DC Filter Capacitors With Metallized Film Technology Show Volumetric Efficiencies For Medium Voltage Motor Drives

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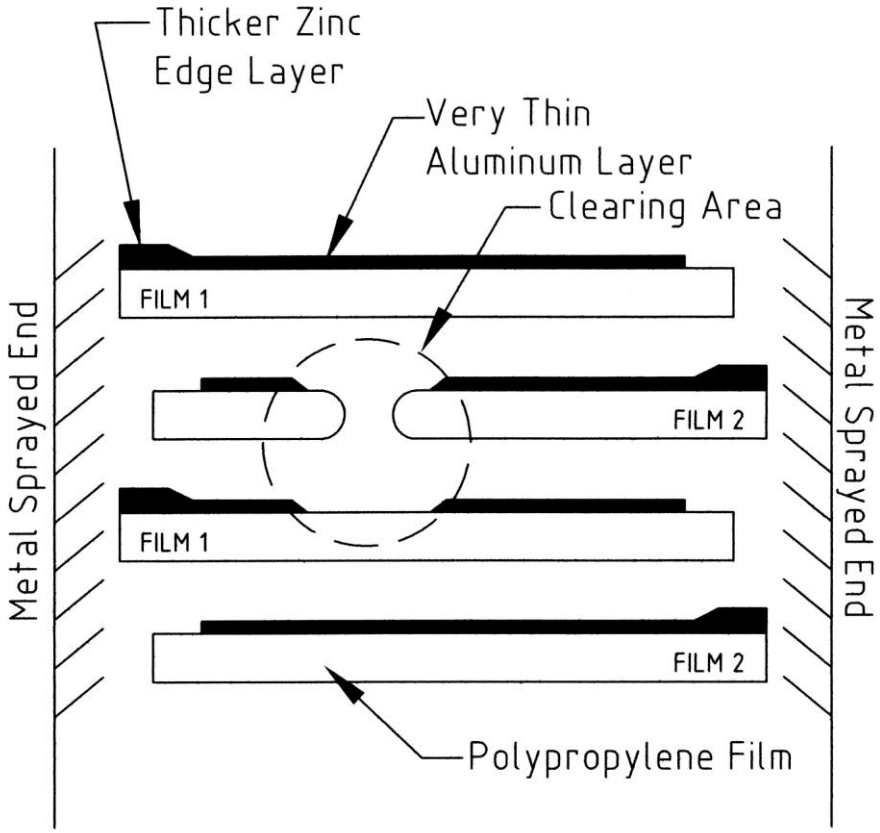
Outline

- Overview of metallized polypropylene film capacitors.
- Thermal characteristics of a metallized polypropylene capacitor.
- Thermal comparison of a metallized polypropylene capacitor with and without liquid cooling.

