Powder Core Development and High Frequency Considerations

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Overview

- Powder Core Development
  - Expansion of Kool Mμ® Max product line
  - XFLUX®, new permeabilities
  - Shapes Development
    - Round Leg U-Core Geometries
    - EQ26
  - R&D Pipeline
    - Improved High Flux (58 and 59 materials)
    - High Frequency Powder Core Material
- High Frequency Considerations
  - Current Material Comparison
    - Perm vs. Frequency
    - Core Loss

Kool Mµ MAX

- Superior DC Bias performance and lower losses compared to standard Kool Mµ
- Lower cost compared with MPP and High Flux.

General Information	
Permeability	26µ, 40µ, 60µ
Alloy Composition	Fe/Si/Al
Saturation Flux Density	1 Tesla
Curie Temperature	500°C
Operating Temperature Range	-55 to 200°C
OD Size Range (mm)	13.5 - 134
Coating Color	Black

00 79 050 A7

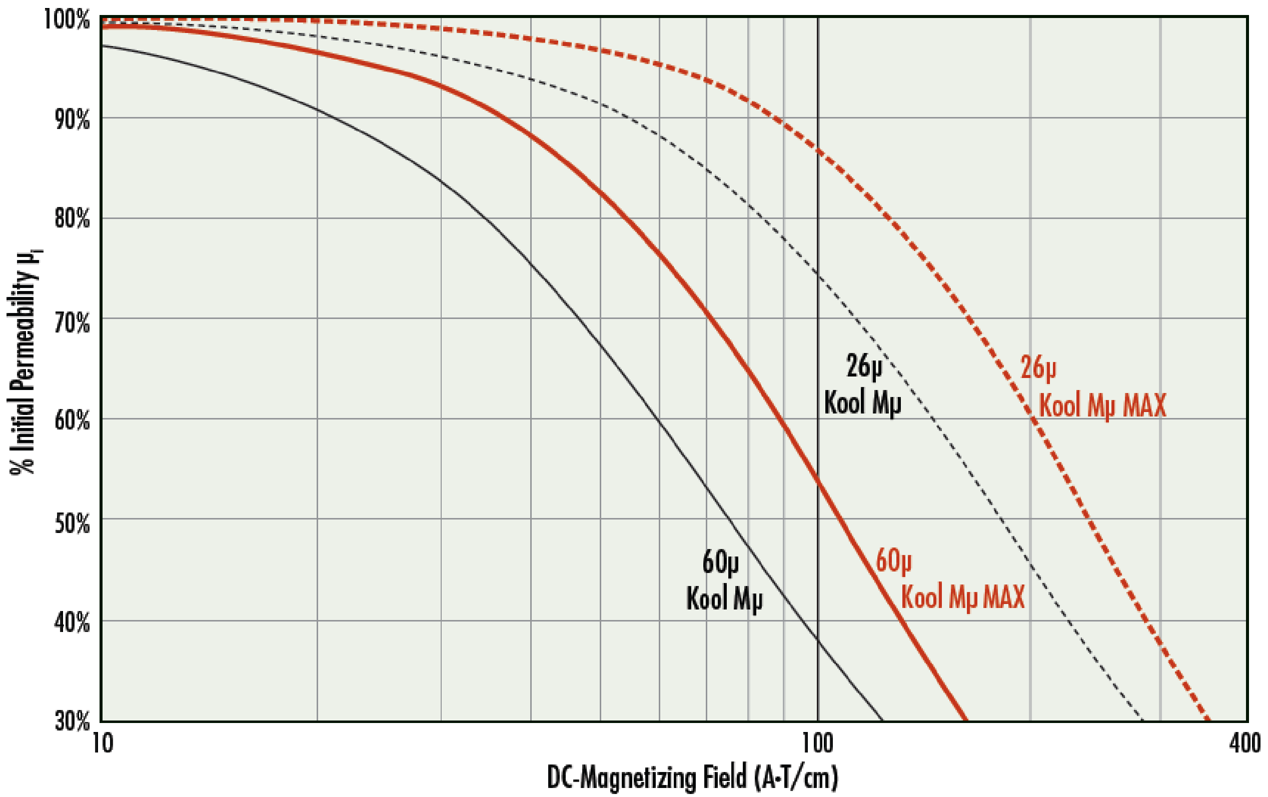
- A7 → Core finish code
- 050 → Catalog Number (size)
- 79 → Material Code (79 = Kool Mµ MAX)
- 00 → Grading Code

