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VIRTUAL CONFERENCE
EV ENGINEERING

Managing Temperature and Partial Discharge by Insulation Materials in E-Motors

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Axalta Webinar

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Axalta's Global Breadth and Scope

$4.5 Billion in Revenue

100,000+
Customers

4,000+
Distributors

~14,000
People

130
Countries

50+
Brands

48
Manufacturing Centers

54
Training Centers

4
R&D Technology Centers

30+
Laboratories

150+
Years in the Industry

Durable coatings that protect, enhance productivity and add beauty

Overview

Questions to be answered today

- How can I use full material potential in a given motor design?
- Which aging mechanisms impact motor insulation?
- Which strategies are in place today to reduce aging effects in a motor?
- What impact will the change of the insulation material have?

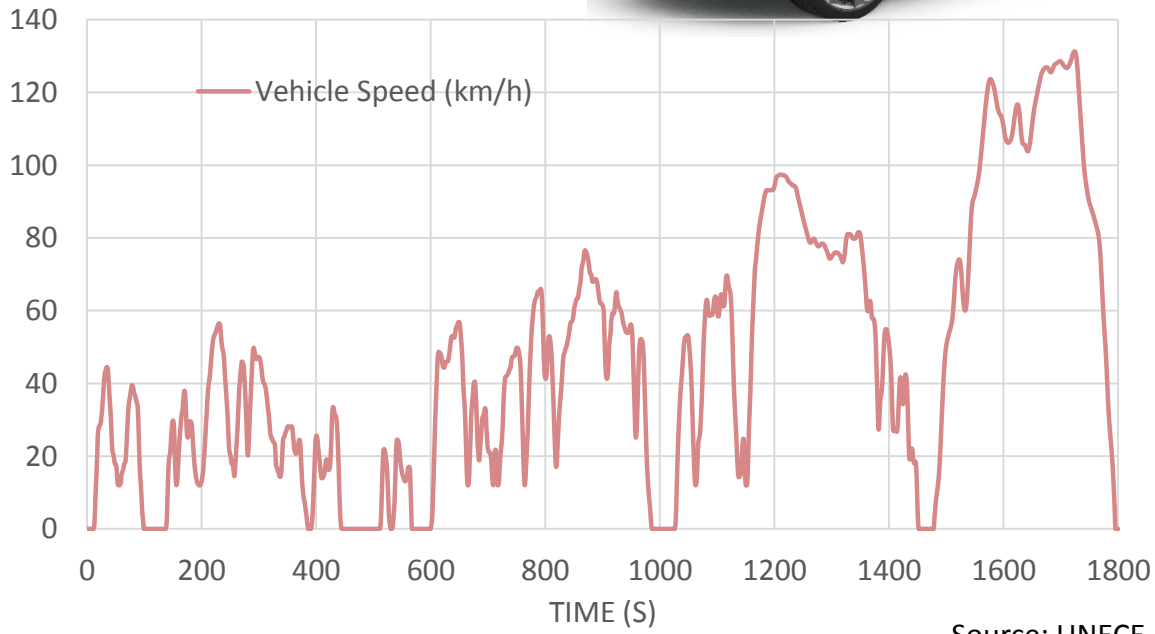
WLTC as an Example of E-motor Usage

Worldwide Harmonized Light-Duty Vehicles Test Cycle

- Industrial applications – constant load (e.g. pump, drives, fans…)

- e-mobility – highly dynamic
  - Multitude of stresses present
    - Mechanical
    - Electrical
    - Chemical
    - Thermal

  - **Stresses will lead to accelerated aging of insulation**
    - No equilibrium
    - Overvoltage
    - High switching frequency
    - High temperature peaks



Source: UNECE

E-Motor

Main Design Factors and Insulation Toolbox

- Operating Temperature
- Operating Voltage
- Inverter Technology
- Power to Weight
- Cost per Unit

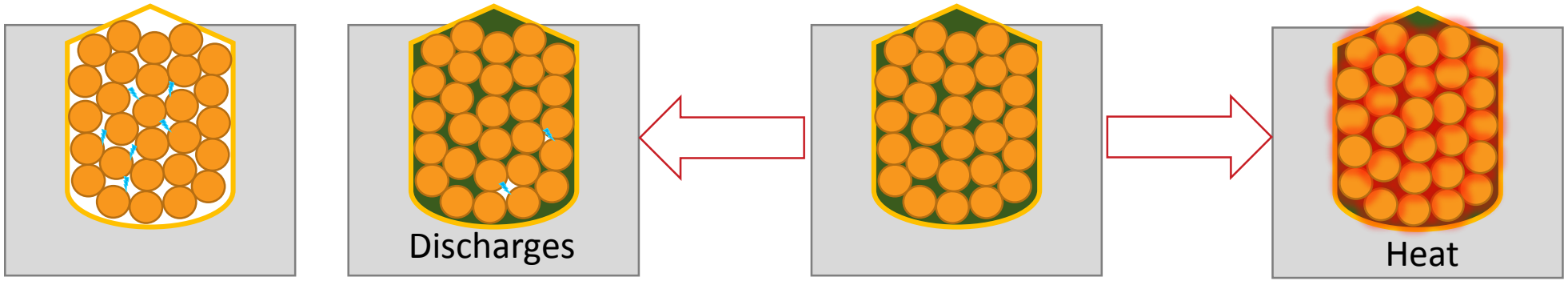
Wire Enamels

Electrical Steel Coatings

Impregnating Resins

… of crucial importance!