Metallized Film Construction



Metallized Polypropylene Capacitors

- **Have 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 degrees C.**

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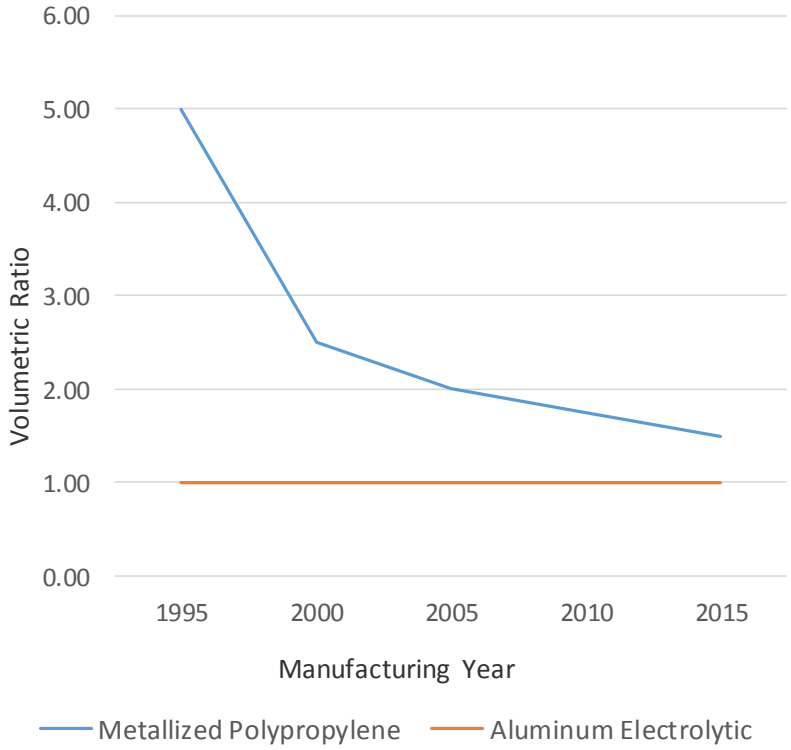
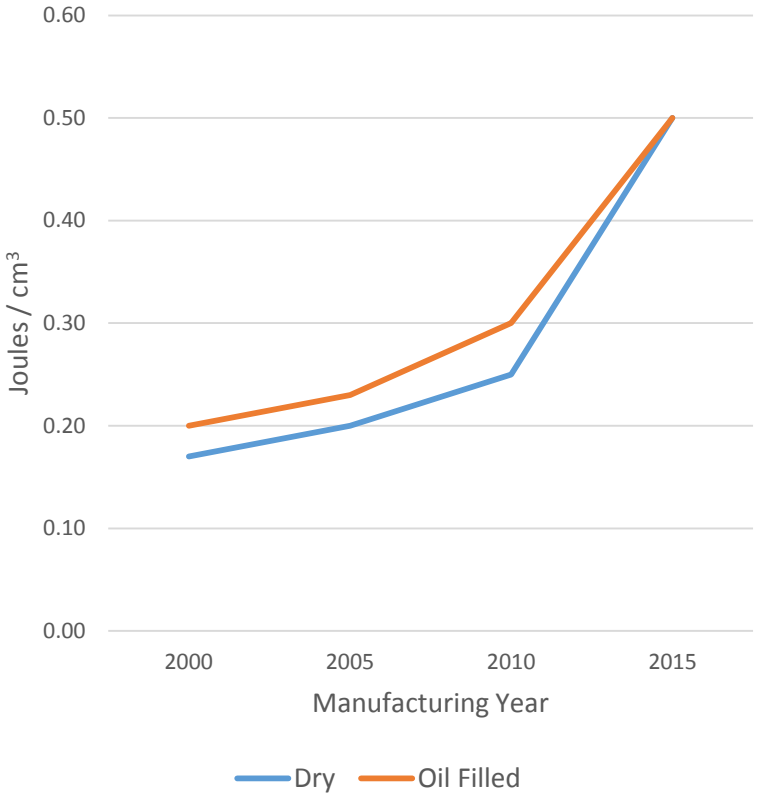
Volumetric Comparisons (The Metallized Polypropylene Designs are For 20 Year Life at 70°C)

Metallized Polypropylene In Medium Voltage Systems vs. Aluminum Electrolytic

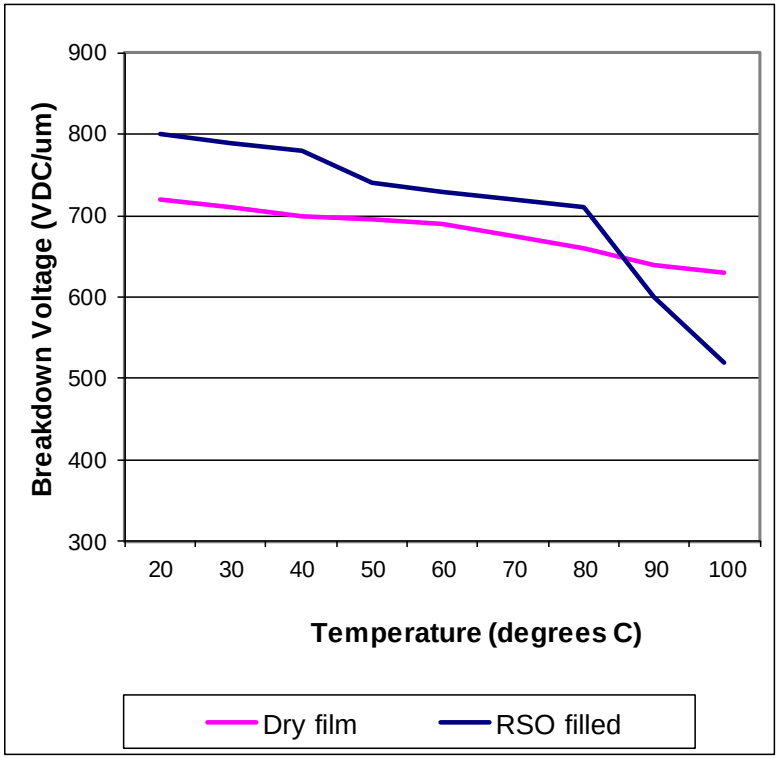


Metallized Polypropylene Specific Energy Densities



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.