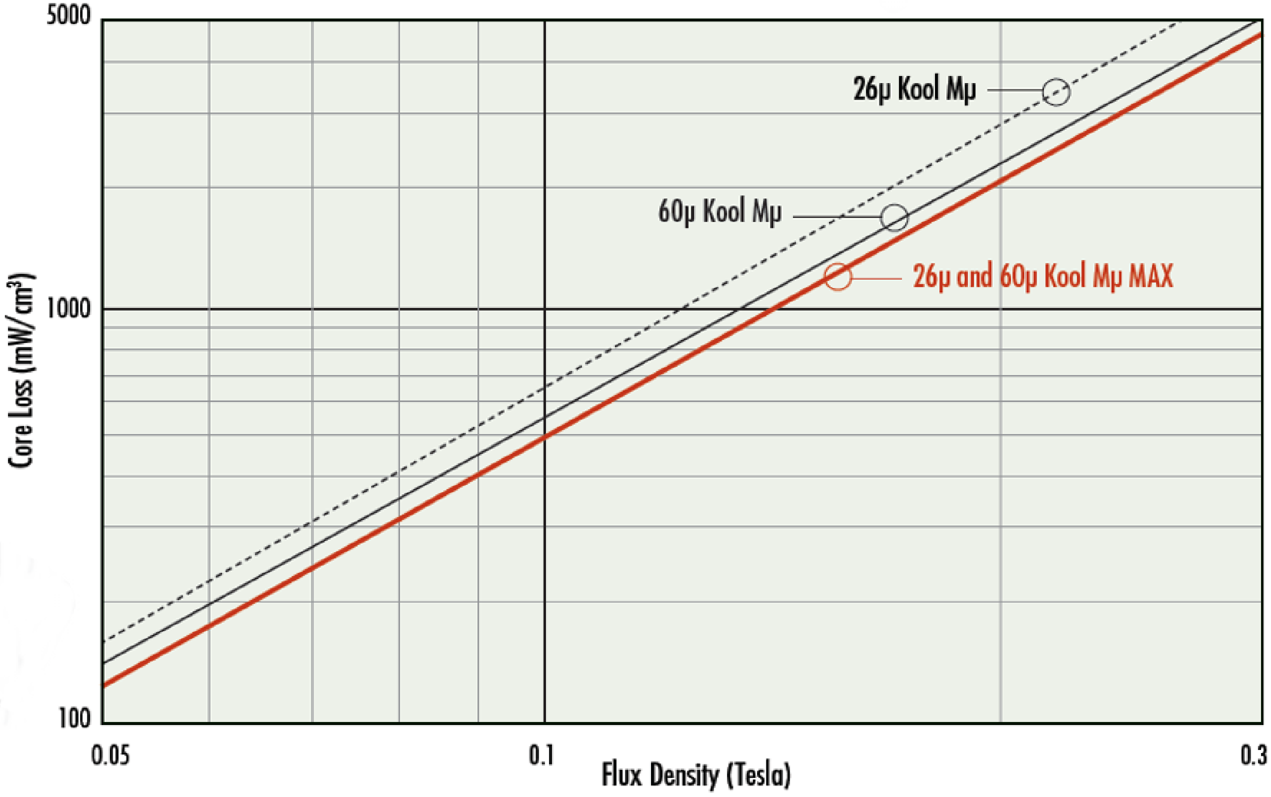
- 19µ /75µ/90µ and Shapes (E-Cores, U-Cores, Blocks) in Development

