.10	0.12	0.14	0.25	0.16	0.30	0.25

* DARAK is available with a backweb thickness down to 0.35 mm (thin backweb is mainly used in gel batteries)
** Measured after 2 h soaking in acid at 25 °C except for polyethylene separator (measured after 10 minutes boiling in water and 20 minutes soaking in acid)

Table 1: Comparison of Key Properties of Industrial Separators

DARAK separators deliver the best combination of high porosity, small average pore size, low acid displacement, and electrical resistance, all of which can be attributted to its chemistry and production process. DARAK separators are manufactured by using an aqueous solution of a modified phenolic resin, carried by a fleece and is polymerized by means of heat. With progressive curing, the water solubility of the phenolic resin decreases and a phase separation occurs. Finally, the resin crosslinks in a three-dimensional microporous structure and the water is dried off.

2.1 Pore Size

Not only is the average pore diameter of DARAK below 1 micron, it also has an unrivaled narrow pore size distribution as illustrated in fig. 1. Ninety percent of all pores are within the range of 0.3 and 0.8 micron and virtually no pores exceed 1 micron. Therefore, DARAK separators minimize the risk of shorts by penetration of lead and lead dioxide particles through the separator.

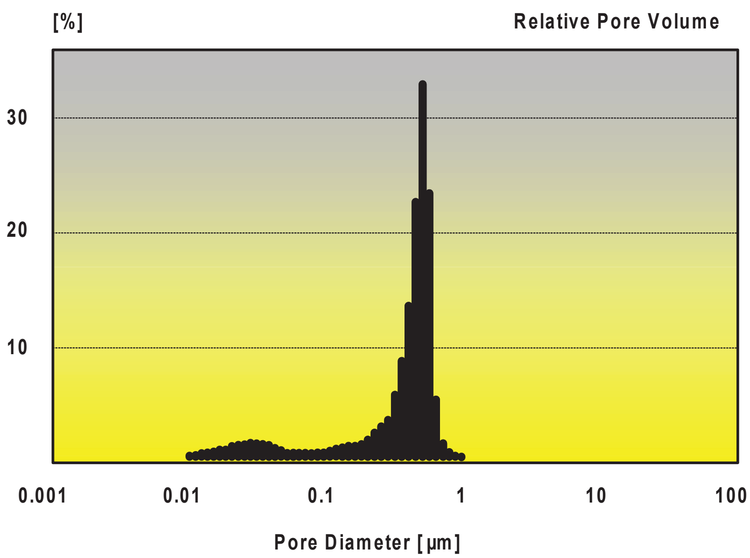


Figure 1: Pore Diameter Distribution of DARAK Separators

2.2 Porosity

The exceptionally high porosity of DARAK is an important key element to achieve a low electrical resistance and acid displacement.

2.3 Electrical Resistance

The combination of high porosity, low backweb thickness and good wettability translates into exceptionally low electrical resistance and makes DARAK the separator of choice for high rate discharge stationary batteries, high power traction batteries and other high power applications.

2.4 Acid Displacement

DARAK's high porosity and low backweb thickness combine to reduce acid displacement. Acid displacement can be further optimized by selecting suitable separator profiles. Low acid displacement means higher availability of acid resulting in higher performance batteries. Therefore, DARAK separators are the best choice for critical applications in terms of acid limitation.

3. Acid and Oxidation Stability

Separators used in industrial cells are exposed to an aggressive environment for a long time. Some stationary cells have a service life of up to 20 years. Therefore, the separator must be absolutely stable against acid and oxidation. The composition of DARAK, a three-dimensional, phenol-formaldehyde polymer in combination with a polyester fleece, provides excellent acid and oxidation stability even at high temperatures.

Battery test results shown in figure 3 demonstrate the superior battery performance of DARAK separators. It's performance can be attributed to the properties discussed above, well as stiffness which can help counteract the expansion of the negative plate during cycling.

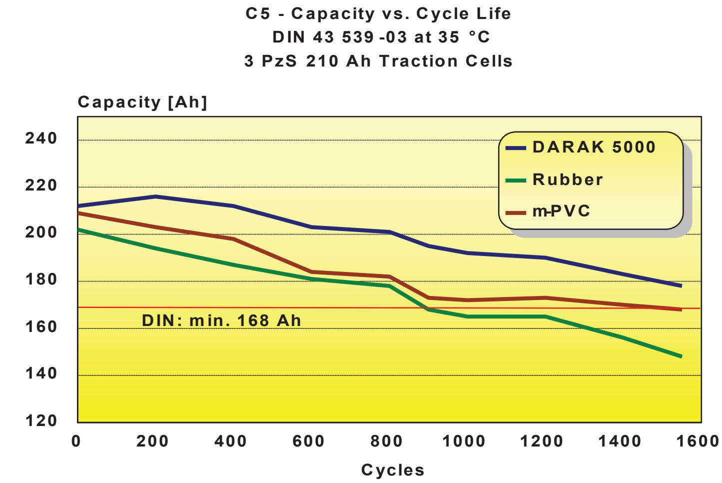


Figure 3: Capacity & Cycle Life Performance

4. Contamination

Separators must not release substances which are harmful to the battery, i.e. cause corrosion or undesirable effects on the electrode reactions. For example, chlorine can be converted into perchlorate, which causes pole and grid corrosion. DARAK separators do not contain any harmful additives or substances.