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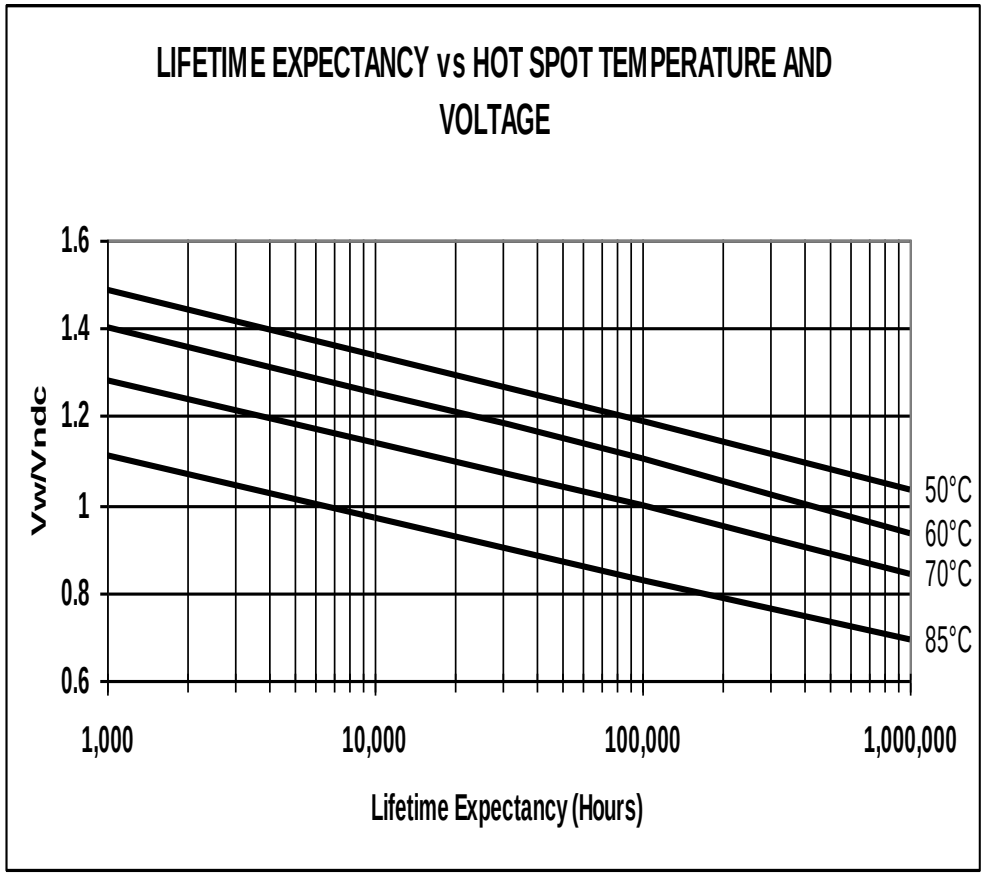
Power Film Capacitor Packaging

Dry Resin Filled

Vegetable Oil Filled

Capacitor Life Is Determined By the Voltage Stress and Hot Spot Temperature.



As the voltage increases or decreases versus the voltage rating, the life can be expressed as:

$$A_v = (V_n / V_w)^9 \qquad (1)$$

Where A_v is the acceleration due to voltage.

V_w is the application voltage and

V_n is the rated voltage of the capacitor

Life Acceleration With Temperature

- Is based upon an a constant "n" as used in:

$$A_T = 2^{(HS_R - HS_A)/n} \quad (2)$$

A_T is the acceleration due to temperature.

HS_R is the rated hot spot temperature.

HS_A is the hot spot temperature in the application.

