

# 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

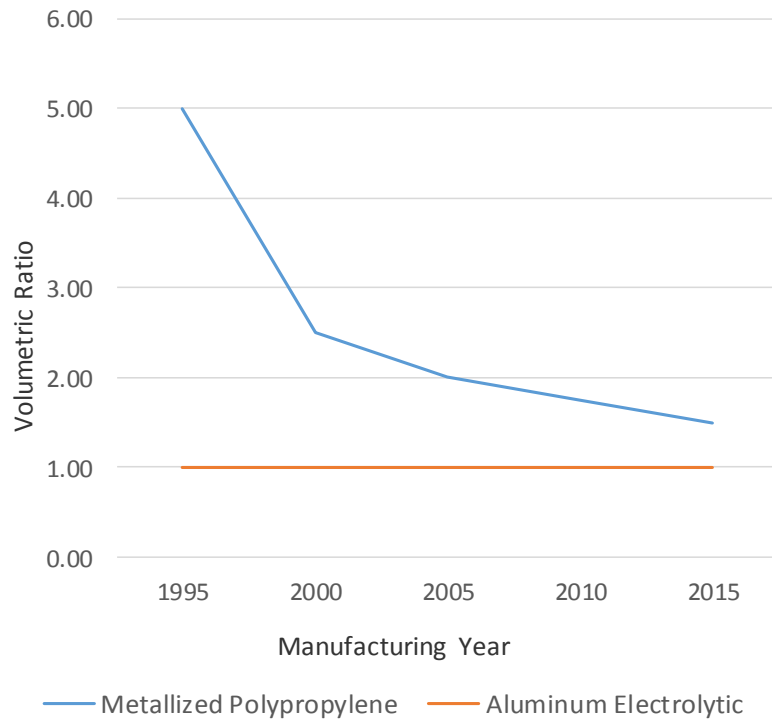
- Characteristics of a metallized polypropylene capacitor.
- Characteristics of alternative film technologies.
- Representative test methods for power electronic film capacitors in large vehicles.
- Focus is large DC capacitors for Filter and DC Link applications.

# Characteristics of Metallized Polypropylene Capacitors

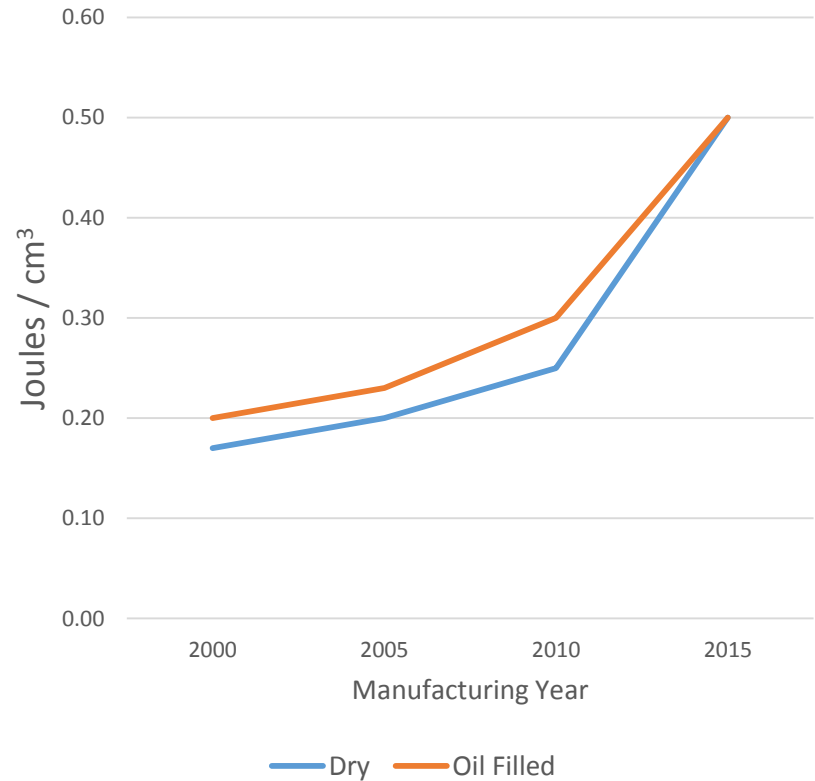
- **Self-healing properties**
- **High crystalline films increase temperature and voltage capabilities.**
- **Can be packaged with dielectric oils or insulating resins.**
- **Can be in metallic or non-metallic cases.**
- **Continuous operation possible of 115°C.**

