Thermal vs. Power Loss Efficiency Considerations for Powder Core Materials

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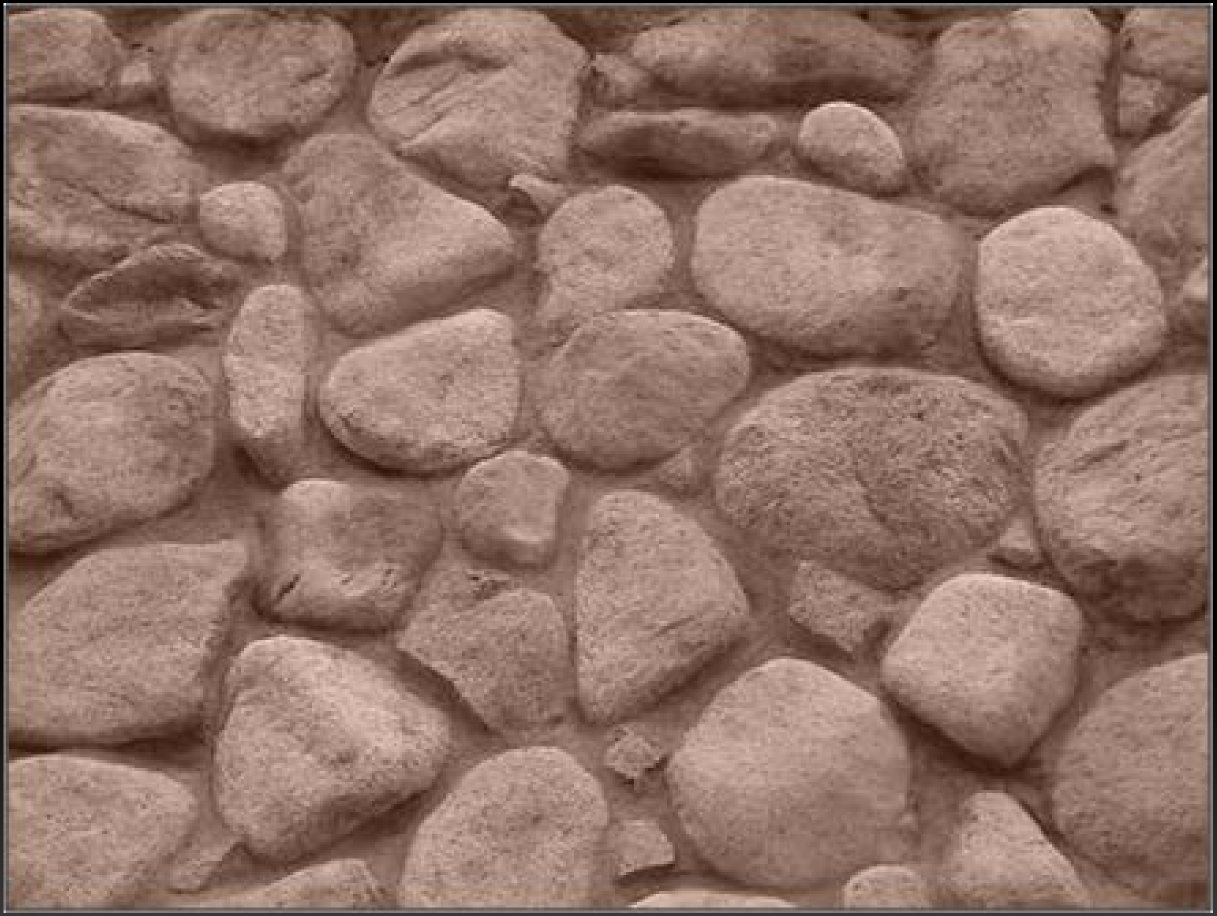
Outline

- Powder Cores Description
- What properties change with temperature
- Measurement Technique
  - Sample Preparation
  - Measurement Process
- Permeability vs. Temperature
- Core Loss vs. Temperature
  - Hysteresis Loss / Eddy Current Loss Model
  - Measure / Model Each Seperately
- Bsat vs. Temperature
  - Greatest impact near Curie Temperature
  - Negligible impact due to high Curie Temperatures.
- Core Loss – Thermal Aging

What is a Powder Core?



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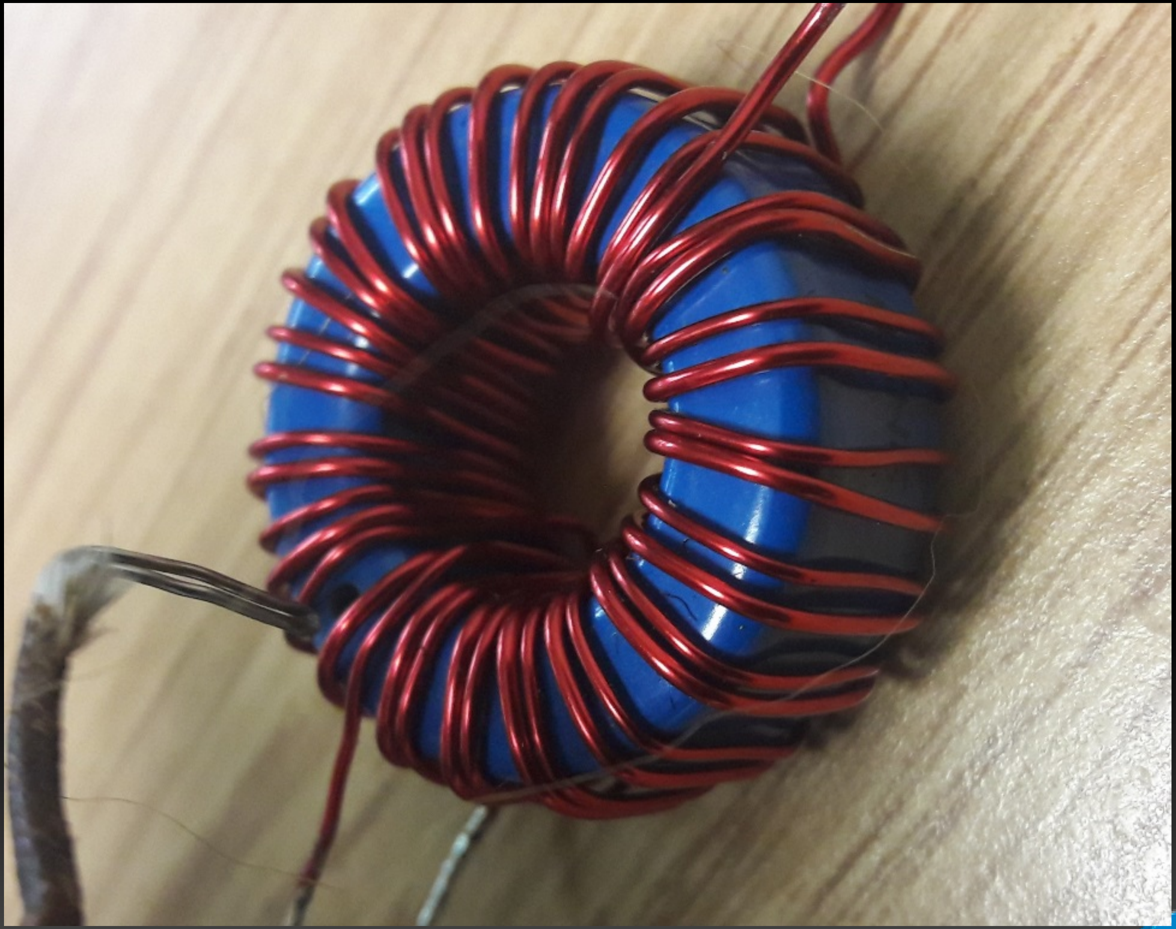
Powder Core Characteristics

- Distributed Air gap
- Discrete gap not required – minimal Fringing
- Eddy Currents restricted to flowing within particles
- “Soft” Saturation
- Flexible Material Choices
  - Bsat
  - Losses
- Permeability controlled by Insulation Level

What Properties Change with Temperature?