Consider Impregnation Process during Design and Material Choice



Application Process	Process Time	Complexity	Resin Fill Grade Resin Retention
Atmospheric Dipping	Medium	Low	**Low**
Vacuum Dipping or VPI	Long	High	**Low to Medium**
Trickle / Dip-Roll	Short	Medium	**Medium to High**
Resistance Heating incl. Hot Dip / Gel	Medium	High	**Very High**
Full Encapsulation	Long	Very High	**Maximum**

Electric Aging

Fundamentals

Occurrence

- For inverter driven motors as of 400 V
- PDIV is reduced at elevated temperatures

Mechanism of degradation

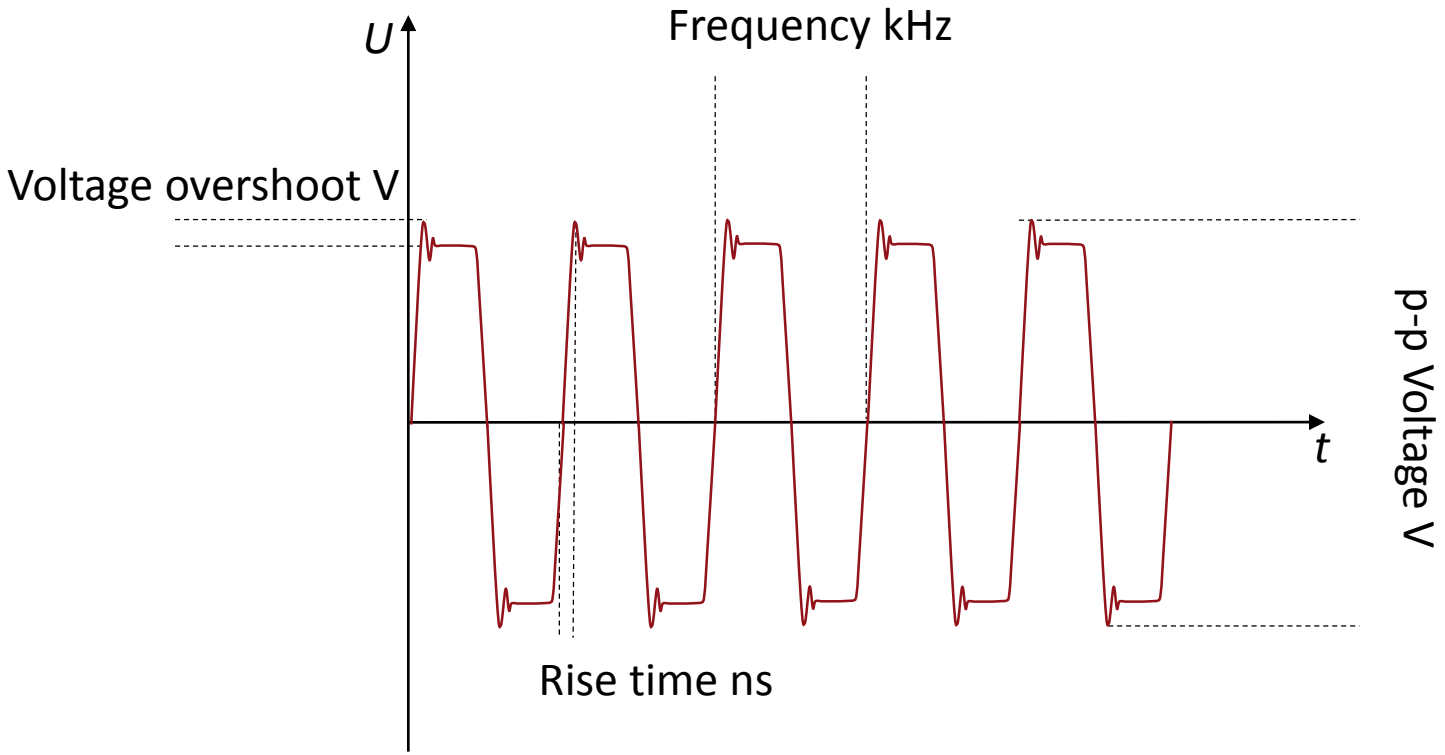
- UV-radiation
- Reactions forming ozone that degrades organics
- Ionized matter
- Accelerated aging in humid atmosphere

Kinetics

- Follow the inverse power law
- within tens to hundreds of hours for primary insulation