# Improvements In Metallized Polypropylene Capacitors

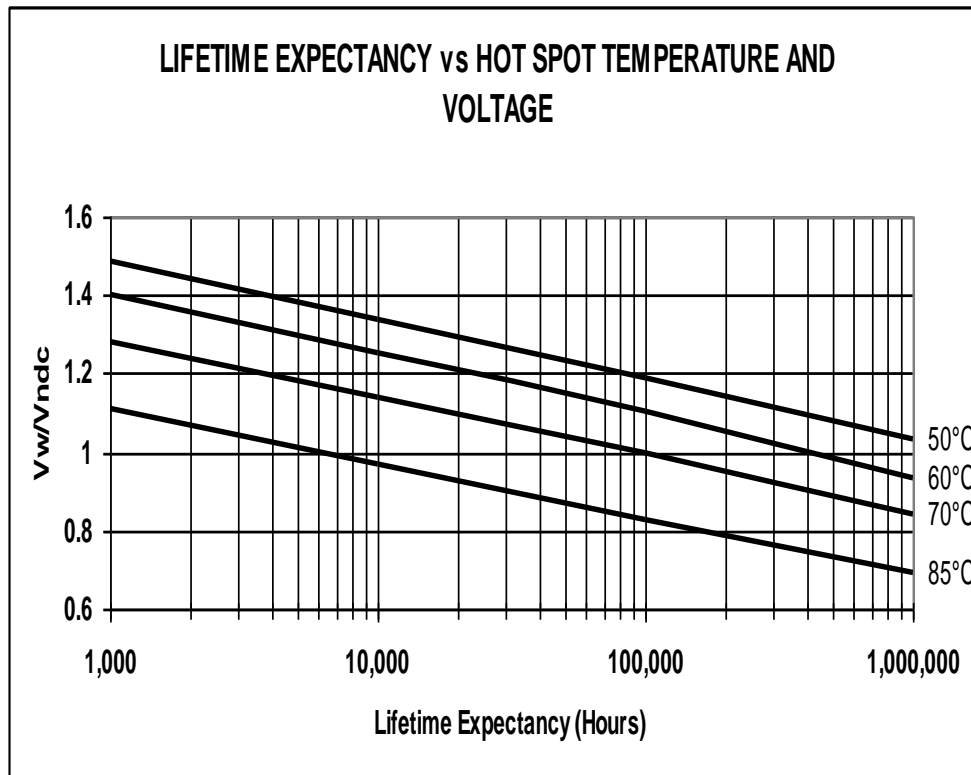
## Metallized Polypropylene Capacitors in Medium Voltage Systems