- Reversible Changes
  - Permeability
    - Dependent on Alloy System
    - Both Quasi-Linear and Non-linear performance
  - Core Loss
    - Effects on Hysteresis Loss
    - Effects on Eddy Current Loss
  - Bsat
    - Critical consideration of Ferrite Materials – Low Tc
    - Minor impact on Powder Core Materials – High Tc
- Irreversible Changes
  - Core Loss – Thermal Aging
    - Does not impact most Alloy Cores
    - Well characterized for Iron Powder Cores

Sample Preparation:
Wound and Drilled Sample



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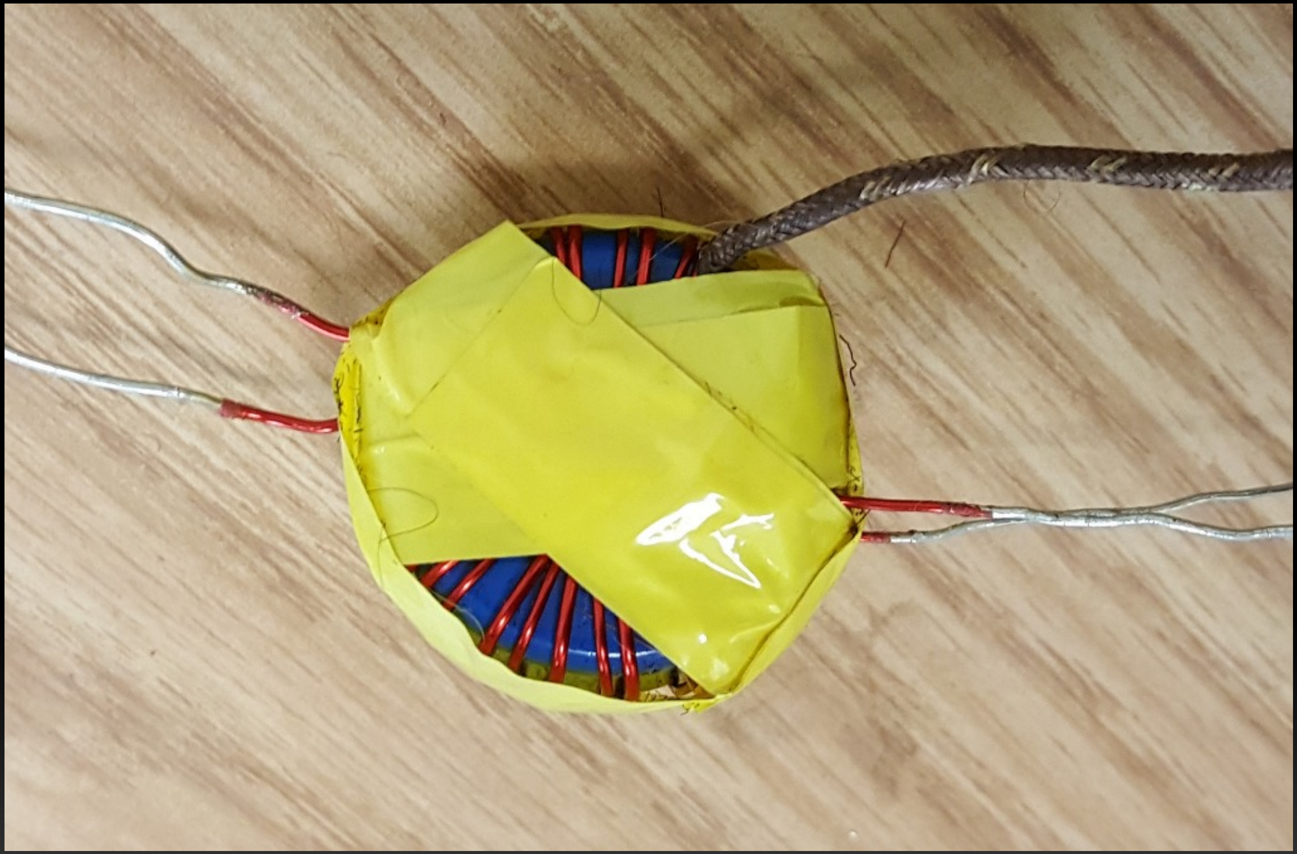
Sample Preparation: Taped Sample



Sample Preparation: Insulating Layer

Sample Preparation: Ready for Testing

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Sample Preparation:
Pre-heat / Pre-chill Sample

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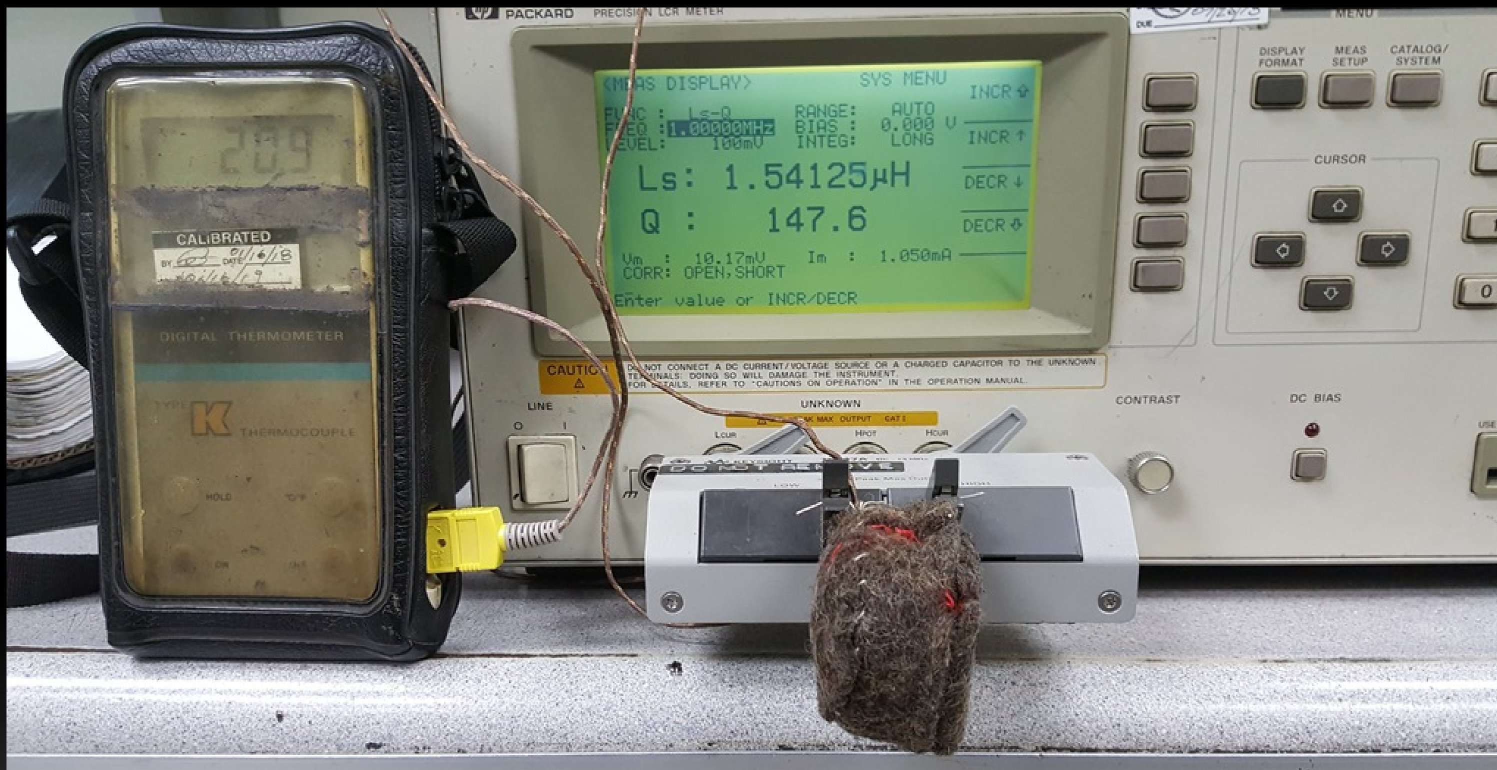
Sample Preparation: Record Measurements