Bottlenecks

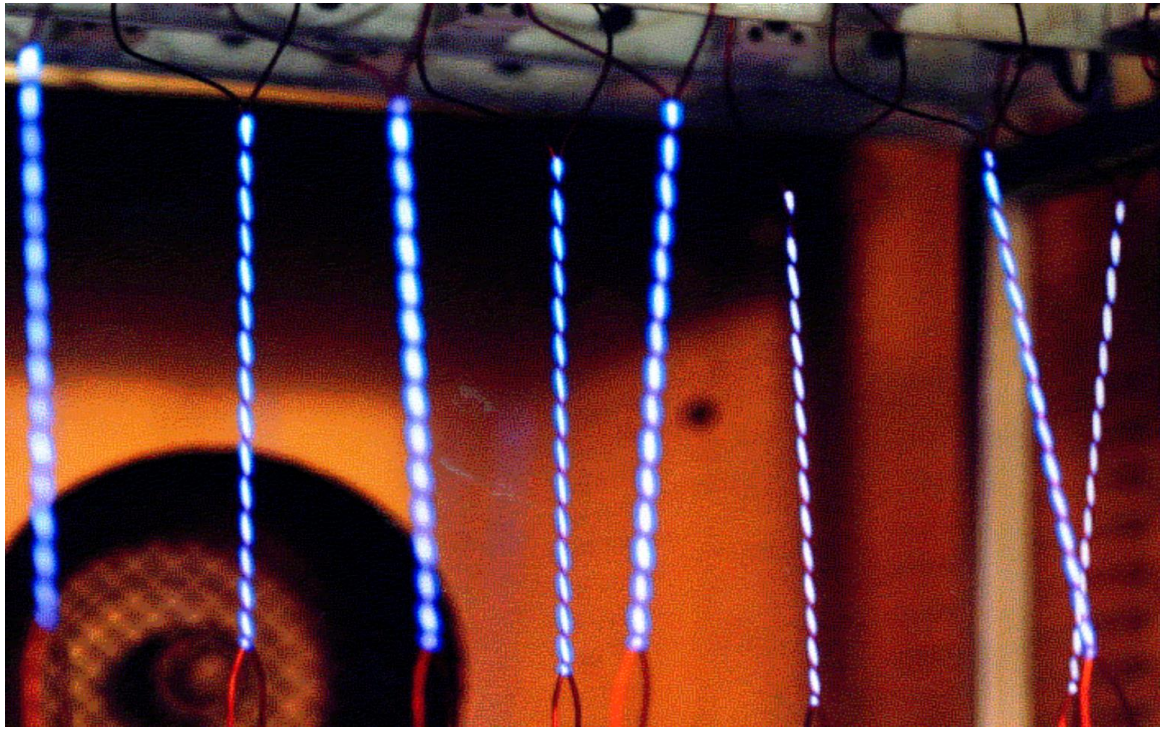
- Voids
- Slot entry
- Phase to phase discharges in end windings



Electric Aging

Management Strategies in Design – Increase PDIV

- Increase distance on critical spots
  - Heavy insulation build on magnet wires
    - Co-Extrusion process
    - Taped Wires
  - Insulation papers
    - Aramide
    - Laminates (PI, PEEK, PAI)

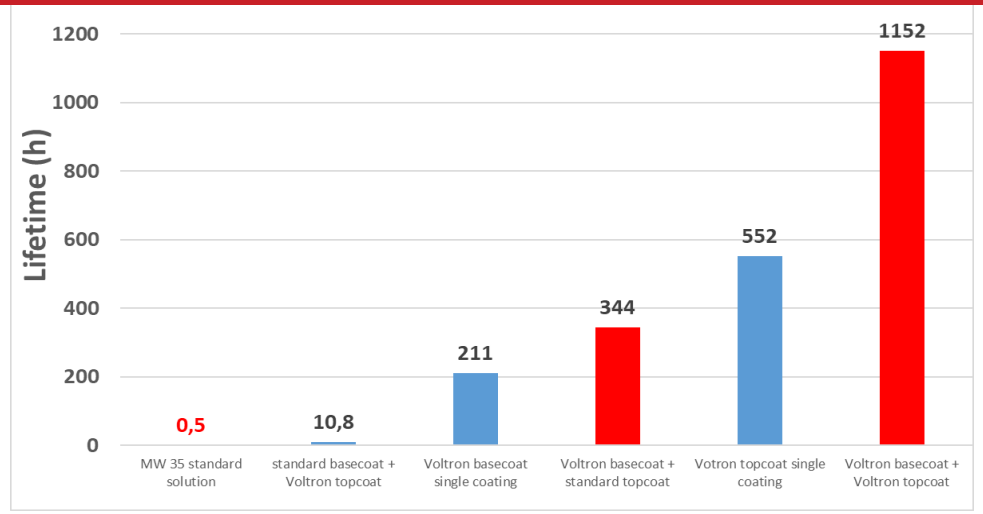


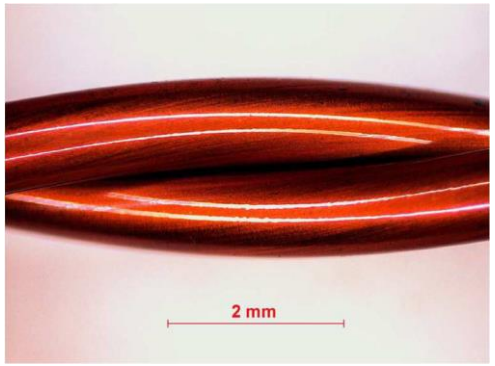
- Fill all voids
  - Impregnating resins
    - Optimized impregnation process