## Specific Energy Densities of These Capacitors



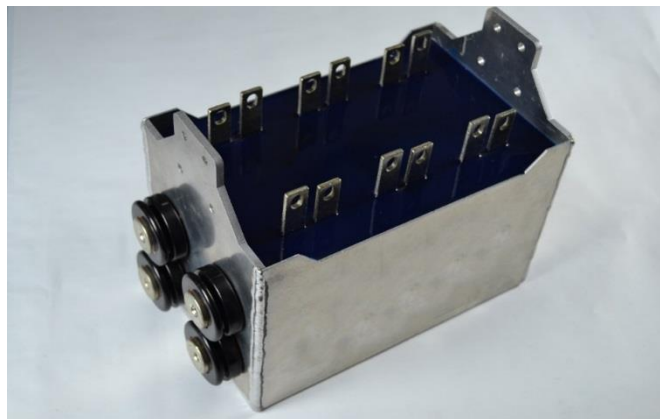
# Polypropylene Film Capacitor Life



- 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.**

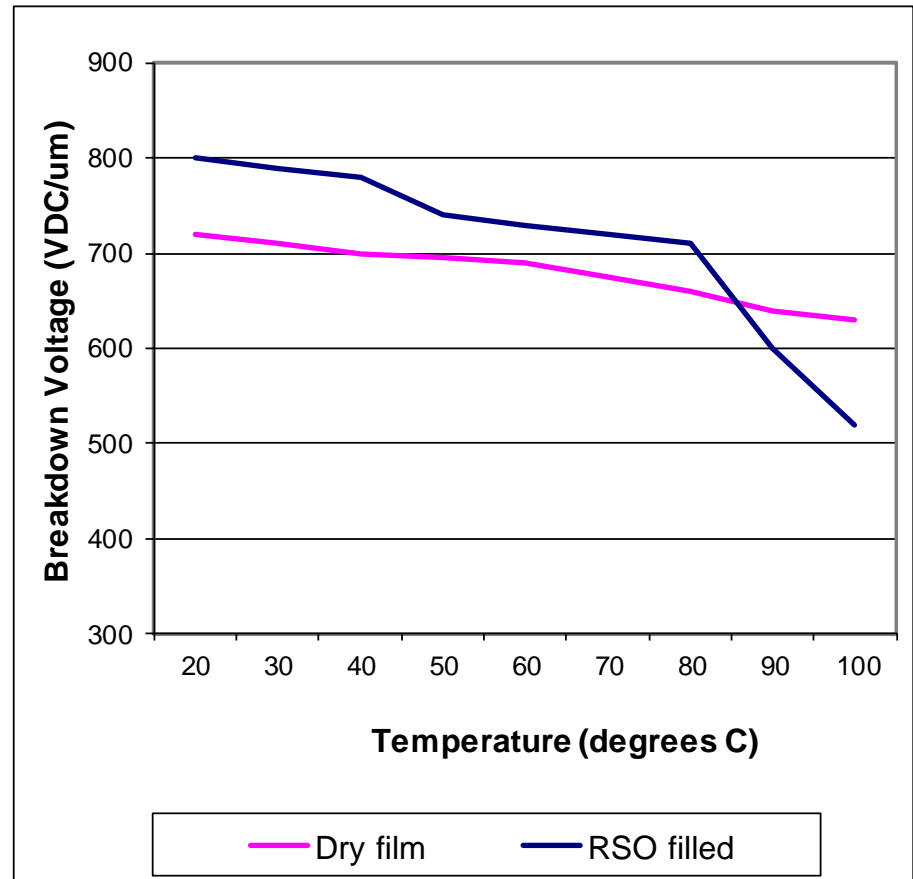


**Vegetable Oil Filled- Air and Liquid Cooling**



# Contrast of Oil Filled Metallized Polypropylene Film Capacitors versus Dry Potted Versions

- 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- Is polyphenylene sulfide.
- PEI is Polyetherimide.
- PTFE is tetraflouroethylene
- BOPP remains the film of choice until a  $\approx 100^{\circ}\text{C}$  Hot Spot.
- WBG (GaN or SiC) applications may need higher Hot Spot Temperatures

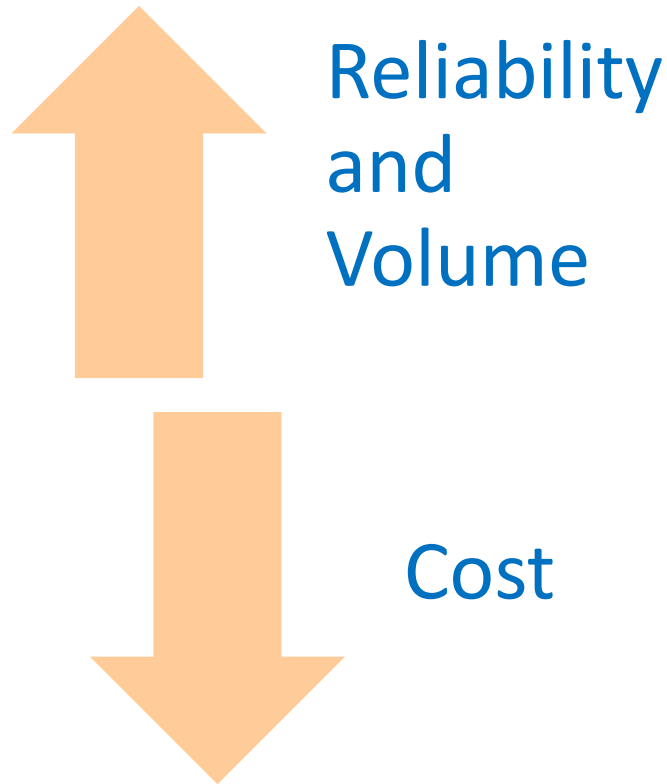
# Select Film Dielectric Electrical Properties