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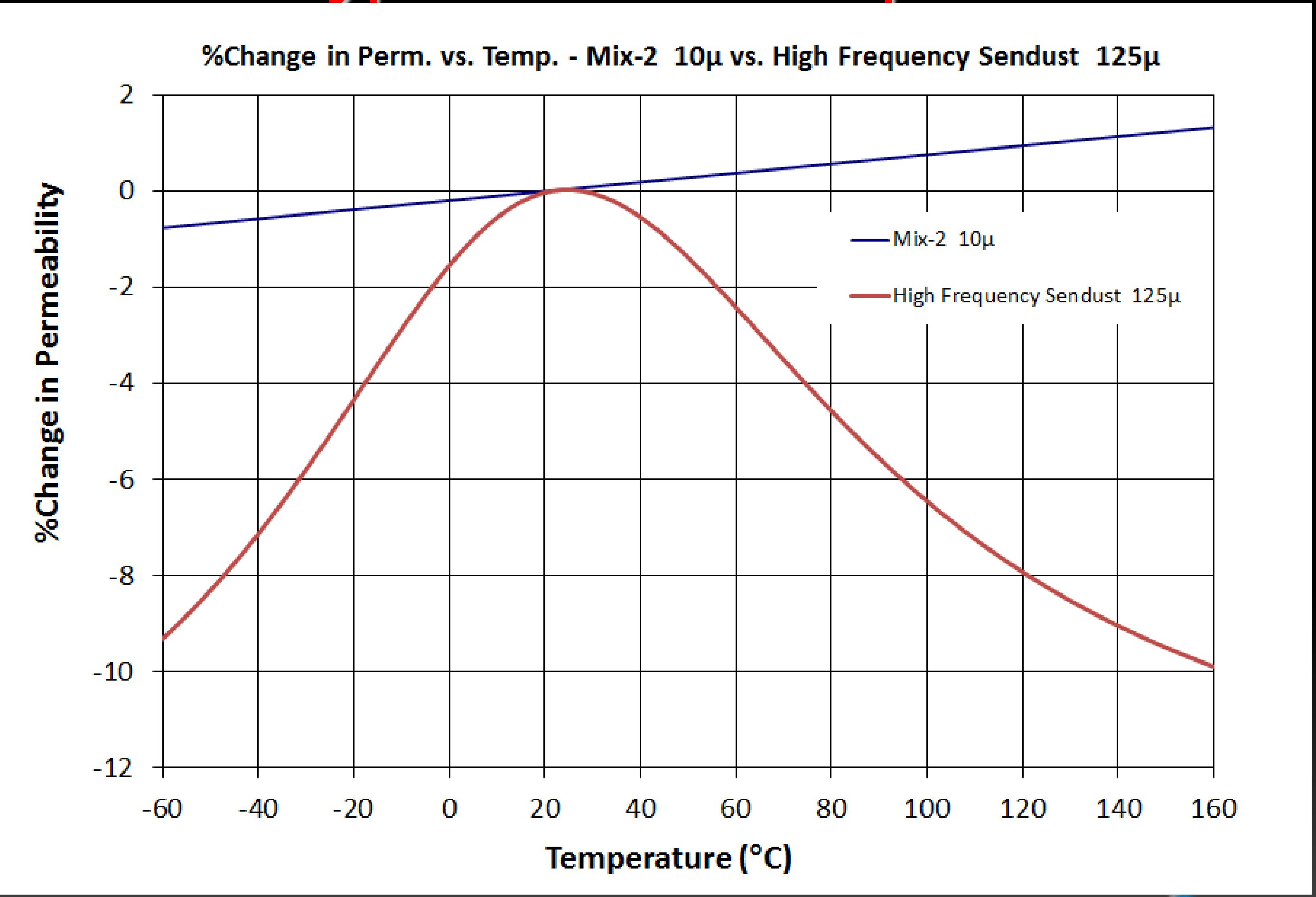
Permeability vs. Temperature: Testing

- Meter: Standard LCR meter
- Winding
  - Cover core uniformly – Minimize leakage
  - Single Winding
  - Minimize effect of Rdc and Rac
- Frequency: In linear region for material (Q>20)
- Drive Level: For Initial Permeability, >1mT (10G)
- As Core heats/cools, Record Inductance, Temperature
- Verification: Meter drift, Slow Cooling Rate
- Convert to Inductance to Permeability
- Plot Permeability vs. Temperature
- Model the Relationship

Permeability vs. Temperature: Typical relationships



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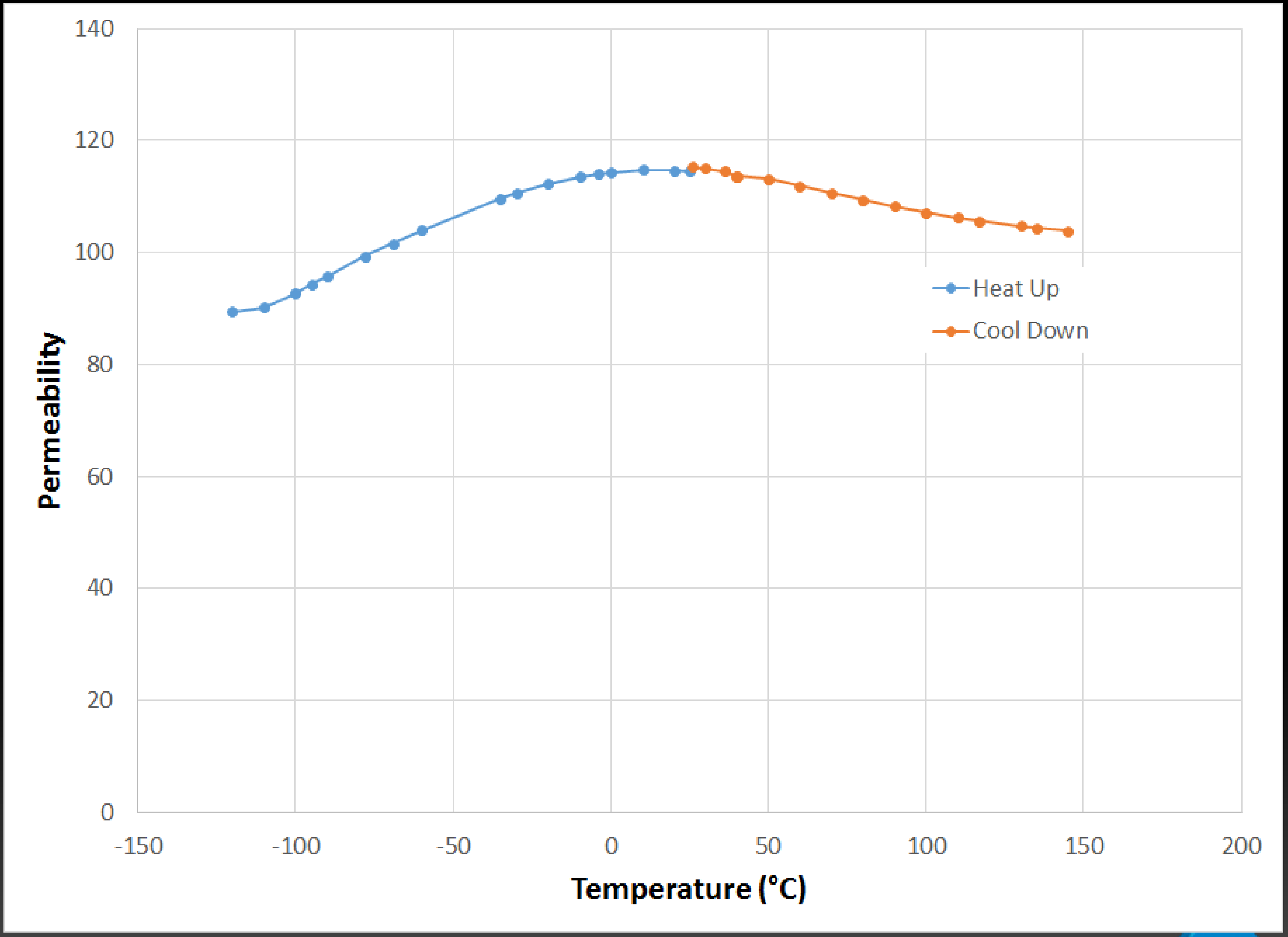
Permeability vs. Temperature: Testing

- Part Number: SH-106125-2
  - High Frequency Sendust
  - 125 Permeability
- Winding: 10 turns #20 AWG (0.8 mm)
- Frequency: 1 MHz
- Meter: Agilent 4284A LCR
- Drive Level: 1V open
- Approximate Flux Density: 2 G (0.2 mT)