- The constant "n" is usually referred to as the Arrhenius Constant.
- When n is 10, it means the life is halved for every 10°C increase in hot spot.
- A temperature dependence coefficient of 7 or 8 is considered appropriate for polypropylene dielectric capacitors with a hot spot over 85°C.

Hot Spot Temperature For a Metallized Polypropylene Power Capacitor.

$$\theta_{HS} = \theta_{amb} + (P_d + P_t) \cdot R_{th} \qquad (3)$$

$$P_d = [\, ½ \cdot C_n \cdot (VRipple)^2 \cdot f \,] \cdot (2 \times 10^{-4}) \qquad (4)$$

$$P_t = R_s \cdot I^2rms \qquad (5)$$

P_d and P_t are the dielectric and termination losses respectively.

Dissipation Factor of Polypropylene is a constant 2 x 10^{-4} versus temperature and frequency.

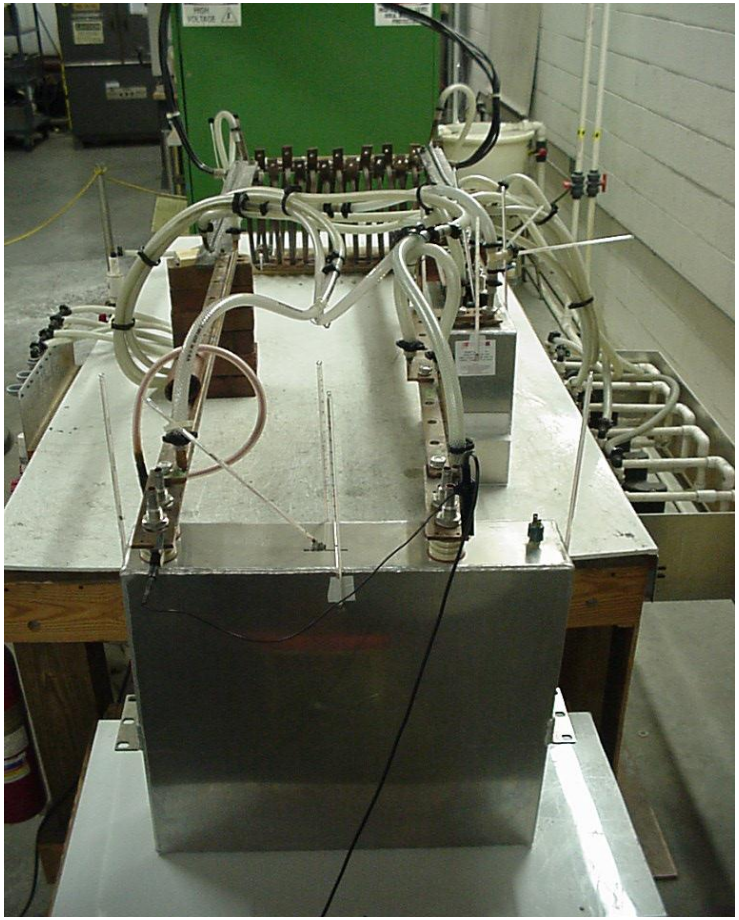
Why Not Pursue Integral Liquid Cooling For Power Film Capacitors?

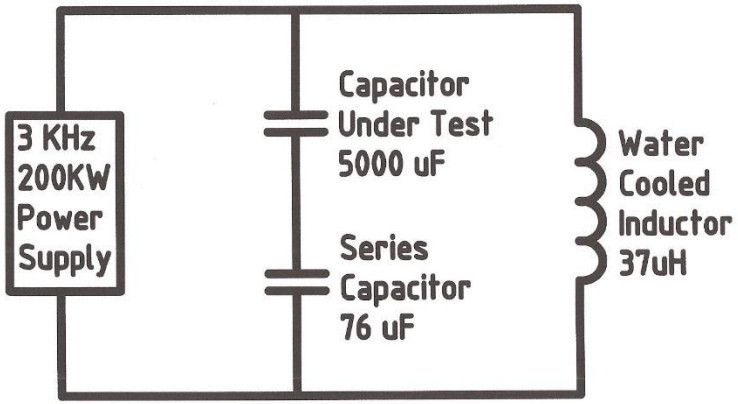
- Power Semi-conductors and other components are now commonly liquid cooled so the technology already is available.
- Designers have placed capacitors on cold plates for many years.
- Film capacitors with integral liquid cooling are available and a proven technology.