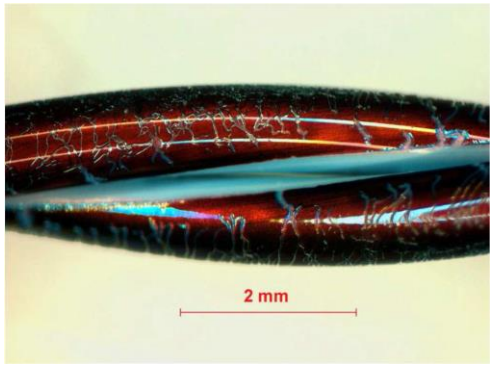
Electric Aging

Management Strategies in Design – Increase Resistance to PD

Wire Enamel

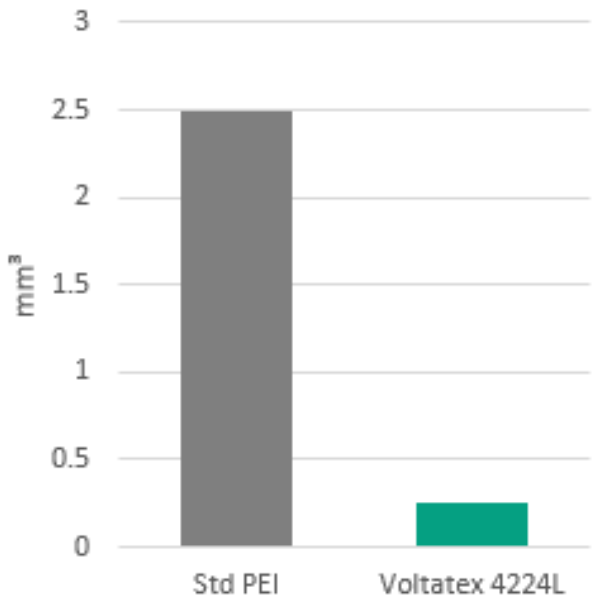




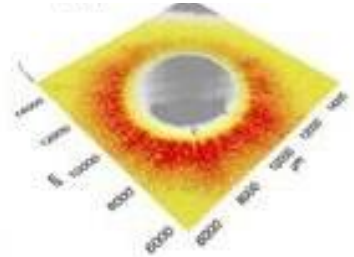


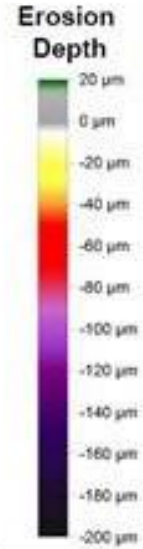
Impregnating Resin

Erosion Volume by Toepler setup

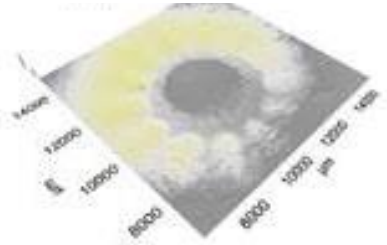


Standard PEI





Voltatex® 4224 L



Thermal Aging

Fundamentals

Occurrence

- Elevated temperatures
- Relevant for e-mobility as of 150°C
- Almost entire insulation system aging constantly

Mechanism of degradation

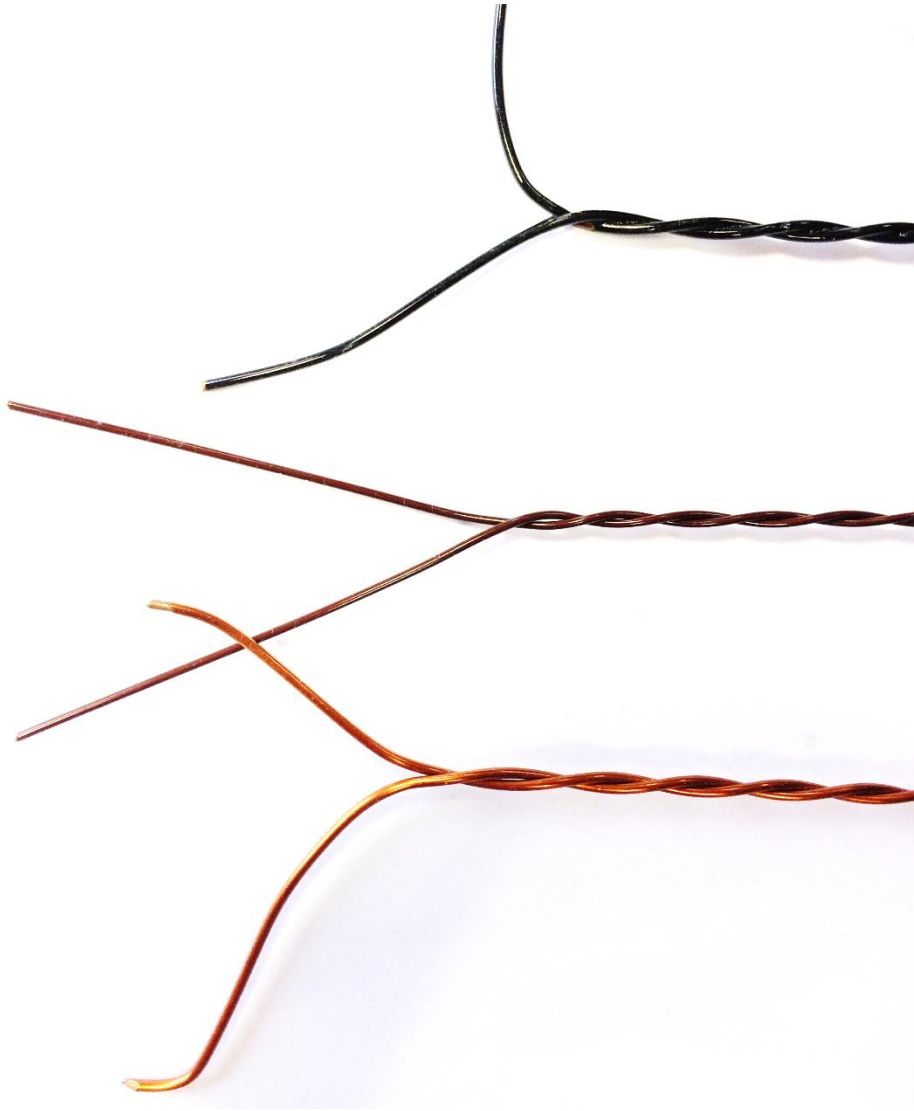
- Oxidation
- Chemical environment
- Depolymerisation
- Formation and stabilization of radicals