Permeability vs. Temperature: Measured Values 125 perm High Freq. Sendust



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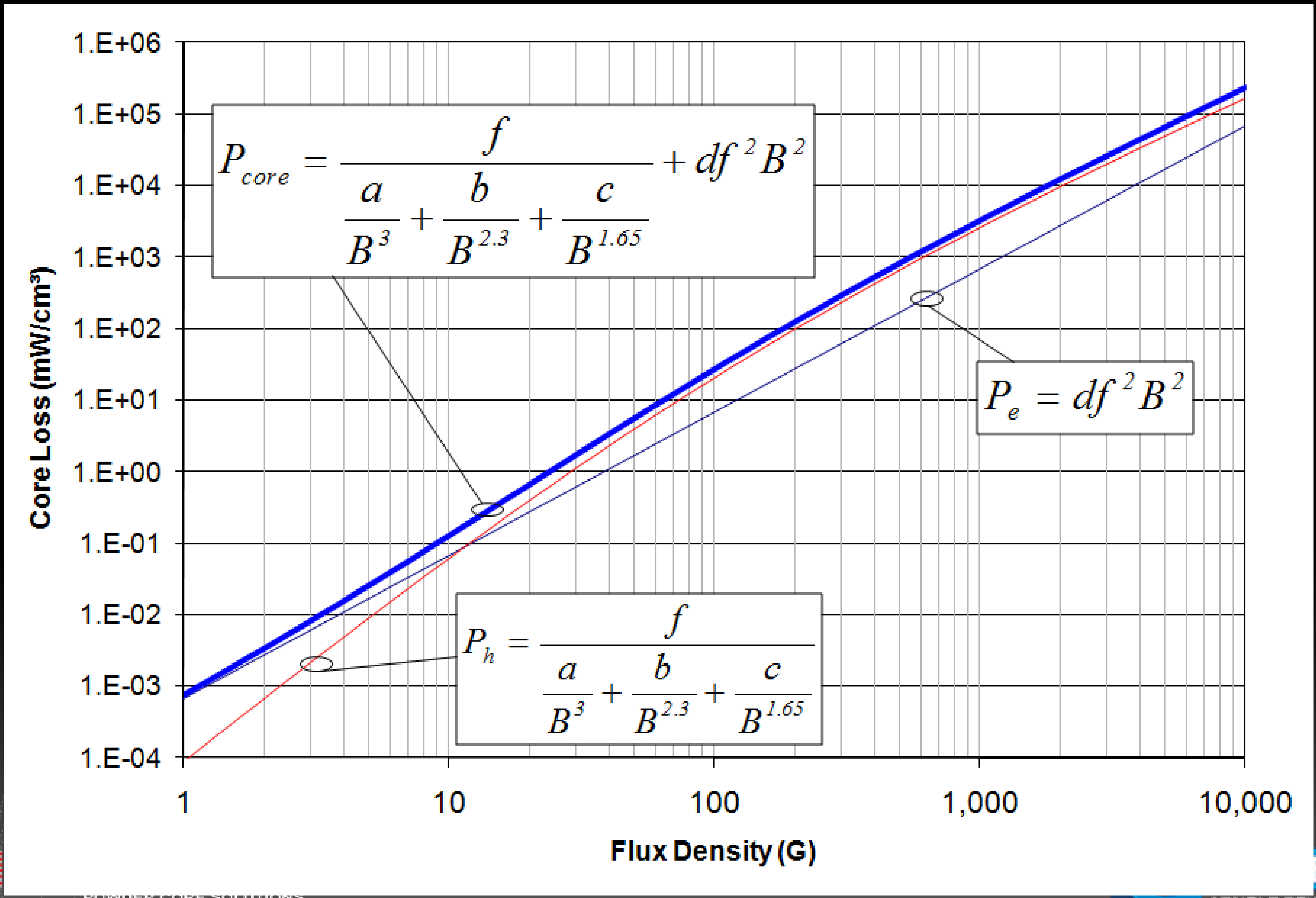
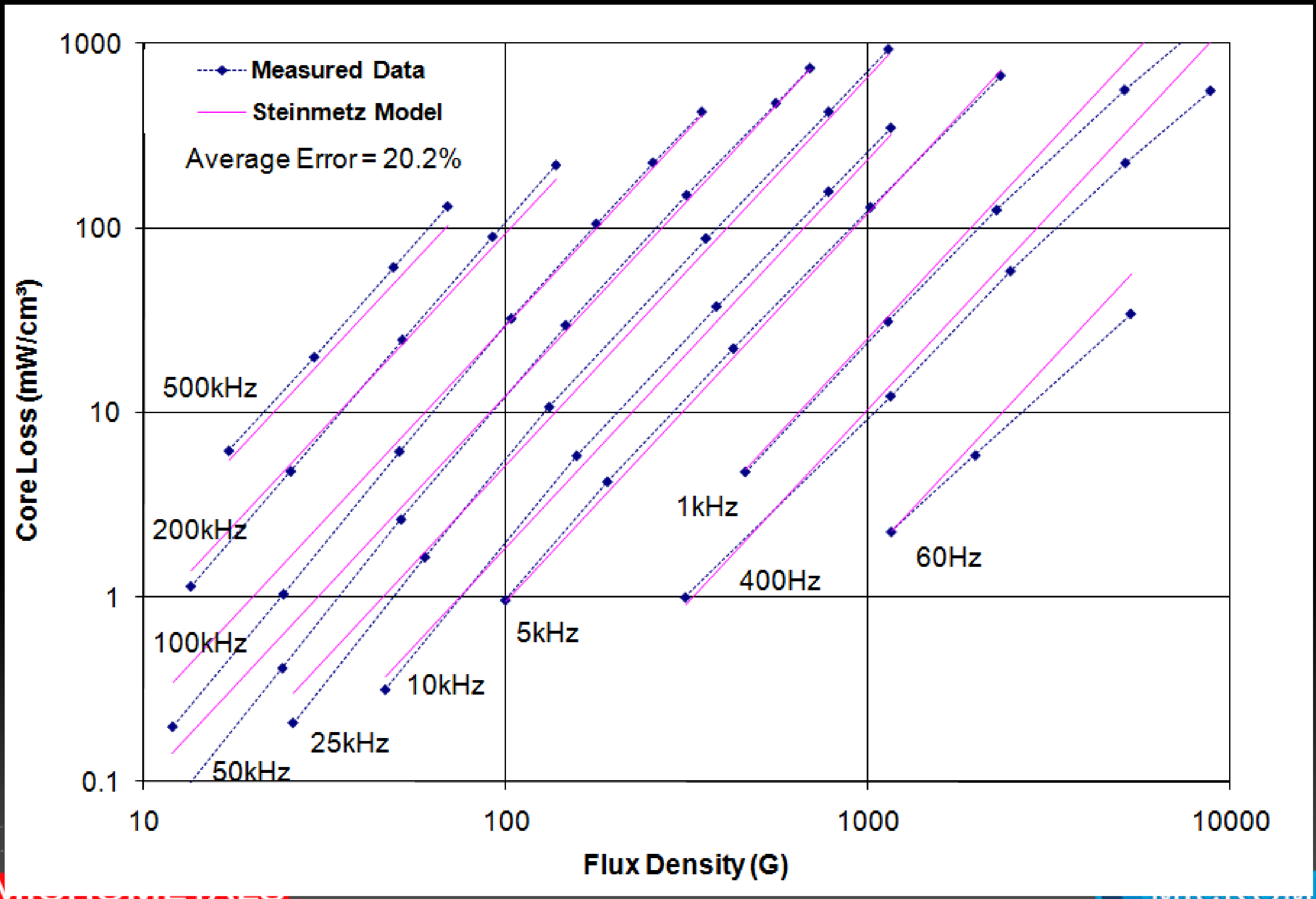
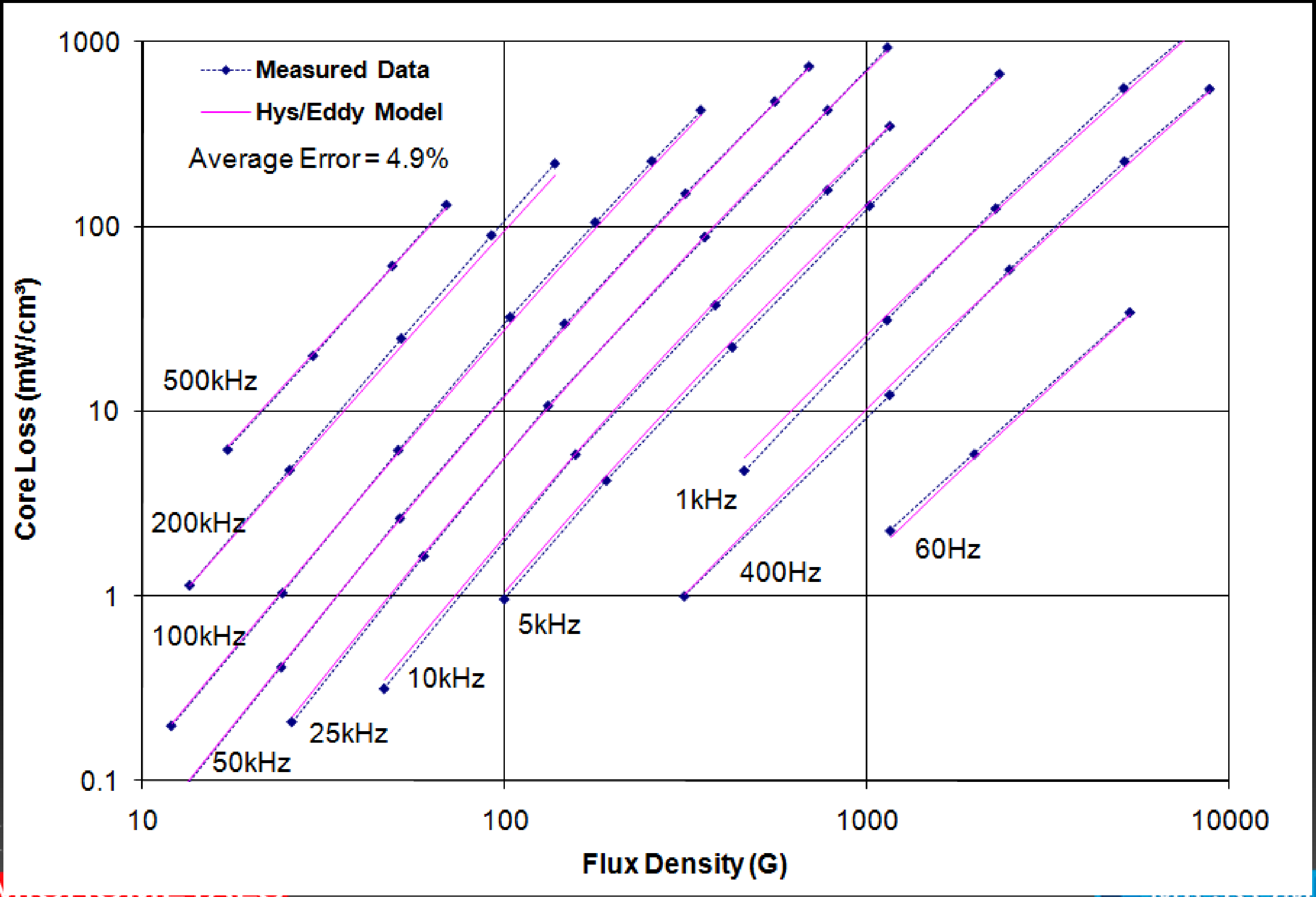
Development of Core Loss Model Combining Hysteresis and Eddy Current Loss



