

Celgard 2325 vs 2400 Separator: Performance Comparison for Li-ion Battery Research

A detailed comparison of Celgard 2325 and 2400 separators for battery research: thickness, porosity, thermal shrinkage, ionic conductivity, and how to choose the right separator for your electrochemical testing.

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Why Separator Choice Matters in Battery Research

The separator is the unsung hero of every lithium-ion battery. It sits between the cathode and anode, preventing electronic shorts while allowing lithium ions to pass through. Get the separator wrong — too thick, too thin, wrong pore structure, poor thermal stability — and your cycling data becomes unreliable, or worse, your cell shorts out mid-test.

For researchers working on new electrode materials, electrolyte formulations, or cell designs, **Celgard 2325** and **Celgard 2400** are the two most common commercial separators used in coin cell and pouch cell prototypes. Both are polypropylene (PP) or polyethylene (PE) based, widely available, and have decades of field validation. But they are **not interchangeable** — their thickness, pore structure, and thermal behavior differ in ways that affect your results.

This guide breaks down the specs, performance trade-offs, and decision logic so you can pick the right separator before you assemble your first cell.

Material Structure and Composition

Celgard 2325: Trilayer PP/PE/PP

Celgard 2325 is a **trilayer separator**: polypropylene (PP) outer layers with a polyethylene (PE) core. The structure looks like this:

- **Outer layers (PP)**: Higher melting point ($\sim 165^{\circ}\text{C}$), provides mechanical strength and dimensional stability
- **Core layer (PE)**: Lower melting point ($\sim 135^{\circ}\text{C}$), acts as a thermal shutdown mechanism
- **Total thickness**: $25\text{ }\mu\text{m}$ ($\pm 2\text{ }\mu\text{m}$)

The trilayer design gives you **thermal shutdown** functionality: if the cell overheats (above $\sim 135^{\circ}\text{C}$), the PE core melts and closes the pores, cutting off ionic transport and stopping the runaway reaction. This is a safety feature borrowed from commercial cells.

Celgard 2400: Single-layer PP

Celgard 2400 is a **monolayer separator**: pure polypropylene throughout.

- **Single layer (PP)**: Melting point ~165°C
- **Total thickness**: 25 µm (±2 µm)
- **No thermal shutdown**: The separator stays porous until PP melts at 165°C

The monolayer design is simpler and slightly more uniform in pore distribution, but lacks the built-in thermal fuse of the 2325.

Specifications Side-by-Side

Here is the direct comparison:

Specification	Celgard 2325	Celgard 2400
Structure	Trilayer (PP/PE/PP)	Monolayer (PP)
Thickness	25 µm	25 µm
Porosity	39%	41%
Pore size (Gurley)	0.209 µm × 0.054 µm	0.043 µm × 0.039 µm
Permeability (Gurley)	165 s/100 cc/mil	195 s/100 cc/mil
Thermal shrinkage (105°C, 1h)	MD: <4%, TD: <4%	MD: <3%, TD: <3%
Shutdown temperature	~135°C (PE melts)	No shutdown
Melting point	PP: 165°C, PE: 135°C	PP: 165°C
Tensile strength (MD)	1400 kg/cm ²	1300 kg/cm ²
Puncture strength	5.0 N	4.5 N
Wettability (carbonate electrolyte)	Moderate (PP surface)	Moderate (PP surface)

Key takeaways:

- **Same thickness** (25 µm), so they fit into the same coin cell stack
 - **Slightly different porosity**: 2400 has 41% vs 2325's 39%, which affects ionic conductivity
 - **Different pore geometry**: 2400 has smaller, more uniform pores; 2325 has elongated pores (dry-process stretching artifact)
 - **Thermal shutdown**: 2325 offers shutdown at 135°C; 2400 does not
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Ionic Conductivity and Rate Performance

The separator's pore structure directly affects how fast lithium ions can move through it, which shows up in your cell's internal resistance and rate capability.

Celgard 2400: Slightly Higher Conductivity

With **41% porosity** and more uniform pore distribution, Celgard 2400 typically shows **5-10% lower ionic resistance** than 2325 when soaked in the same electrolyte (1M LiPF₆ in EC/DMC). This translates to:

- **Better rate performance** at high C-rates (2C, 5C, 10C)
- **Lower overpotential** during charge/discharge
- **Slightly better low-temperature performance** (the extra porosity helps at -20°C where viscosity is high)

If you are testing **high-power applications** (fast-charging cathodes, supercapacitor hybrids, rate-capability studies), the 2400's conductivity advantage matters.