Comparison of a DC Filter Capacitor With and Without Liquid Cooling at 3 KHz.

- The Test Capacitor was 5000 microfarads nominal with a 1000 Vdc Metallized Polypropylene Dielectric System.
- Tap water was used with 7.56 Liters/Min. thru the 12.7 mm OD (10.8 ID) copper cooling coils.
- Test frequency was 3.12 KHz
- A thermal equilibrium at 1600 amps rms and then at 2000 Arms was obtained.
- A Re-test was performed at 800 amps rms without liquid cooling for comparison was performed.

Liquid cooled capacitor connected to a 3 KHz power supply.





Total Watts With Liquid Cooling

For this type of high frequency test on a DC rated capacitor, P_d can be ignored.

The constant (2×10^{-4}) which is the tan δ of polypropylene makes P_d approach zero.

The measured ESR at 3 KHz on the 5000 µF capacitor was .00081Ω

Then the total watts at 2000 amps are essentially:

$P_t = R_s \times I^2_{rms}$

$P_t = .00081 \times (2000)^2 = 3240$ watts

Prediction For Air Cooled Example

From previous NWL tests we have seen approximately .023 watts/cm^2 for this type of welded metal case produces a Hot Spot $\Delta T = 10°C$.

To obtain $\Delta T = 27°C$ we can calculate.062 watts/cm^2. The case area is 8733 cm^2. We can therefore calculate watts as 541.4 for P_t and predicted Arms =817.5.

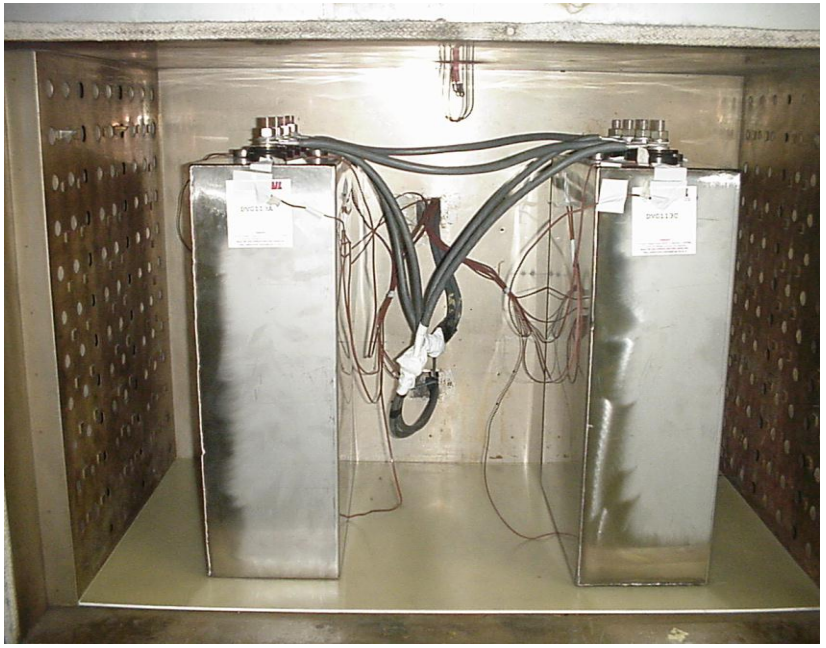
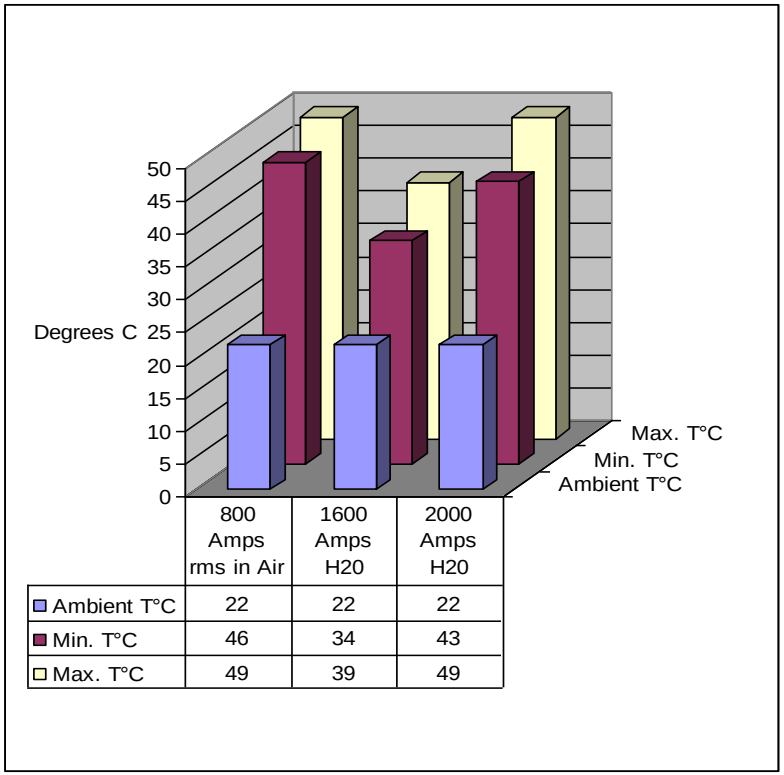


