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UL 2591

Outline of Investigation for Battery Cell Separators

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Summary of Topics

This is the third issue of the Outline of Investigation for Battery Cell Separators and covers requirements for separators for use in lithium ion cells. This new issue includes test procedures on battery cell separators with respect to pore measurements (Porosity, Pore size and distribution), wettability and heat-of-combustion. Analytical tests to characterize battery cell separator material and the need to have a Quality Assurance (QA) program is also included. Revisions to Puncture Strength Test (inclusion of blunt-puncture test) and Dimensional Stability Test (inclusion of an alternate oven-method) were also made.

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INTRODUCTION

1 Scope

1.1 These requirements cover short-term test procedures to be used for the evaluation of battery cell separators for use in lithium ion cells.

1.2 These separators are intended to provide electrical insulation between the lithium-ion cell electrodes while still allowing for ion transport between the electrodes, when filled with electrolyte.

1.3 The test procedures covered in this outline provide information with respect to the physical, mechanical, thermal, flammability and other properties of the battery cell separator under consideration.

2 Units of Measurement

2.1 Values stated without parentheses are the requirement. Values in parentheses are explanatory or approximate information.

3 References

3.1 Any undated reference to a code or standard appearing in the requirements of this Outline shall be interpreted as referring to the latest edition of that code or standard.

3.2 Appendix B contains references to procedures in the Standard for Polymeric Materials – Short Term Properties, UL 746A, that are used in this Outline.

4 Glossary

4.1 For the purpose of this Outline the following definitions apply.

4.2 MACHINE DIRECTION – The direction parallel to that taken by the majority of molecules in plastic separator film, or the direction of the separator film web as it moves through the film-making machine. Also called Longitudinal Direction.

4.3 MELT TEMPERATURE (SEPARATOR) – The temperature at which the separator material begins to change from a crystalline solid phase to liquid phase in a first order transition (i.e. with an abrupt change in the volume and a transfer of heat from the sample to its surroundings as a signal of the transition).

4.4 PERMEABILITY (SEPARATOR) – The ability of a fluid to penetrate the separator. For the purposes of this outline, the fluid used is air. Permeability is usually a reflection of the ionic resistance of the separator.

4.5 SHUTDOWN TEMPERATURE (SEPARATOR) – The temperature at which there is a sudden increase in the resistance of the separator due to the melting of the polymer and filling of the pores, which stops the flow of ions between the electrodes of the lithium ion battery. This is a critical parameter of the separator as this feature of the separator serves as a safety mechanism for a lithium ion cell that is overheating due to an abnormal condition.

4.6 TRANSVERSE DIRECTION – The direction perpendicular to the machine direction of the separator film.

PERFORMANCE

5 Supplementary Test Procedures

5.1 The separator shall be resistant to deterioration as a result of exposure to the contents of the lithium-ion cell. Compliance is determined through the heating test of the Standard for Lithium Batteries, UL 1642.

6 General

6.1 The list of tests carried out on the separator and the test sample information for each test are as outlined in Table 6.1.

Table 6.1
List of tests performed on the separator

	Parameter / measurement	Samples			Test clause
		Number / conditioning ^a	Dimensions of a test sample		
			mm	(in)	
Physical	Permeability	10 / conditioned	60 x 60	2.36 x 2.36	7.1
	Thickness	1 / conditioned	1000 cm in machine direction	39.4 inch in machine direction	7.2
	Porosity	2 / conditioned	60 x 60	2.36 x 2.36	7.3
	Pore size and pore size distribution	5 / conditioned	60 x 60	2.36 x 2.36	7.4
	Wettability	2 / conditioned	60 x 60	2.36 x 2.36	7.5
Mechanical	Tensile Strength	12 / conditioned	25.4 x 200	1 x 7.87	8.1
	Puncture Strength	5 / conditioned	60 x 60	2.36 x 2.36	8.2
Thermal	Dimensional Stability	2 / conditioned	60 x 60	2.36 x 2.36	9.1
	Shutdown Temperature	2 / conditioned	60 x 60	2.36 x 2.36	9.2
	Melt Temperature ^b	1 / conditioned	60 x 200	2.36 x 7.87	9.3
Combustion	Heat of combustion	2 / conditioned	60 x 60	2.36 x 2.36	10.1
Material Characterization	FTIR, TGA, DSC, SEM/EDX, Ash Content, MFI, Sp.Gravity	1 / conditioned	60 x 200	2.36 x 7.87	11

^a Unless otherwise noted in the individual test methods, the conditioning shall consist of min. 48 hours at 23 ±2°C (73.4 ±1.8°F) and 50 ±10% RH prior to testing.

^b Melt Temperature measurement has been covered under DSC Measurement

7 Physical Property Tests on the Separator

7.1 Permeability

7.1.1 The permeability of the separator shall be determined as a result of subjecting it to the test methods outlined in the Standard Test Method for Resistance of Nonporous Paper to Passage of Air, ASTM D726.

7.1.2 Air permeability is expressed in terms of its "Gurley" value, (i.e. represents the time required for 100 cc of air to pass through a specific area of separator under the pressure 4.88 inches-H₂O). The required sample set shall consist of separator samples obtained from different rolls to check product consistency.

7.1.3 The number of samples and dimensions of the samples are as outlined in Table 6.1. Prior to testing, the samples shall be conditioned in an atmosphere of 50.0 ±10.0% RH and 23.0 ±2.0°C (73.4 ±1.8°F) for a minimum of 48 hours.

7.2 Thickness

7.2.1 The separator thickness is determined by utilizing an instrument designed for measuring easily-deformed work pieces. The measuring instrument is adjusted so that an extra-low measuring force is placed on the sample when measuring the thickness. A flat tip with large area (such as rigid flat plate) is used to increase the specimen contact area. A sharp or radiused tip shall be avoided as it may "sink" into the material and produce a false, low reading for thickness.

7.2.2 The thickness of the sample is measured at every 20 cm (7.87 in) in the machine direction of the sample for a total of 5 measurements. The thickness of the sample is calculated as the average of the 5 measurements.

7.2.3 The number of samples and dimensions of the samples are as outlined in Table 6.1. Prior to testing, the samples shall be conditioned in an atmosphere of 50.0 ±10.0% RH and 23.0 ±2.0°C (73.4 ±1.8°F) for a minimum of 48 hours.

7.3 Porosity

7.3.1 The most practical method for measuring porosity is liquid absorption method. This method is suitable for both polyolefin and composite separators where density is not known. Instrumental techniques such as Porosimeter and Porometer may also be used to determine the porosity.

7.3.2 A separator measuring 60 mm x 60 mm (2.36 in x 2.36 in) is soaked with a liquid capable of wetting the substrate for a minimum of 5 minutes, preferably oil or an alcohol, although the latter is more susceptible to evaporation.

7.3.3 The porosity is measured by the weights of separator before and after the absorption as the following equation:

$$\text{Porosity (\%)} = (W - W_0 / \rho_L V_0) \times 100$$

Where

W_0 and W represent the weights of separator before and after immersing a liquid, respectively;

ρ_L is the density of the liquid; and