5. Environmental

Unlike PVC, where recycling issues are a concern, DARAK separators do not contain chlorine and pose no issues for battery recycling.

6. Handling

DARAK leaf separators are easy to handle and thereby contribute to effective battery production.

Attributes	DARAK 2003	DARAK 2000	DARAK 5005	DARAK 5000	DARAK 9000
Overall Thickness (mm)	2.0	2.0	2.0	2.0	2.9
Backweb Thickness (mm)	0.35	0.4	0.5	0.6	0.9
Porosity (%)	70	70	70	70	68
Average Pore Size (µm)	0.5	0.5	0.5	0.5	0.6
Maximum Pore Size (µm)	< 1	< 1	< 1	< 1	< 1
Acid Displacement (ml/m²)	180	190	220	240	370
Electrical Resistance (Ωcm²)	0.08	0.09	0.10	0.12	0.14

Table 2: Key Properties of DARAK Separator Range

7. DARAK Separator Range

In addition to DARAK 5000 and DARAK 5005, three additional versions are available: DARAK 2000 and DARAK 2003 with lower backweb; and DARAK 9000 with thicker backweb. The key parameters of the full DARAK separator range are compiled in table 2. Details on DARAK 9000 are available on request. Although DARAK 2000 and 2003 are mainly used in gel batteries, their application in flooded batteries may be worth considering.

8. Dimensions

DARAK separators are available with and without glass mat and can be supplied in the following dimensions (table 3). Other sizes may be available upon request.

	DARAK 2003	DARAK 2000	DARAK 5005	DARAK 5000	DARAK 9000
Backweb Thickness (mm)	0.35	0.40	0.50	0.60	2.9
Height (mm)	87-1250	87-1250	87-1250	87-1250	87-1250
Width (mm)	65-800	65-800	65-800	65-800	65-800
Overall Thickness (mm)	0.65-4.25	0.70-4.30	0.80-4.40	0.90-4.50	*
Thickness with Glass Mat 04 (mm)	1.20-4.50	1.25-4.55	1.35-4.65	1.45-4.75	*
Thickness with Glass Mat 06 (mm)	1.40-4.70	1.45-4.75	1.55-4.85	1.65-4.95	*
Thickness with Glass Mat 08 (mm)	1.60-4.90	1.65-4.95	1.75-5.05	1.85-5.15	*

* Other sizes available upon request

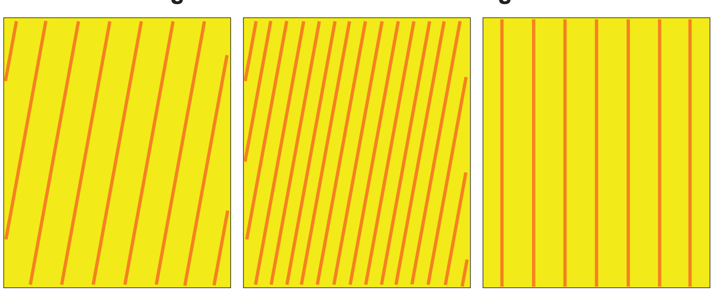
Table 3: DARAK Separator Size Range

Glass mat used in conjunction with DARAK separators help stabilize the positive active mass of pasted plates. Glass mat will increase the electrical resistance (GM 04/06/08: + 0.03/0.04/0.05 Ωcm^2) and acid displacement (GM 04/06/08: + 25/45/65 ml/m^2). With its remarkably high overall thickness capability (max. 4.15 mm without glass mat and max. 4.8 mm with glass mat), DARAK can be used for batteries with large electrode distance without the need for additional spacers.

9. DARAK Profiles

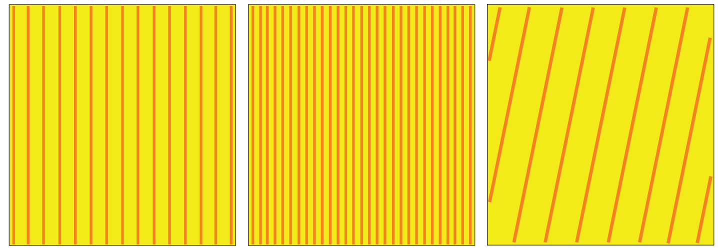
DARAK separators are available with diagonal ribs (standard configuration) and vertical ribs on the positive side. Most commonly, DARAK separators include negative ribs which facilitate the filling of gel electrolyte (see separate technical bulletin "DARAK Separator for Gel Batteries"). Available profile configurations are shown in figure 2. Additional profiles are available upon request.

Figure 2: DARAK Profile Configurations



Positive Diagonal Ribs (10^{o} Slope)
Rib Pitch 6 and 12 mm

Positive Vertical Ribs
Rib Pitch 12 mm



Negative Vertical Ribs
Rib Pitch 3 and 6 mm

Negative Diagonal Ribs (10^{o} Slope)
Rib Pitch 12 mm

10. Conclusion

DARAK's combination of properties makes it the best choice for flooded stationary batteries, submarine batteries, high power traction batteries and other high power batteries. DARAK is also the preferred separator for gel batteries (see separate technical bulletin "DARAK for Gel Batteries"). DARAK has been used in these applications for more than 30 years making it a proven industry leader.

DARAMIC®
A POLYPORE Company

Americas
+1 704 587 8599

Asia Pacific
+86 21 38 13 9933

Europe, Middle East & Africa
+33 3 88 82 41 12

India
+91 80 4256 1103