Metallized Polypropylene Capacitors For Electrification of Larger Vehicles

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......being presented by:
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Larger vehicle applications include: trains, mining, farming, ships and the like.

- **Light Rail**
- **Energy Carrying Ships**
- **Farming**
Outline

• Characteristics of a metallized polypropylene capacitor.
• Characteristics of alternative film technologies.
• Representative test methods for power electronic film capacitors in large vehicles.
• Focus is large DC capacitors for Filter and DC Link applications.
Characteristics of Metallized Polypropylene Capacitors

- Self-healing properties
- High crystalline films increase temperature and voltage capabilities.
- Can be packaged with dielectric oils or insulating resins.
- Can be in metallic or non-metallic cases.
- Continuous operation possible of 115°C.
Improvements In Metallized Polypropylene Capacitors

Metallized Polypropylene Capacitors in Medium Voltage Systems

Specific Energy Densities of These Capacitors
Polypropylene Film Capacitor Life

- Life is determined by the rated voltage and the hot spot temperature.

- Higher temperature polypropylene grades increase the voltage rating for a given temperature.
Packaging of Metallized Polypropylene Film Capacitors.

Dry Potted Construction - Air and Liquid Cooling.

Vegetable Oil Filled - Air and Liquid Cooling
The vegetable oil filled designs dielectric voltage exceeds the dry versions until about 90°C.

The vegetable oil penetrates the film and makes the electric field more uniform.

Vegetable oil designs are resurging in higher power applications such as ship drives.
BOPP and other select film dielectric choices

- BOPP stands for biaxially oriented polypropylene and is the common abbreviation for capacitor polypropylene.
- PPS - polyphenylene sulfide.
- PEI is Polyetherimide.
- PTFE is tetraflouroethylene

- BOPP remains the film of choice until a $\approx 100^\circ C$ Hot Spot.
- WBG (GaN or SiC) applications may need higher Hot Spot Temperatures
## Select Film Dielectric Electrical Properties

<table>
<thead>
<tr>
<th>Film</th>
<th>K</th>
<th>DWV 25°C</th>
<th>DWV 120°C</th>
<th>DF (1 KHz)</th>
<th>Self-Healing</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOPP</td>
<td>2.2</td>
<td>700</td>
<td>500</td>
<td>.0002</td>
<td>Excellent</td>
</tr>
<tr>
<td>PPS</td>
<td>3.0</td>
<td>480</td>
<td>480</td>
<td>.0018</td>
<td>Poor</td>
</tr>
<tr>
<td>PEI</td>
<td>3.2</td>
<td>550</td>
<td>520</td>
<td>.0020</td>
<td>TBD</td>
</tr>
<tr>
<td>PTFE</td>
<td>2.0</td>
<td>700</td>
<td>450</td>
<td>.0001</td>
<td>Fair</td>
</tr>
</tbody>
</table>

K = Dielectric Constant  DF = Dissipation Factor
Competing Demands

- Manage the competing demands with new materials and processes
- Use standardized testing to evaluate the performance.
Survey of representative industry standards for capacitor reliability

- IEC 61071 - Capacitors for power electronics.
  - The most cited standard within the field of Power Electronics.
  - IEC is the International Electrotechnical Commission.

- IEC 61881 - Rolling stock equipment - Capacitors for power electronics -
  - Part 2: Aluminum electrolytic capacitors with non-solid electrolyte.
  - Part 3: Electric double layer capacitors.
The rubber meets the road in these IEC standards with Endurance Testing.

- Two choices are offered:
  - A) 1.3 x rated voltage at maximum operating temperature for 500 hours, pulse 1000 times at 1.4 x peak current (2x for IEC 61881) followed by 500 additional hours aging.
  - B) 1.4 x rated voltage at maximum operating temperature for 250 hours, pulse 1000 times at 1.4 x peak current (2x for IEC 61881) followed by 250 hours additional aging.
Representative Aging Results

- 3 samples rated 15,000 \( \mu \text{F} \) 900 Vdc
- Included pulse testing after 250 hours.
- All passed criteria of \( \Delta C/C \leq 3\% \)

![Percent Capacitance Change From Original Value vs Aging Hours at 1270 Vdc](image)

Aging Hours at 1270 Vdc-First 500 Hours at 70° C then balance of test at 75 C
Surge discharge test on full scale 15,000 \( \mu F \)
900 Vdc capacitors.

This was performed after 500 hours of aging before 1500 hours more aging!

This “type test” simulates the effect of semiconductor and other system failures.
Surge Discharge Testing on 15,000μF 900 Vdc Capacitors

- The test was calibrated at 14 Vdc at 4.4 kA.
- The voltage was increased to 1400 Vdc and discharge was performed 5 times.
- The surge current at the test condition was 440 kA or 110% rating.
Thermal Stability test

- Capacitor is subjected to maximum ambient temperature +5°C.
- Power is adjusted to $1.21 \times P_{\text{max}}$.
- Four thermal measurements within a 6 hour period must vary by $<1^\circ\text{K}$.
The DC capacitor type of choice for electrification of larger vehicles

- Metallized polypropylene with high a temperature grade of film.
- Dry resin filled and vegetable oil filled designs are tailored to specific applications.
- Package options can include integral liquid cooling.
What does the Future hold?

- BOPP (Biaxially stretched polypropylene) has outstanding electrical characteristics.
- BOPP improvements have increased its capabilities from 105°C to ≈ 115°C.
- When will a 10 to 20 degrees additional temperature capability justify movement from the known benefits of BOPP?
Thank You