Kinetics

- Follow the Arrhenius law (if no phase transition present)
- within thousands of hours

Bottlenecks

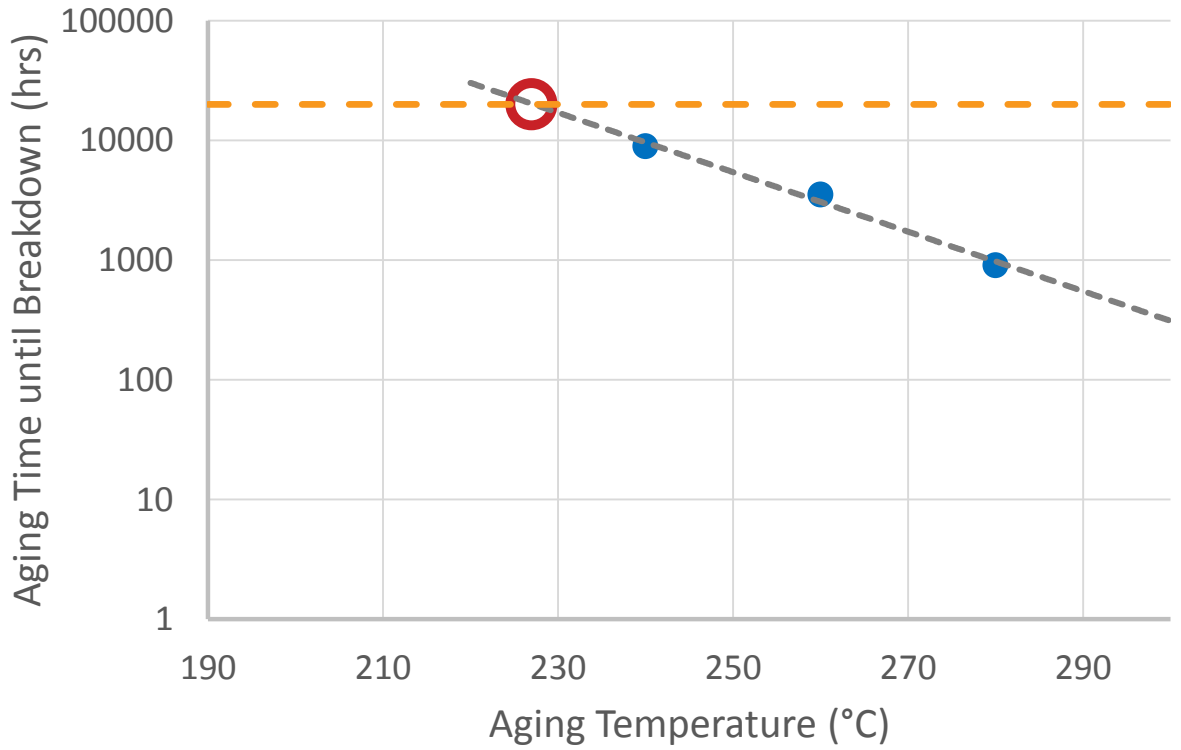
- End windings
- Slots
- Interface with large voids



Thermal Aging

Strategies in Design – Safety Buffer

- Choose a material with rating 180 or above
  - Voltatex 4200, 220 on MW35
- Wire insulation materials
  - TPEI / PAI
  - Primer / PAI
  - PEEK
  - PI
- Impregnating resins
  - UPEI
  - EP
- Insulation papers
  - Aramide
  - Laminates (PI, PEEK, PAI)
- Lamination coatings
  - C5