Measured Data and Fitted Steinmetz Coefficients



Measured Data and Fitted Hys/Eddy Coefficients



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Core Loss vs. Temperature:

- Meter: Standard LCR, V-A-W meter or other
- Winding: Transformer (likely ignore IR drop, Conductor Loss in calculation), uniform core coverage, minimize self capacitance
- Frequency, Drive Level – Suitable for desired Loss component to dominate
  - For Eddy Current, Minimize Conductor and Hysteresis
  - For Hysteresis, Minimize Conductor and Eddy Current
- As Core heats/cools, Record V, A, W, Temperature
- Verification: Meter drift, Slow Cooling Rate
- Plot Core Loss (Hys. or Eddy) vs. Temperature
- Model the Relationship

Core Loss (Eddy Current) vs. Temperature: Testing

- Part Number: SH-106125-2
  - High Frequency Sendust
  - 125 Permeability
- Winding
  - 10 turns #20 AWG (0.8 mm) Frequency: 1 MHz
- Meter: Agilent 4284A LCR
- Drive Level: 1V open
- Approximate Flux Density: 2 G (0.2 mT)
- Calculated Loss Distribution (Room Temp.)
  - Conductor Losses: 1.2%
  - Hysteresis Losses: 1.6%
  - Eddy Current Losses: 97.3%

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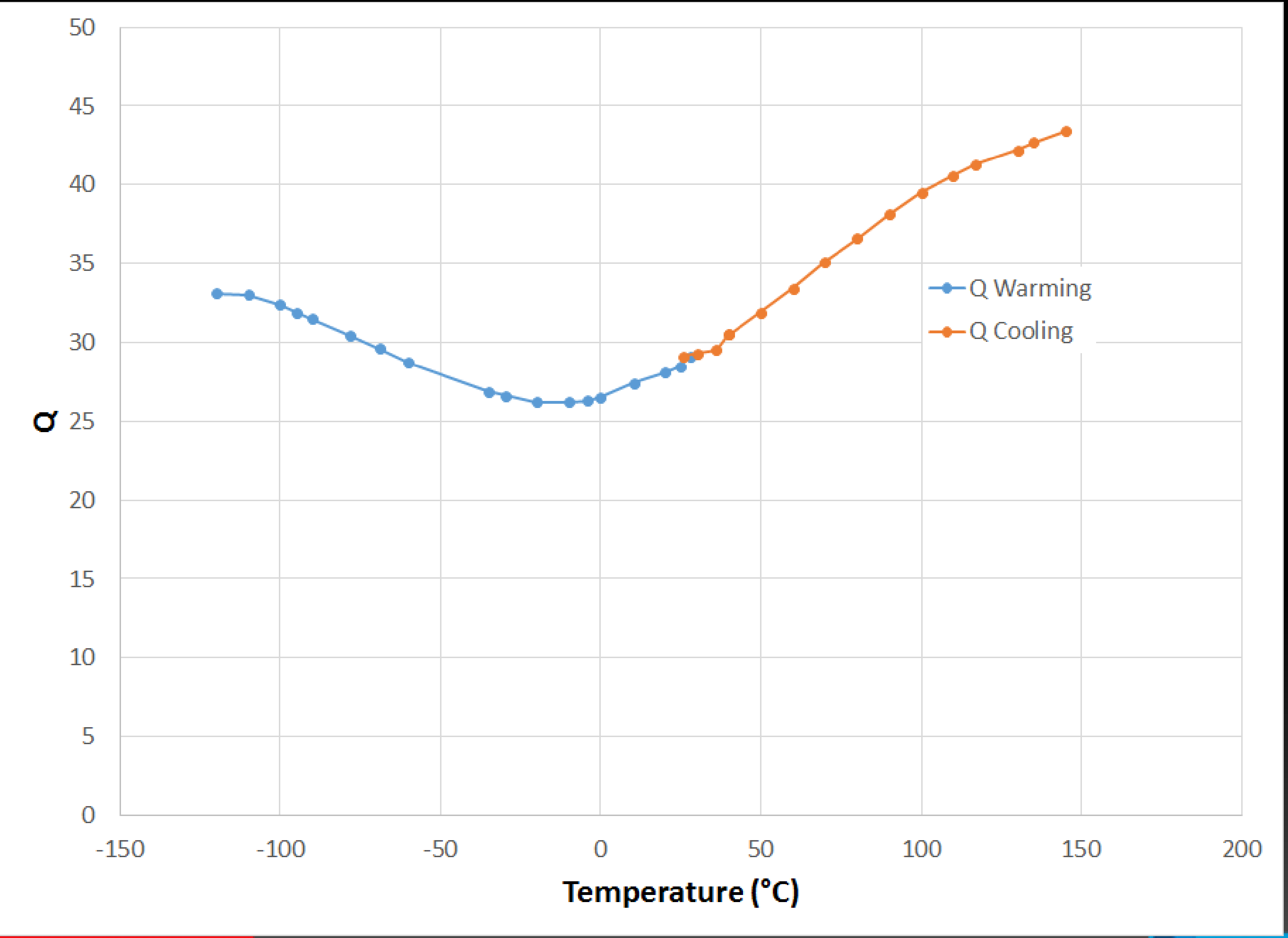
Q vs. Temperature Measurements SH-106125-2 – 1 MHz