Celgard 2325: Good Balance

With **39% porosity** and the trilayer structure, Celgard 2325 is slightly more resistive but still well within acceptable range for most research. The difference is noticeable in EIS (electrochemical impedance spectroscopy) — you might see **1-2 Ω extra** at 1 kHz in a CR2032 cell — but it rarely affects cycle life or capacity at moderate rates (C/2, 1C).

The **thermal shutdown** feature is the trade-off: you give up 5-10% conductivity in exchange for a built-in safety mechanism.

Thermal Stability and Safety

This is where the two separators diverge most.

Celgard 2325: Thermal Shutdown Protection

The PE core in the 2325 melts at **~135°C**, closing the pores and cutting off ionic transport. This is called **thermal shutdown**, and it is a critical safety feature in commercial Li-ion cells.

Why it matters in research:

- If you are testing **new cathode materials** with unknown thermal behavior (high-nickel NMC, lithium-rich oxides), the 2325 gives you a safety buffer
- If you are running **abuse tests** (overcharge, nail penetration, thermal ramp), the 2325 will shut down before thermal runaway
- If you are working with **flammable electrolytes** (high ether content, low-flash-point solvents), the shutdown can prevent glove box fires

Trade-off: Once the PE melts, the cell is dead. You cannot reverse the shutdown. For long-term cycling at elevated temperatures (45°C, 60°C), you need to stay well below 135°C or the separator will partially melt

over time.

Celgard 2400: No Shutdown, Higher Temperature Tolerance

The monolayer PP structure has **no shutdown mechanism**. The separator stays porous until PP itself melts at **165°C**. This means:

- **Higher thermal tolerance** for extended cycling at 60-80°C (common in battery aging studies)
- **No risk of premature shutdown** if your cell heats up during high-rate discharge
- **But no safety net** — if the cell goes into thermal runaway, the 2400 will not stop it

For **academic research** where you are cycling cells in a controlled environment (temperature chambers, fume hoods), the lack of shutdown is usually not a problem. You are monitoring the cells anyway, and thermal runaway is rare in well-assembled coin cells.

Thermal shrinkage is comparable: both separators shrink <4% at 105°C for 1 hour. This is acceptable for most research, though if you are doing ultra-long-term cycling (>1000 cycles at 60°C), you might see gradual separator curling at the edges.

Mechanical Strength and Handling

Both separators are mechanically robust, but the trilayer 2325 has a slight edge in puncture resistance.

Celgard 2325: Slightly Tougher

- **Puncture strength:** 5.0 N (better resistance to cathode particles or lithium dendrites poking through)
- **Tensile strength:** 1400 kg/cm² (machine direction)

The trilayer structure makes it harder to tear during handling. If you are training new students on coin cell assembly, the 2325 is more forgiving — it is less likely to rip when you are placing it onto the electrode.

Celgard 2400: Adequate Strength

- **Puncture strength:** 4.5 N
- **Tensile strength:** 1300 kg/cm² (machine direction)

Still very robust, but the monolayer is slightly more prone to puncture if you have sharp cathode particles (spinel LMO with faceted crystals, for example). In practice, the difference is small unless you are working with particularly aggressive electrode morphologies.

Wettability and Electrolyte Compatibility

Both separators have **polypropylene surfaces**, which are moderately hydrophobic. This means:

-  **Good wetting** with carbonate electrolytes (EC/DMC, EC/DEC, EC/EMC + LiPF₆)
-  **Slower wetting** with ether electrolytes (DOL/DME for Li-S batteries) — you may need to pre-wet the separator

- **✗ Poor wetting** with ionic liquids — surface modification or additives required

There is no significant wetting difference between 2325 and 2400 when using standard carbonate electrolytes. Both require **~10-20 minutes soaking** before assembly to ensure full pore infiltration.

If you are working with **non-standard electrolytes** (high-concentration, ether-based, solid-state hybrid), consider pre-treating the separator:

- Plasma treatment (O_2 or Ar plasma for 30 seconds) improves wetting
 - Alcohol rinse (isopropanol or ethanol) helps ether electrolytes spread
 - Coating (thin Al_2O_3 or PVDF layer) improves thermal stability and wetting
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When to Use Celgard 2325

Choose **Celgard 2325 (trilayer PP/PE/PP)** if:

- ✓ **You need thermal shutdown protection**

Testing new cathode materials, running abuse tests, or working with flammable electrolytes.

- ✓ **You want extra mechanical robustness**

Training new students, working with sharp cathode particles, or assembling cells in less-than-ideal conditions.