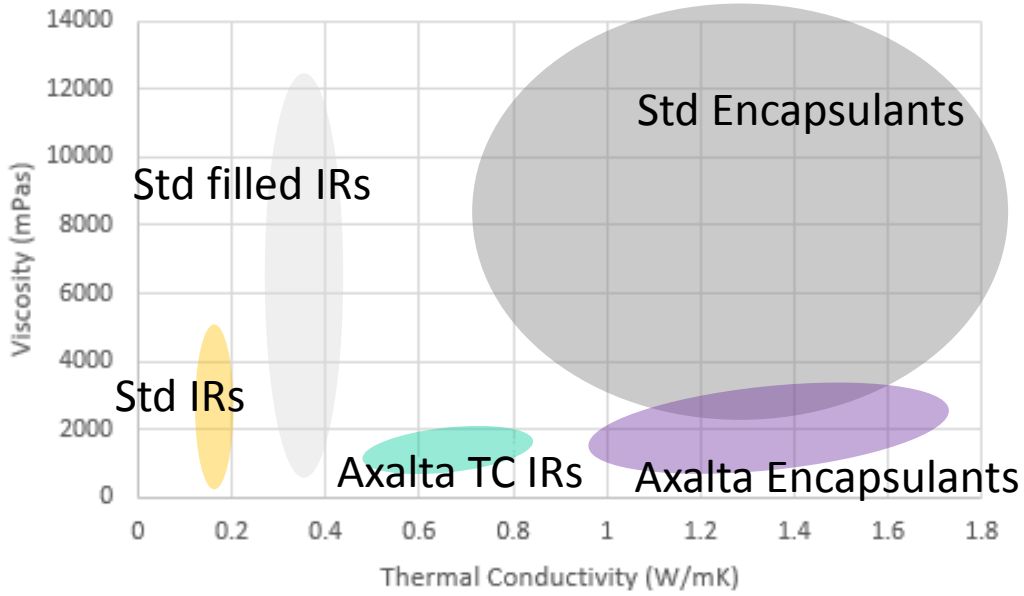


IEC 60085: Breakdown is 50% of initial breakdown voltage

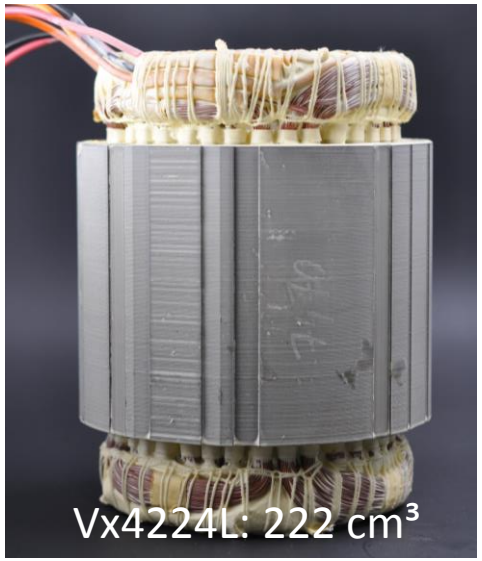
Impregnation Process

Thermal Management - Impact on Material Choice

- Good penetration of slots
- Wetting of insulation paper
- Limited film build on winding ends
- Limited film build on lamination core



- Increase thermal conductivity of entire stator to unleash full potential
- Mind interfaces & increase cooling efficiency
- Lower operating temperature
- Improve power to weight ratio