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

**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

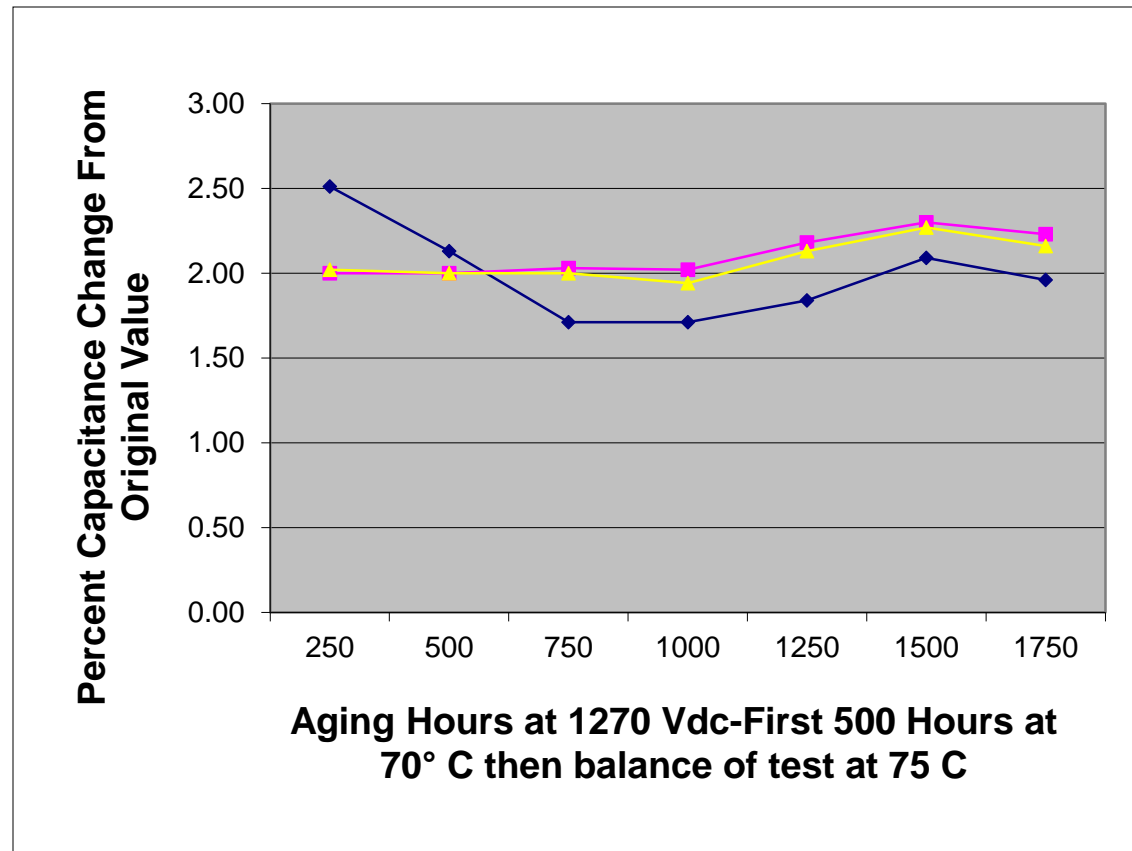
- IEC 61071- Capacitors for power electronics.
- The most cited standard within the field of Power Electronics.
- IEC is the International Electrotechnical Commission.
- IEC 61881- Rolling stock equipment- Capacitors for power electronics-
- Part 1: Paper/plastic film capacitors.
- Part 2: Aluminum electrolytic 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

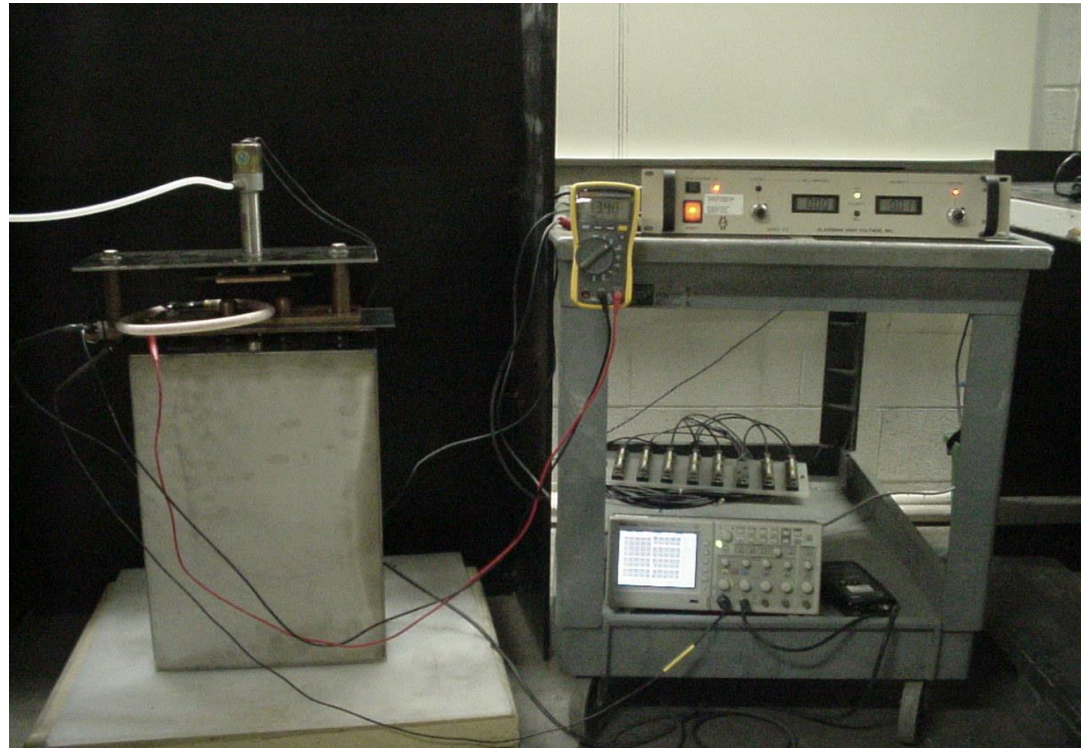
- 3 samples rated 15,000  $\mu\text{F}$  900 Vdc
- Included pulse testing after 250 hours.
- All passed criteria of  $\Delta C/C \leq 3\%$