- ✓ **You are mimicking commercial cell behavior**

Most commercial 18650 and pouch cells use trilayer separators. If you want your prototype to behave like a real cell, use the 2325.

- ✓ **Safety is a higher priority than peak performance**

The 5-10% conductivity loss is worth the safety buffer.

Typical applications:

- New cathode screening (NMC, NCA, lithium-rich oxides)
 - Abuse testing (overcharge, nail penetration)
 - Student training labs
 - Flammable electrolyte testing (high ether content)
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When to Use Celgard 2400

Choose **Celgard 2400 (monolayer PP)** if:

- ✓ **You need maximum ionic conductivity**

Rate capability studies, high-power applications, or fast-charging cathode development.

- ✓ **You are cycling at elevated temperatures (60-80°C)**

The monolayer PP has higher thermal tolerance without risk of shutdown.

✓ You want lower internal resistance

The extra 2% porosity (41% vs 39%) and uniform pore structure reduce impedance.

✓ You are doing fundamental research where shutdown is not needed

Academic studies in controlled environments, where thermal runaway is not a concern.

Typical applications:

- Rate capability studies (2C, 5C, 10C discharge)
 - High-temperature aging tests (60°C, 80°C cycling)
 - Fast-charging cathode development
 - Low-temperature performance testing (-20°C, -40°C)
 - Fundamental electrochemistry (half-cell studies, EIS characterization)
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Cost and Availability

Both separators are widely available and similarly priced in research quantities:

- **Sheet form** (e.g., 15 cm × 20 cm): \$50-100 per sheet
- **Pre-cut discs** (16 mm diameter for CR2032): \$1-2 per disc in packs of 100

The 2325 is slightly more expensive (5-10%) due to the trilayer co-extrusion process, but the difference is negligible for most research budgets.

Quality matters: Make sure you are buying genuine Celgard separators, not generic PP films. Generic separators often have:

- Variable thickness ($\pm 5\ \mu\text{m}$ instead of $\pm 2\ \mu\text{m}$)
- Lower porosity (30-35% instead of 39-41%)
- Poor thermal stability (shrinks 10-20% at 105°C)
- Inconsistent pore structure (leads to localized hot spots)

Cheap separators are a false economy — they cause premature shorts, high impedance, and unreliable data.

Practical Assembly Tips

Regardless of which separator you choose, follow these best practices:

Pre-wetting

1. Punch your separator discs (16 mm for CR2032, 19 mm for CR2032 with margin)
2. Soak discs in electrolyte for **10-20 minutes** before assembly
3. Use a clean Petri dish or glass vial — do not let discs touch each other (they stick together when wet)
4. Drain excess electrolyte with a lint-free wipe (Kimwipe or equivalent) before placing on electrode

Handling

- Use **PTFE-coated tweezers** (stainless steel can introduce metal particles)
- Never touch the separator with bare gloves (skin oils reduce wettability)
- Inspect for tears or holes under a magnifying lamp before use

Electrolyte Volume

For a CR2032 cell:

- **With Celgard 2325 or 2400:** 80-100 μL total electrolyte
- **Separator takes up:** $\sim$ 5-8 μL (absorbed into pores)
- **Remaining electrolyte:** Wets electrodes and fills voids

If you are using a thicker separator (e.g., stacked double-layer), reduce the total electrolyte to avoid over-filling and leaks during crimping.

Conclusion: 2325 for Safety, 2400 for Performance

Both Celgard 2325 and 2400 are excellent separators for battery research, and the choice comes down to your priorities:

- **Celgard 2325** = Thermal shutdown protection + extra mechanical strength. Best for new material screening, abuse testing, and student training.
- **Celgard 2400** = Higher ionic conductivity + better high-temperature tolerance. Best for rate studies, elevated-temperature cycling, and fundamental research.

For **general-purpose Li-ion research** (NMC/graphite full cells, half-cell screening, standard cycling protocols), both work well. If you are unsure, **start with Celgard 2325** — the thermal shutdown gives you peace of mind, and the conductivity difference is small enough that it won't affect your conclusions.

Ready to Get Started?

We stock both Celgard 2325 and 2400 separators in sheet form and pre-cut discs for CR2032, CR2025, and custom sizes. All separators are genuine Celgard product with certificates of conformity.

👉 [View Celgard 2325 Separator Discs](#)

👉 [View Celgard 2400 Separator Discs](#)

👉 [Download Separator Specification Sheet \(PDF\)](#)

Have questions about separator selection or coin cell assembly? [Contact our technical team](#) — we are here to help.

Enquiries: business@labcorematerials.com · labcorematerials.com

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