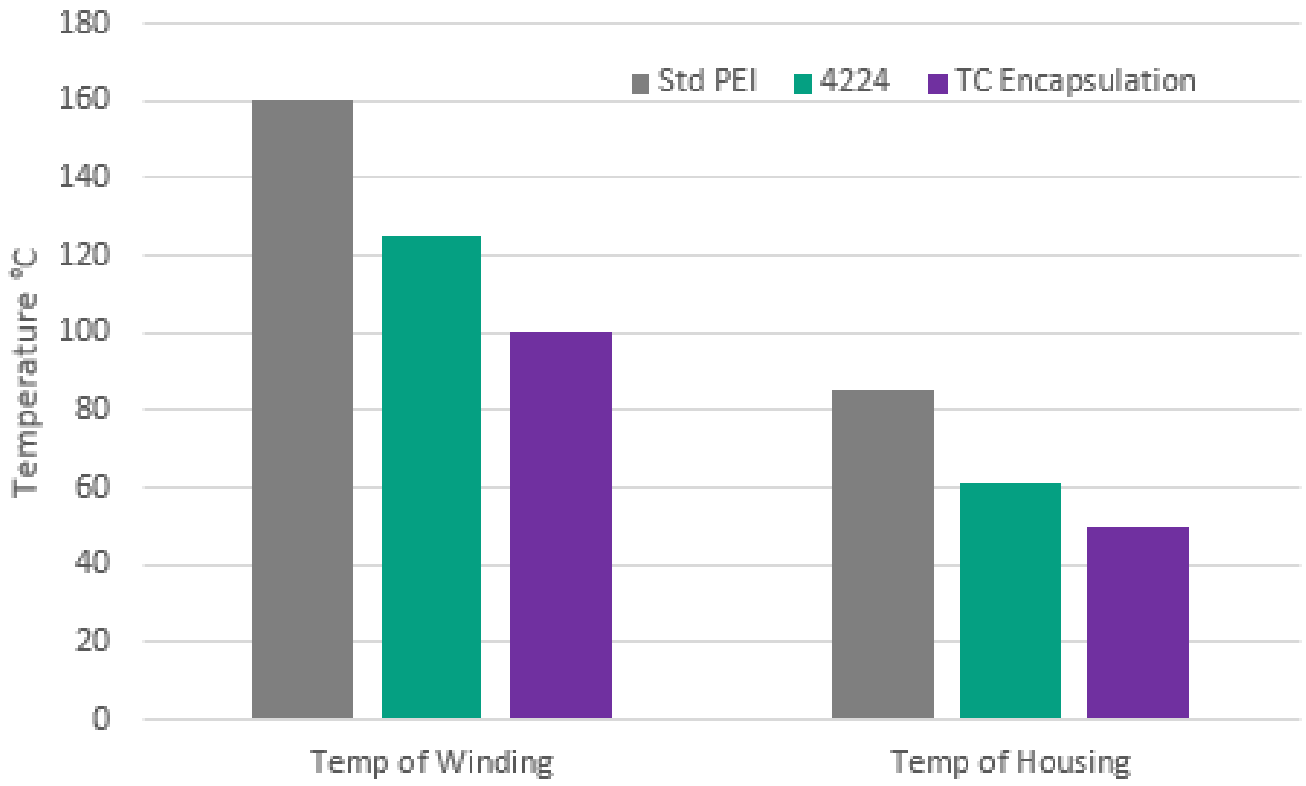


Thermal Aging

Strategies in Design – Thermal Management

Example 1

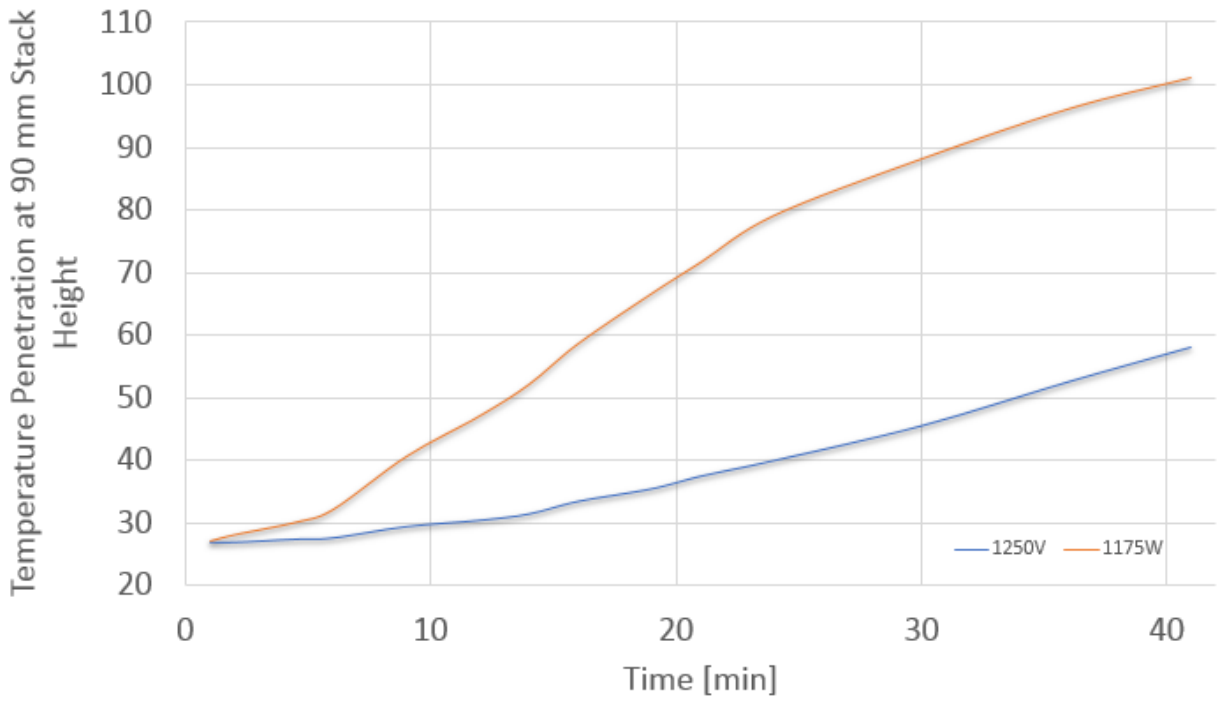
- Standard UPEI Impregnating resin
  - Std PEI 0.2 W/mK
  - 2000 mPas at 25°C
  - Resistance heating process best
  - Trickling or D&B also possible
- Encapsulation process
  - Thermally Conductive EP: 1.0 – 1.6 W/mK
  - 2400 mPas at 25°C
  - Highest performance – complex process
- Standard impregnation process
  - Thermally Conductive IR: 0.5 – 0.8 W/mK
  - 900 mPas at 25°C
  - Resistance heating process best
  - Trickling or D&B also possible