Figure shows Example of thermal stability test per IEC 61071

Results For 3KHz Capacitor Test

- The Hot Spot at 2000 Arms with Liquid Cooling was 49°C, ΔT = 27°C
- The Hot spot at 800 Arms with Air Cooling was 49°C, ΔT = 27°C.



	800 Amps rms in Air	1600 Amps H20	2000 Amps H20
Ambient T°C	22	22	22
Min. T°C	46	34	43
Max. T°C	49	39	49

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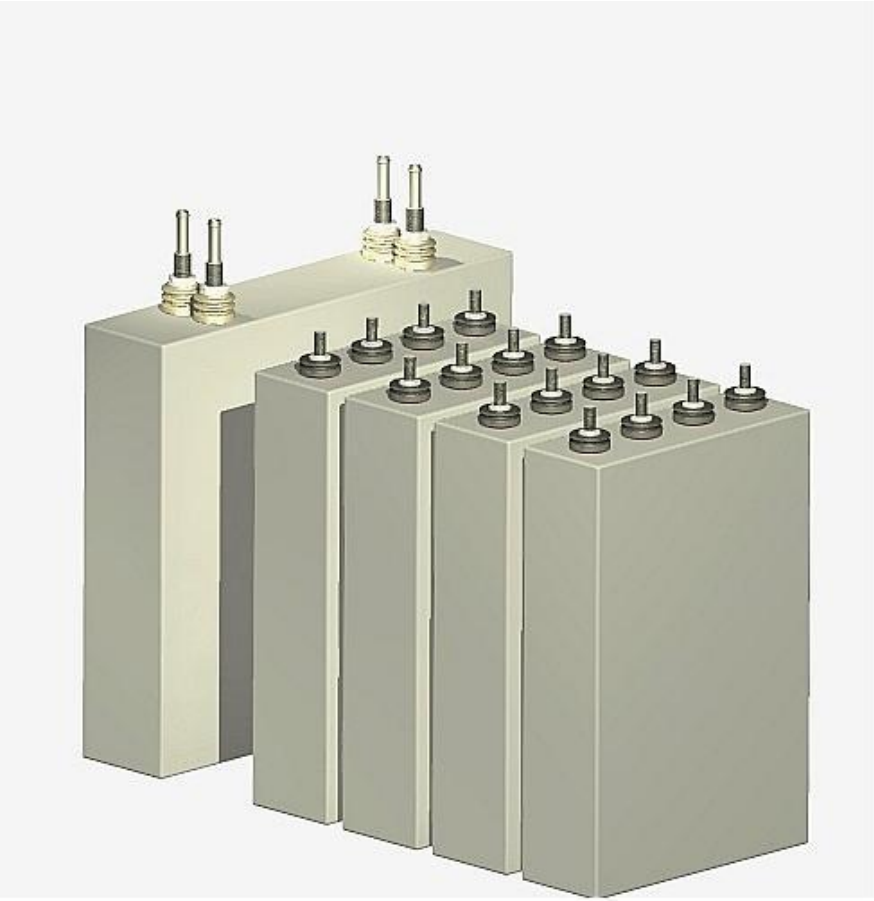
Volume of Liquid Cooled design and Equivalent Air Cooled Version

Liquid Cooled .038 m^3



Example of 2000 Arms, ΔT= 27°C

Air cooled 0.1 m^3