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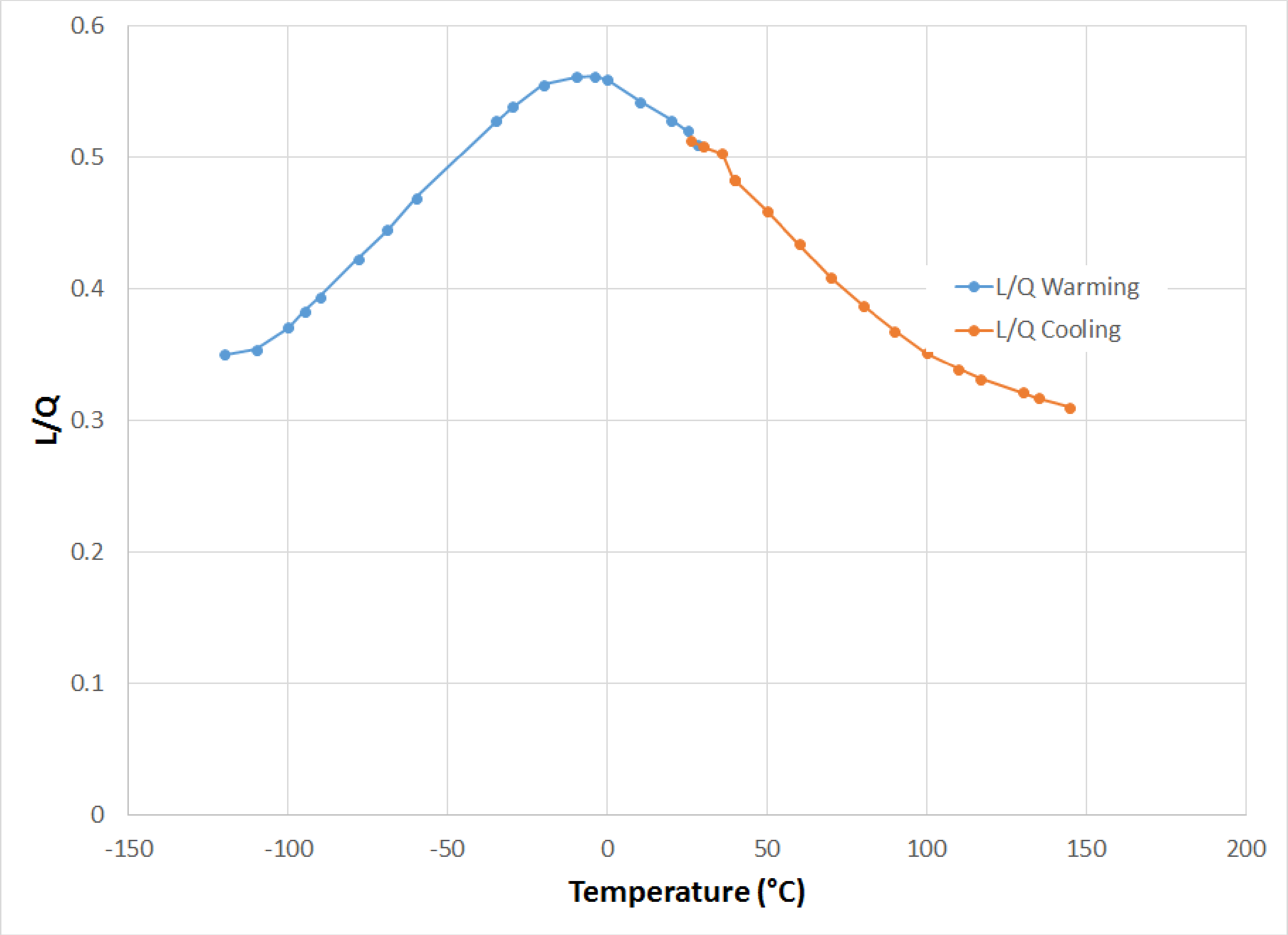
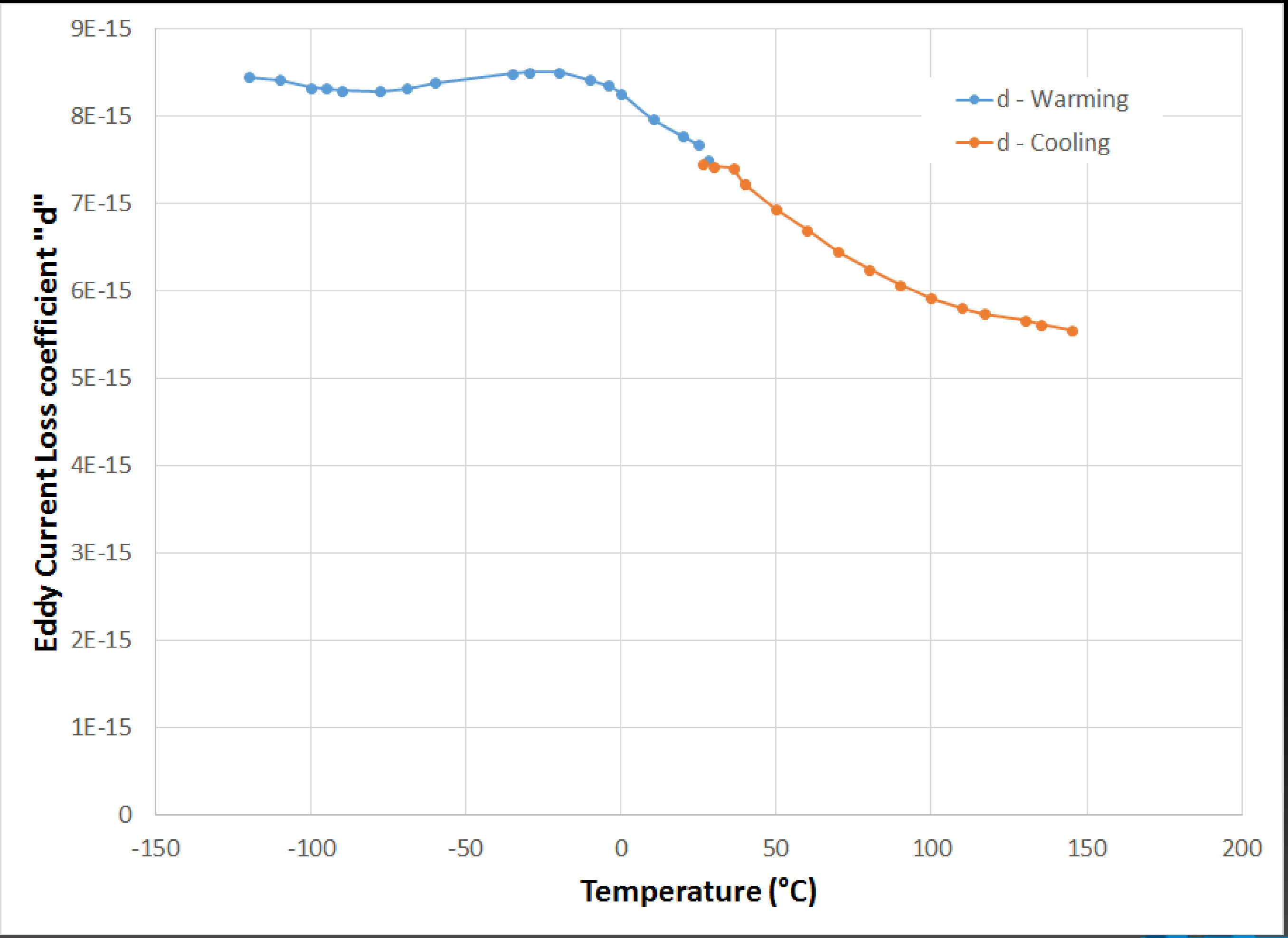
L/Q vs. Temperature SH-106125-2 – 1 MHz