Thermal Aging

Strategies in Design – Thermal Management

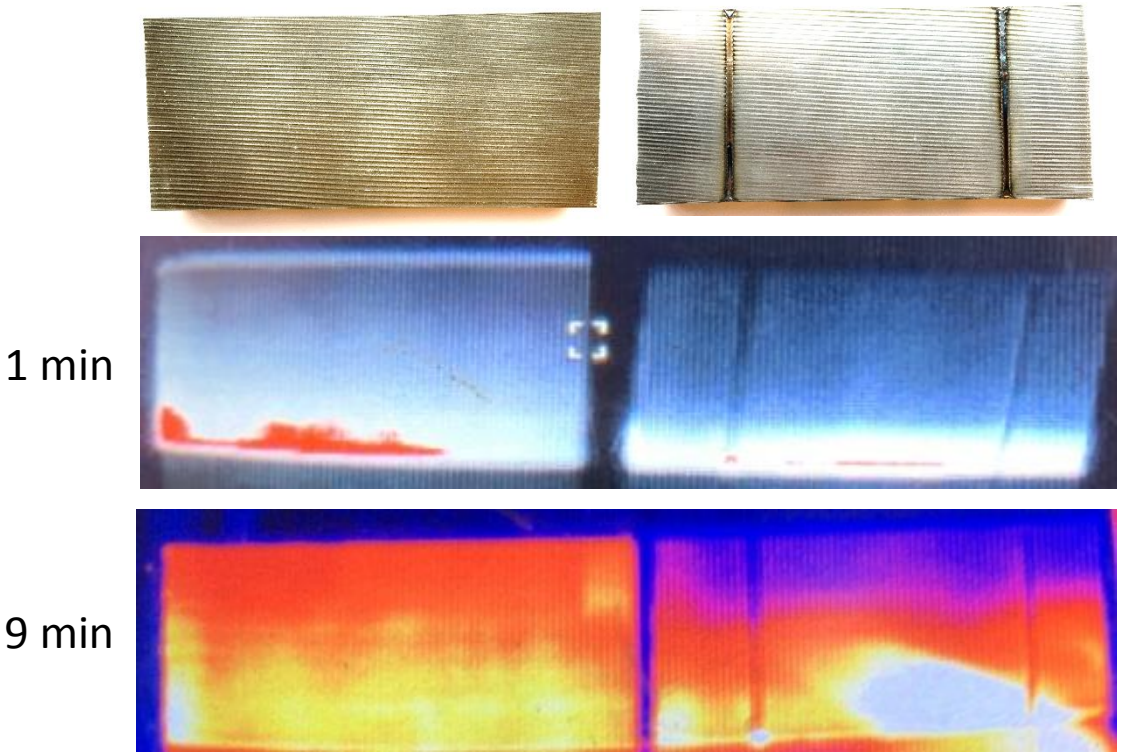
- Two Stacks (900x210x23 mm) heated on a hot plate



Example 2

Voltatex 1175W bondable
3.8 µm per side

Voltatex 1250V C5 welded
1.5 µm per side



Energy Solutions – Voltatex Products for e-mobility

Wire Enamels

- Flat / round / rectangular wire coatings
- Voltron - Improved lifetime under PD conditions
- Thermal Index up to 220
- ATF Oil resistant

Electrical Steel Coatings

- Voltatex 1250V - High performance C5 coating
- Voltatex 1254 – Thin layer C5 coating
- Voltatex 1175W – state of the art bondable coating

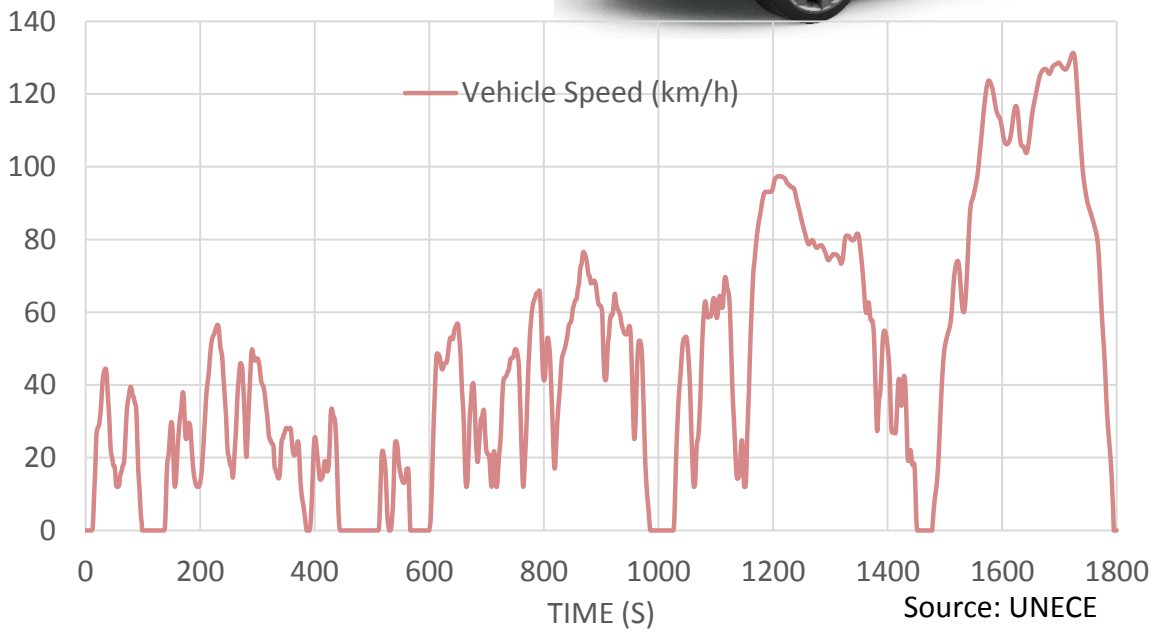
Impregnating Resins

- Voltatex 4200 – Thermal Index 220 & easy use
- Voltatex 4224 – Thermally conductive IR
- Voltatex 4210 – Automotive trickle resin
- Voltatex 44xx – Epoxy product line
- Voltatex gelcoats for hairpins
- Voltacast casting resins for encapsulation
- Powder coatings for insulation applications

Summary

Take Aways

- Materials and process should be considered during motor design to unleash full potential
- Aging processes can be reduced by material choice
- Materials should be aligned to each other
- A single material can improve the system
- Optimization of impregnation process is key



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