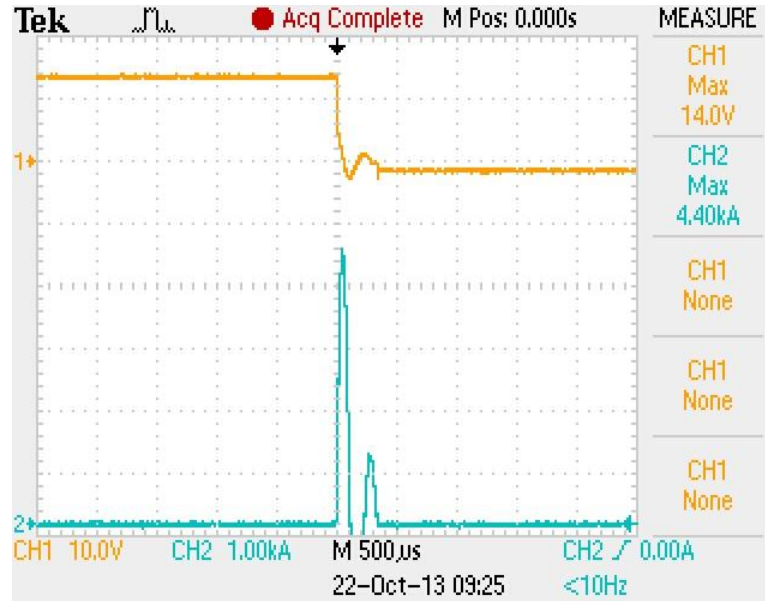
# Surge discharge test on full scale 15,000 $\mu\text{F}$ 900 Vdc capacitors.

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.



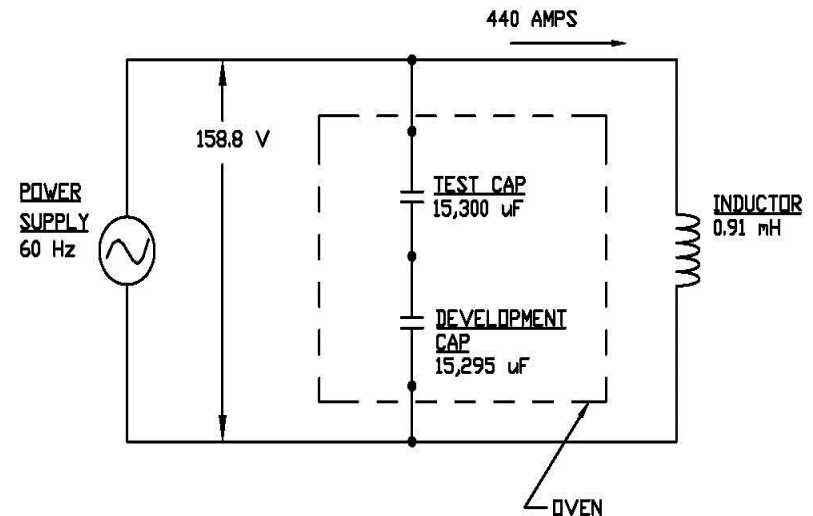
# Surge Discharge Testing on 15,000 $\mu$ F 900 Vdc Capacitors



- 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  $+5^{\circ}\text{C}$ .
- 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  $\approx 115^\circ\text{C}$ .
- When will a 10 to 20 degrees additional temperature capability justify movement from the known benefits of BOPP?



**Thank You**