Eddy Current Coefficient vs. Temperature SH-106125-2 – 1 MHz



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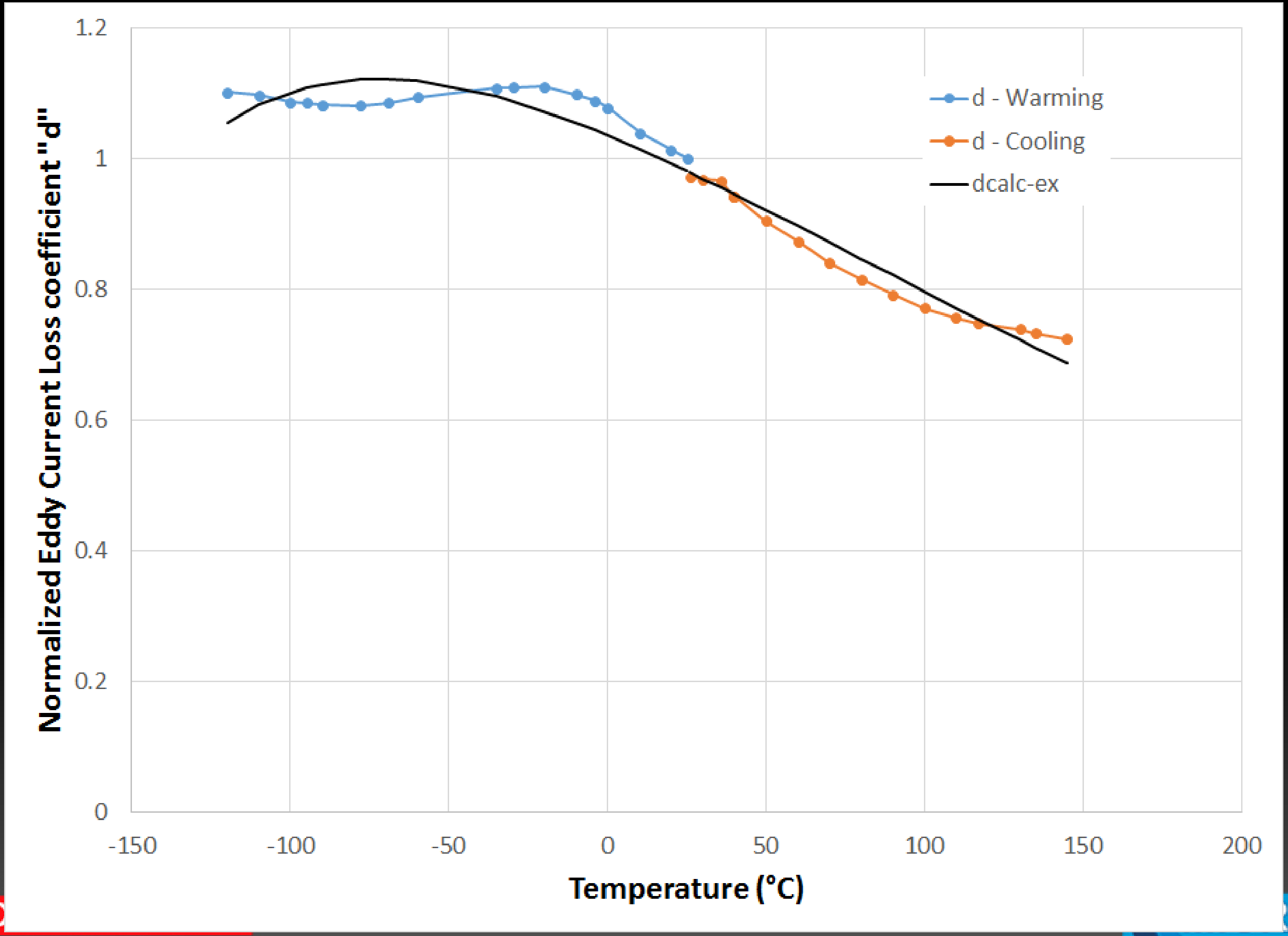
Eddy Current Coefficient vs. Temperature SH-106125-2 – 1 MHz



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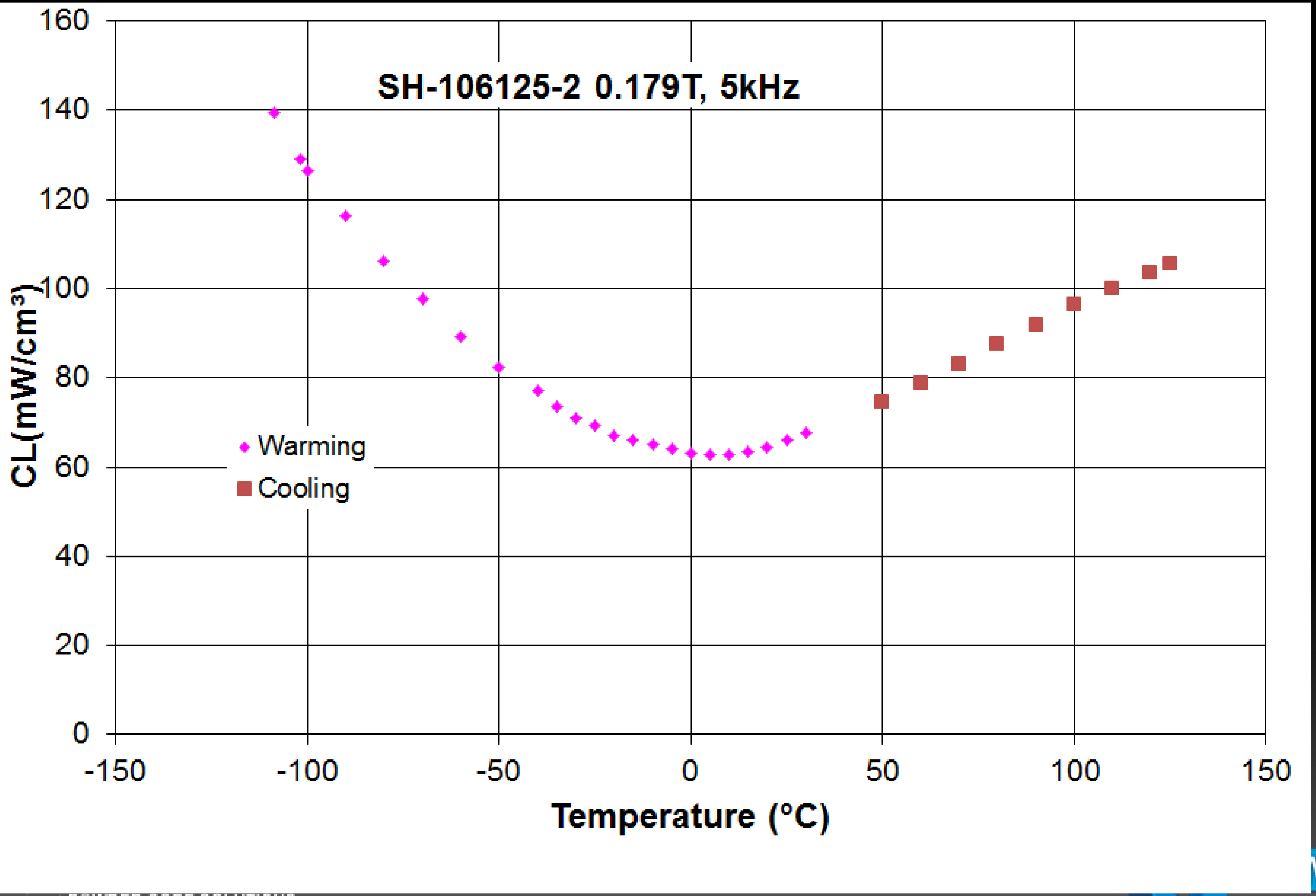
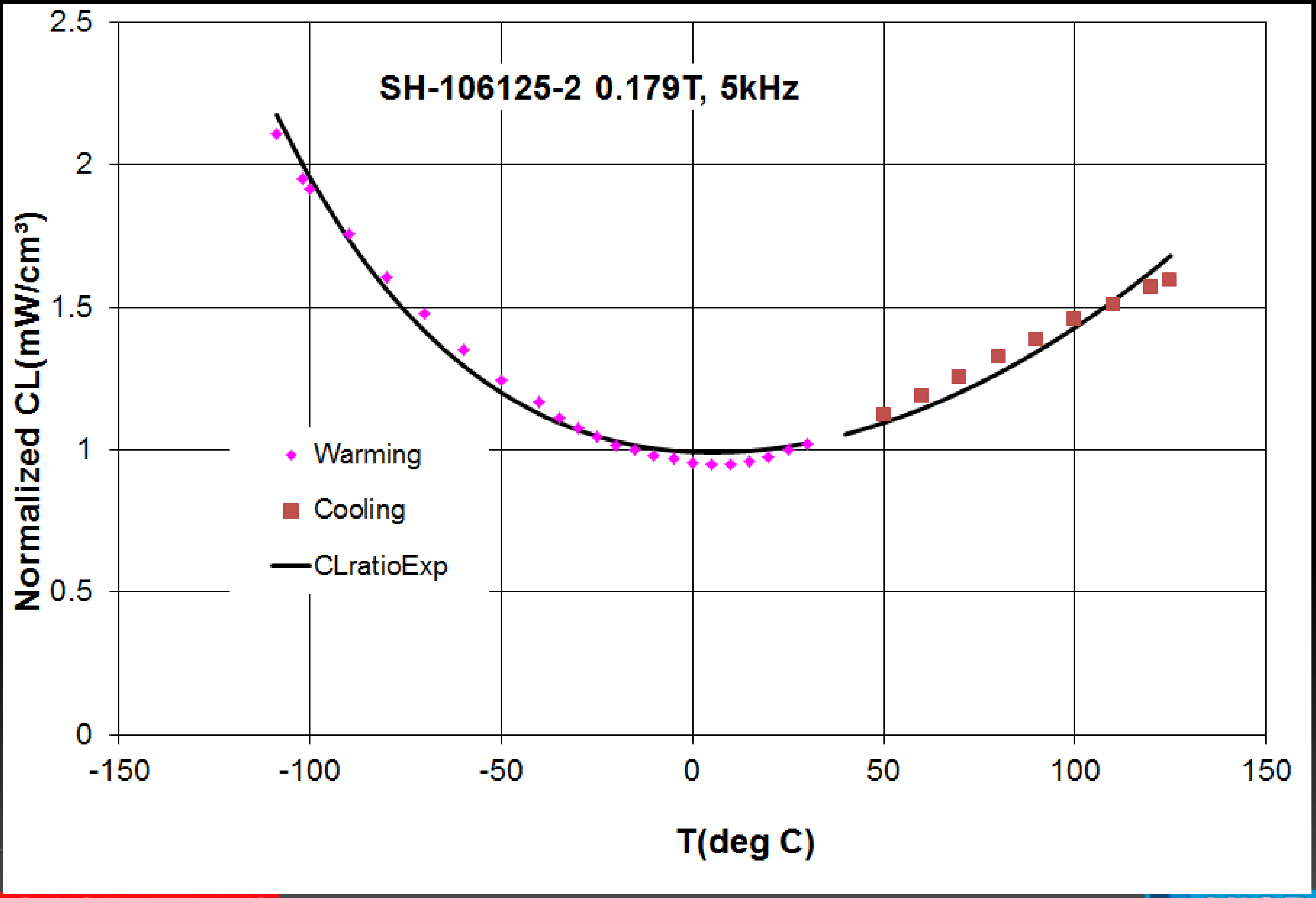
Core Loss (Hysteresis Loss) vs. Temperature