Kool Mµ Max - Performance Comparison

Material (60µ)	DC Bias at x Ls (Oe)		Core Loss (mW/cm³)		Cost Ratio
	80%	50%	$W_{1000\ G,\ 50\ kHz}$	$W_{1000\ G,\ 100\ kHz}$	Price Scale
Kool Mµ MAX	68	135	190	500	2.0
Kool Mµ	43	95	210	550	1.0
XFLUX	89	175	680	1550	1.2
High Flux	87	165	350	900	4.0
MPP	60	106	175	450	7.0

Kool Mμ Max vs. Kool Mμ



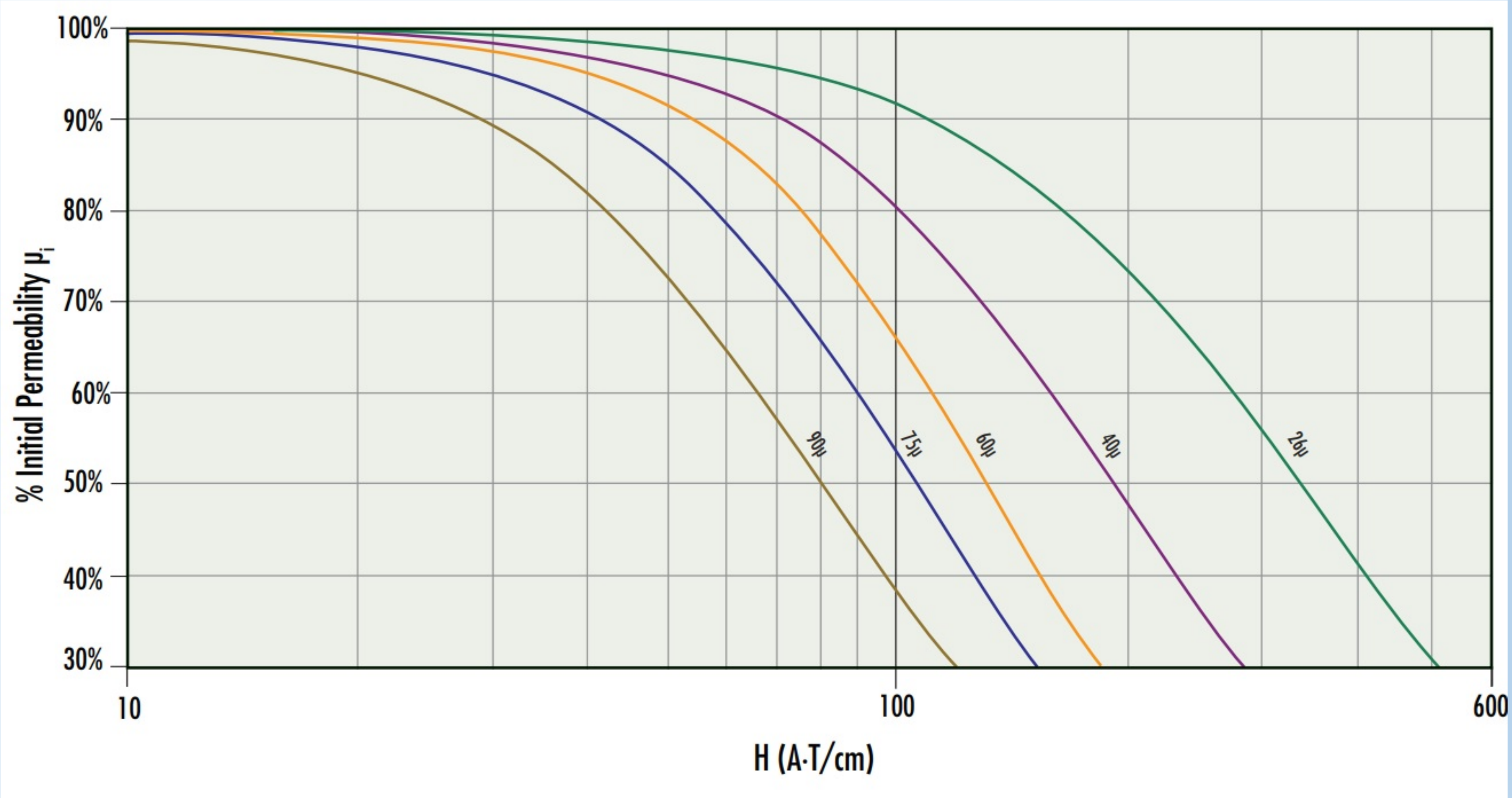


XFLUX– new permeabilities

- Silicon Iron Alloy Powder
- Cost 40-50% less than High Flux
- Applications:
  - Low & medium frequency chokes, where inductance at peak current is critical.
  - Where High Flux would be used but cost is a constraint.
- Available in Toroids, E-Cores, U-Cores, and Blocks

XFLUX – 75µ and 90µ

Now available in 050 (13.5mm OD) to 102 (103mm OD) size toroids.



- 19µ coming in next few months

Shapes Development

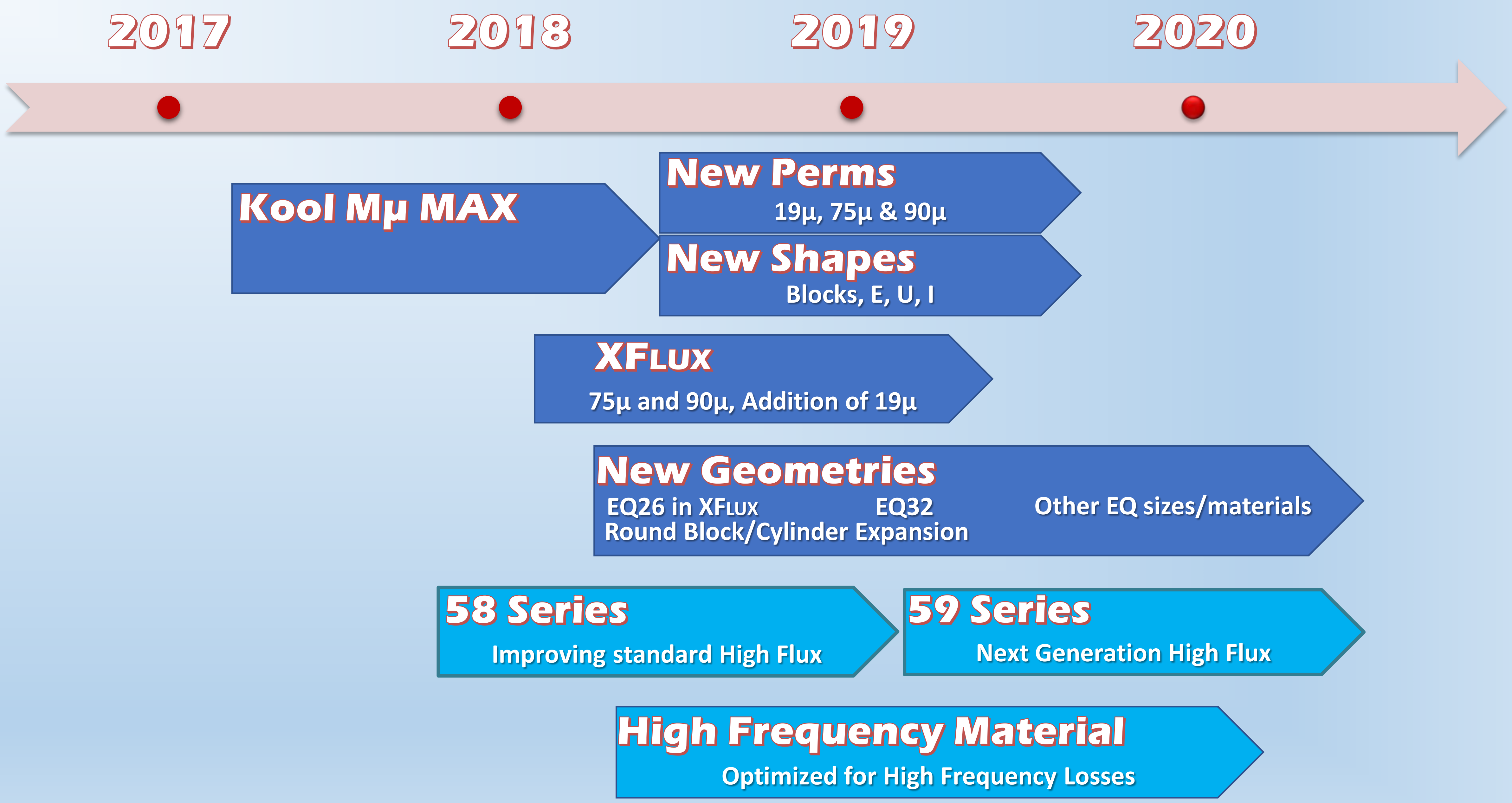
- Round-Leg U-Cores
  - Rounded blocks and cylinders
  - Helical Windings
  - 84mm x 30mm Block + 30mm Cylinder
  - Expanding to industry standard sizes
- EQ Shapes in Powder Core
  - Focused on EQ 26/19, three leg lengths.
  - Available in 60µ XFLUX
  - High Flux and Kool Mµ development next
  - EQ 32 will be next available size