- Part Number: SH-106125-2
  - High Frequency Sendust
  - 125 Permeability
- Winding
  - 20 turns #20 AWG (0.8 mm) Primary
  - 20 turns #22 AWG (0.63 mm) Secondary
- Frequency: 5 KHz
- Meter: Agilent Clarke Hess 258 V-A-W meter
- Drive Level: 5 Vrms across secondary
- Approximate Flux Density: 1790 G (0.179 T)
- Calculated Loss Distribution (Room Temp.)
  - Conductor Losses: Ignored – No current flows in Secondary
  - Hysteresis Losses: 98.9%
  - Eddy Current Losses: 1.1%

Hysteresis Loss vs. Temperature SH-106125-2 – 5kHz



Hysteresis Loss vs. Temperature SH-106125-2 – 5kHz



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Core Loss vs. Temperature Summary

- Part Number: SH-106125-2
- For Temperature going from 25°C to 125°C:
  - Eddy Current Loss decreases by 25%
  - Hysteresis Loss increased by 66%
- To know true effect, one must know the distribution of losses at a given operating point

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Thermal Aging:

- What is thermal aging?
  - When Iron Powder is subjected to prolonged exposure to elevated temperatures, an irreversible increase in core loss is experienced
- What influences the rate at which the core loss increases versus time?
  - There are 6 variables that all interact with each other. Changing any one variable will change the rate at which thermal aging occurs
- Most Alloy Powder Cores do not experience Thermal Aging

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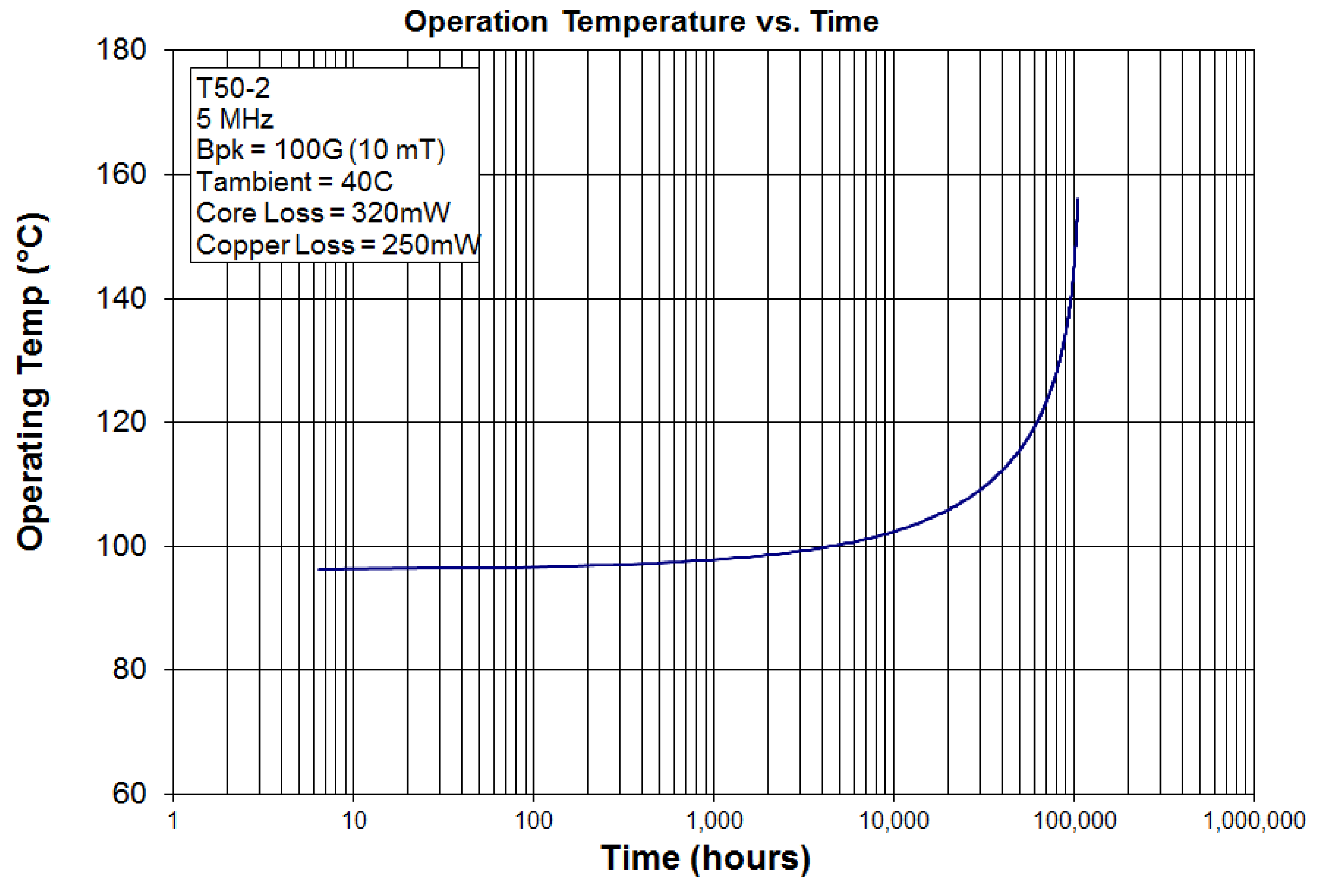
Thermal Aging:

- 6 variables influencing thermal aging:
  - Core Material
  - Peak AC flux density
  - Frequency
  - Core geometry
  - Copper loss
  - Ambient temperature

Thermal Aging:



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