Magnetics' R&D

- Improved High Flux and Next Generation High Flux (59)

Material (60µ)	DC Bias at x Ls (Oe)		Core Loss (mW/cm^3)
	80%	50%	$W_{1000\ G,\ 100\ kHz}$
High Flux	87	165	900
Improved High Flux	100	185	800
Next Gen High Flux (59)	125	215	<500

- High Frequency Powder
  - Optimize Losses from 500kHz to 3MHz
  - Material selection still under consideration – looking at Sendust base
    - Potentially multiple materials optimized for different frequency ranges
  - Looking to market to determine best options
    - Where is highest demand?


2017
2018
2019
2020
Kool Mμ MAX
New Perms
19μ, 75μ & 90μ
New Shapes
Blocks, E, U, I
XFLUX
75μ and 90μ, Addition of 19μ
New Geometries
EQ26 in XFLUX
EQ32
Other EQ sizes/materials
Round Block/Cylinder Expansion
58 Series
Improving standard High Flux
59 Series
Next Generation High Flux
High Frequency Material
Optimized for High Frequency Losses

HIGH FREQUENCY CONSIDERATIONS

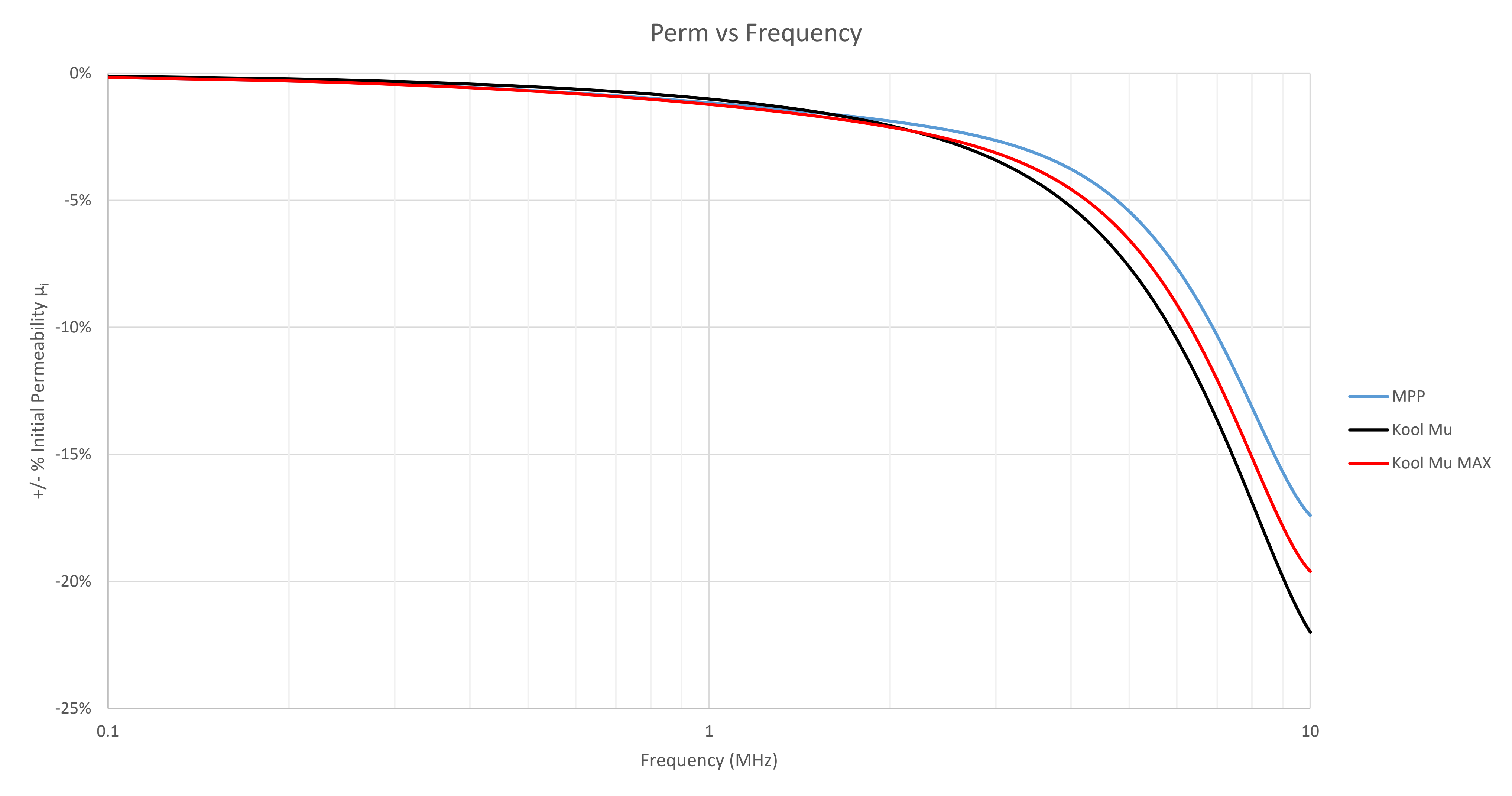
- Focused testing on lower loss materials
  - MPP, Kool Mμ, Kool Mμ MAX

Material (60μ)	DC Bias at x Ls (Oe)		Core Loss (mW/cm^3)
	80%	50%	$W_{1000\text{ G, }100\text{ kHz}}$
MPP	60	106	450
Kool Mμ	43	95	550
Kool Mμ MAX	68	135	500

- Comparing permeability versus frequency up to 10 MHz for 60μ

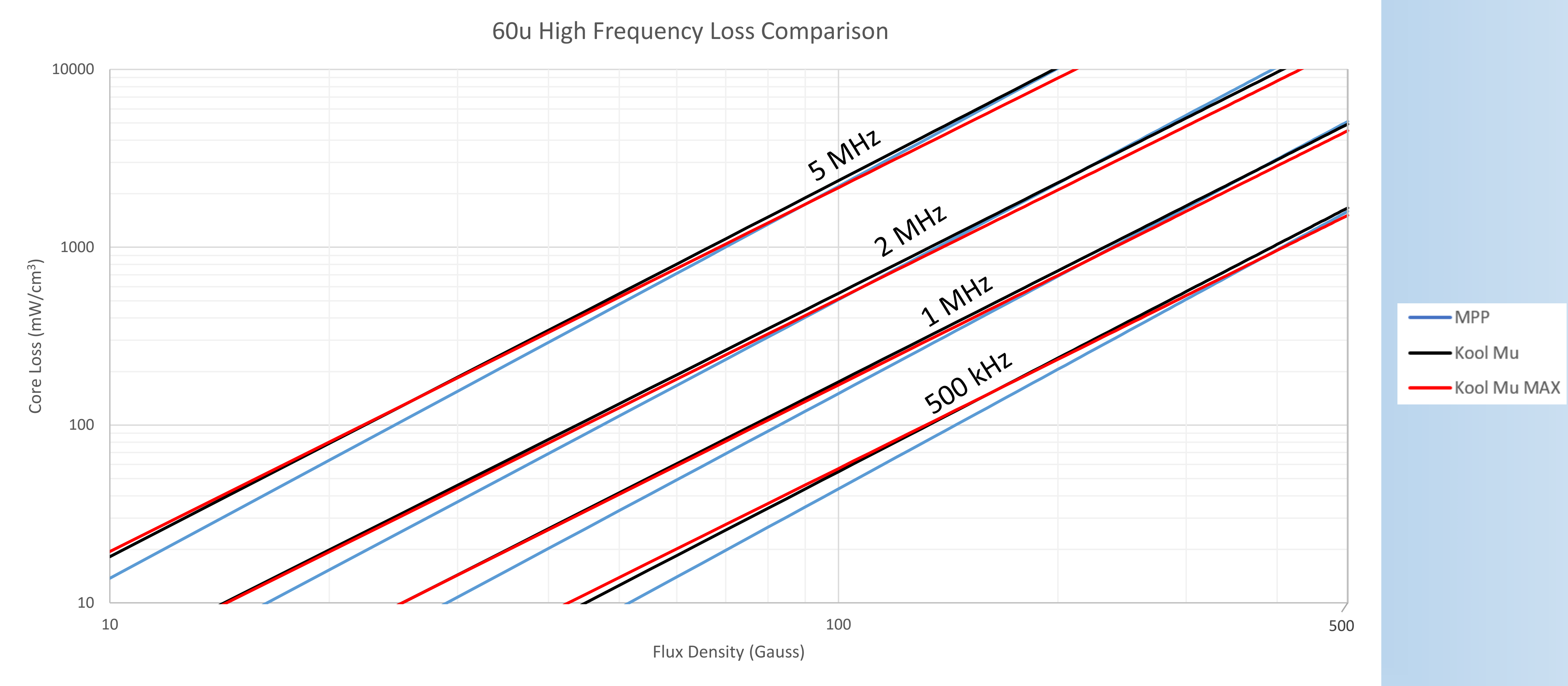
- Comparing core loss at 500kHz, 1MHz, 2MHz, and 5MHz (60μ)

High Frequency Considerations – μ vs. Freq 60μ



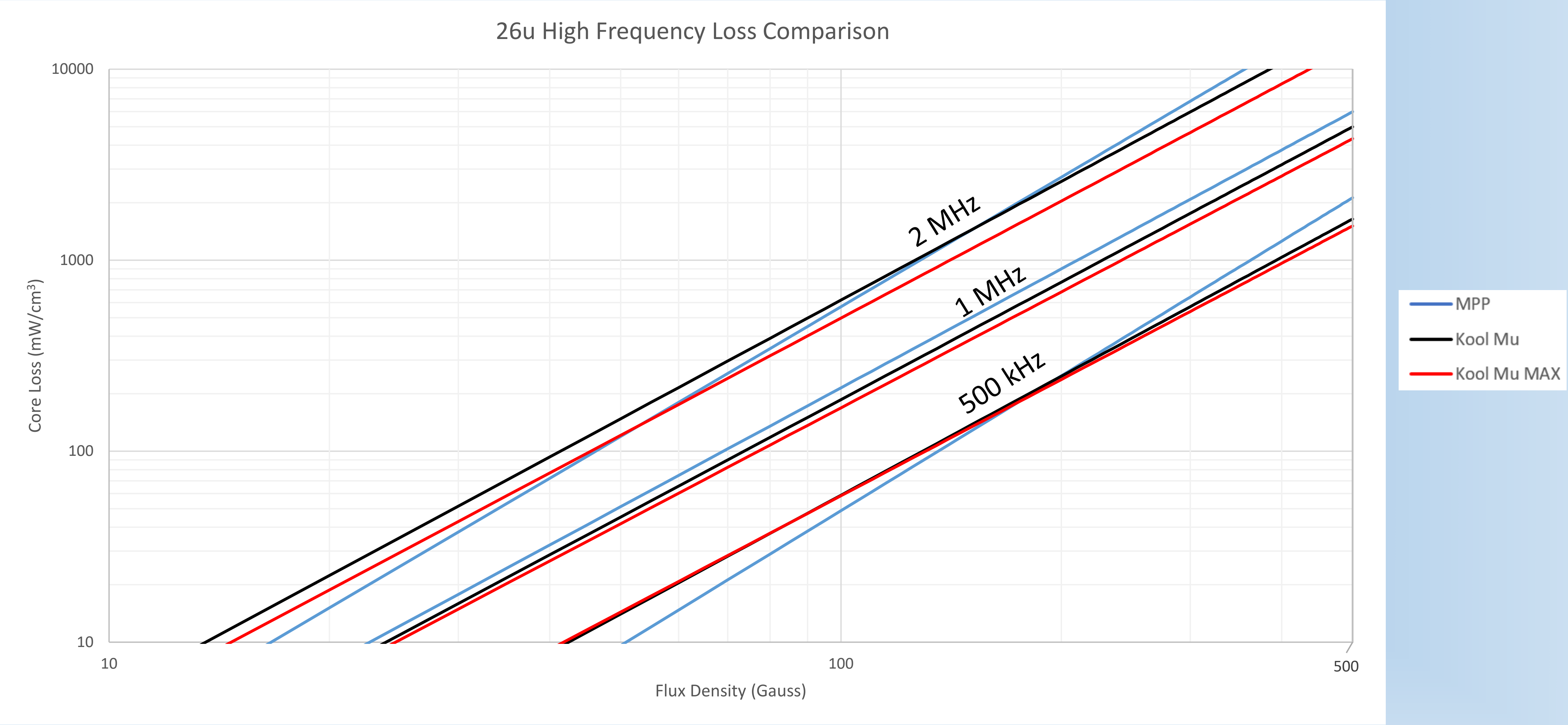
High Frequency Considerations – Core Loss

Data Compilation



High Frequency Considerations – Core Loss

Data Compilation



High Frequency Considerations – Summary

- Summary Table

60µ	MPP	Kool Mµ	Kool Mµ MAX
Core Loss 1MHz, 100G	150 mW/cc	175 mW/cc	165 mW/cc
Core Loss 1MHz, 250G	1110 mW/cc	1100 mW/cc	1090 mW/cc
Core Loss 5MHz, 35G	215 mW/cc	260 mW/cc	250 mW/cc
Core Loss 5MHz, 70G	1000 mW/cc	1100 mW/cc	1040 mW/cc
µ vs. f 5MHz	-5.4%	-7.6%	-6.5%
µ vs. f 10 MHz	-17.4%	-22.0%	-19.6%

- Future Steps
  - Further High Frequency Testing and Curve Development
  - High Frequency Bulletin
  - High Frequency Powder Material

Presentation Conclusions

- Kool Mμ MAX available in 26μ - 60μ
  - 19μ, 75μ, 90μ and shapes soon
- Higher perm XFLUX (75μ & 90μ)
- New Shapes Development
  - EQ26 and Round Leg U-Cores
- R&D Development
  - High Flux Improvement and High Frequency Powder Material
- High Frequency Testing
  - μ vs. Frequency Performance: MPP > Kool Mμ MAX > Kool Mμ
  - Core Loss Performance

QUESTIONS?