Rare Earth Magnet Design Considerations

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Outline

(1) Overview

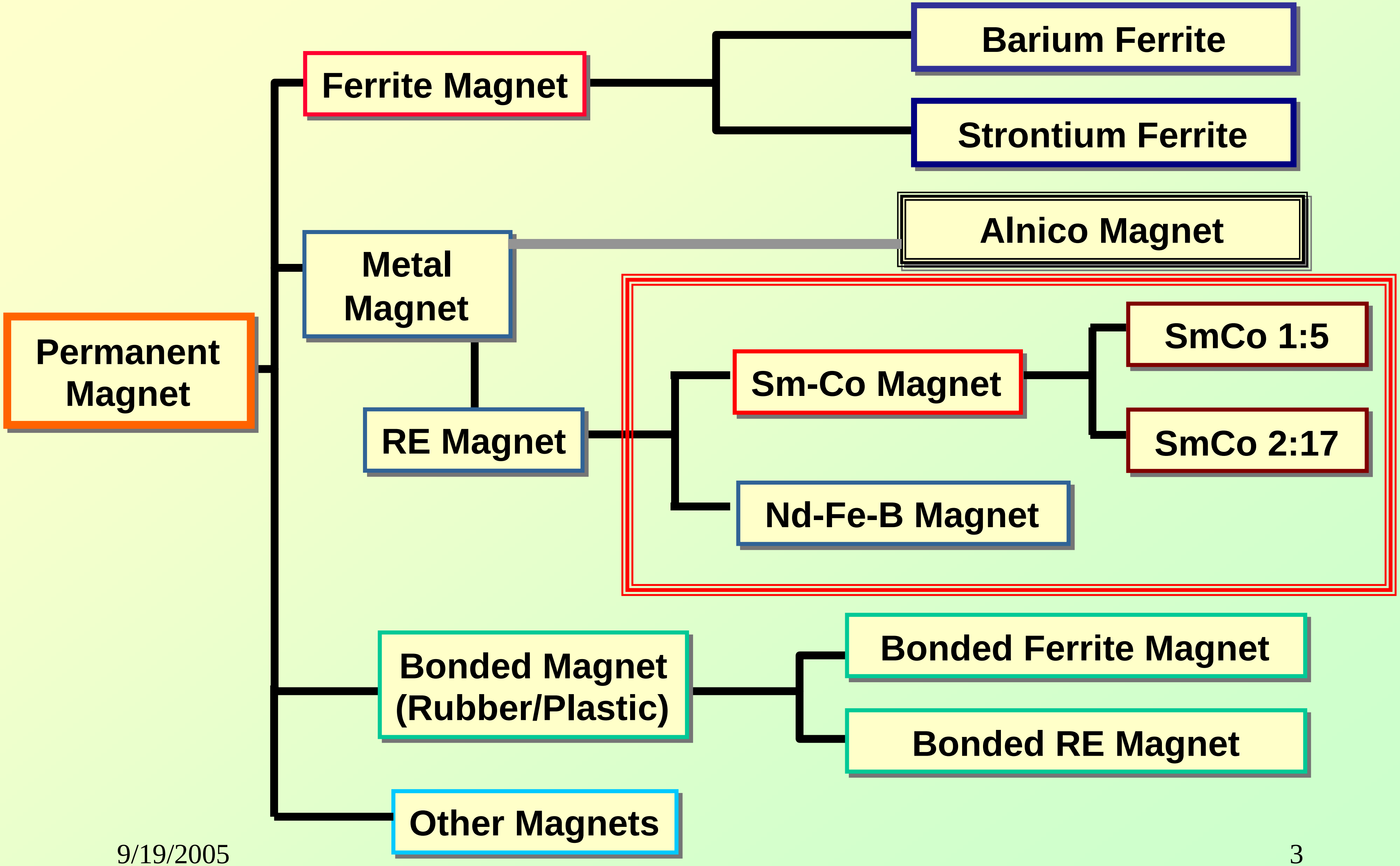
(2) Material selection

(3) Some design considerations

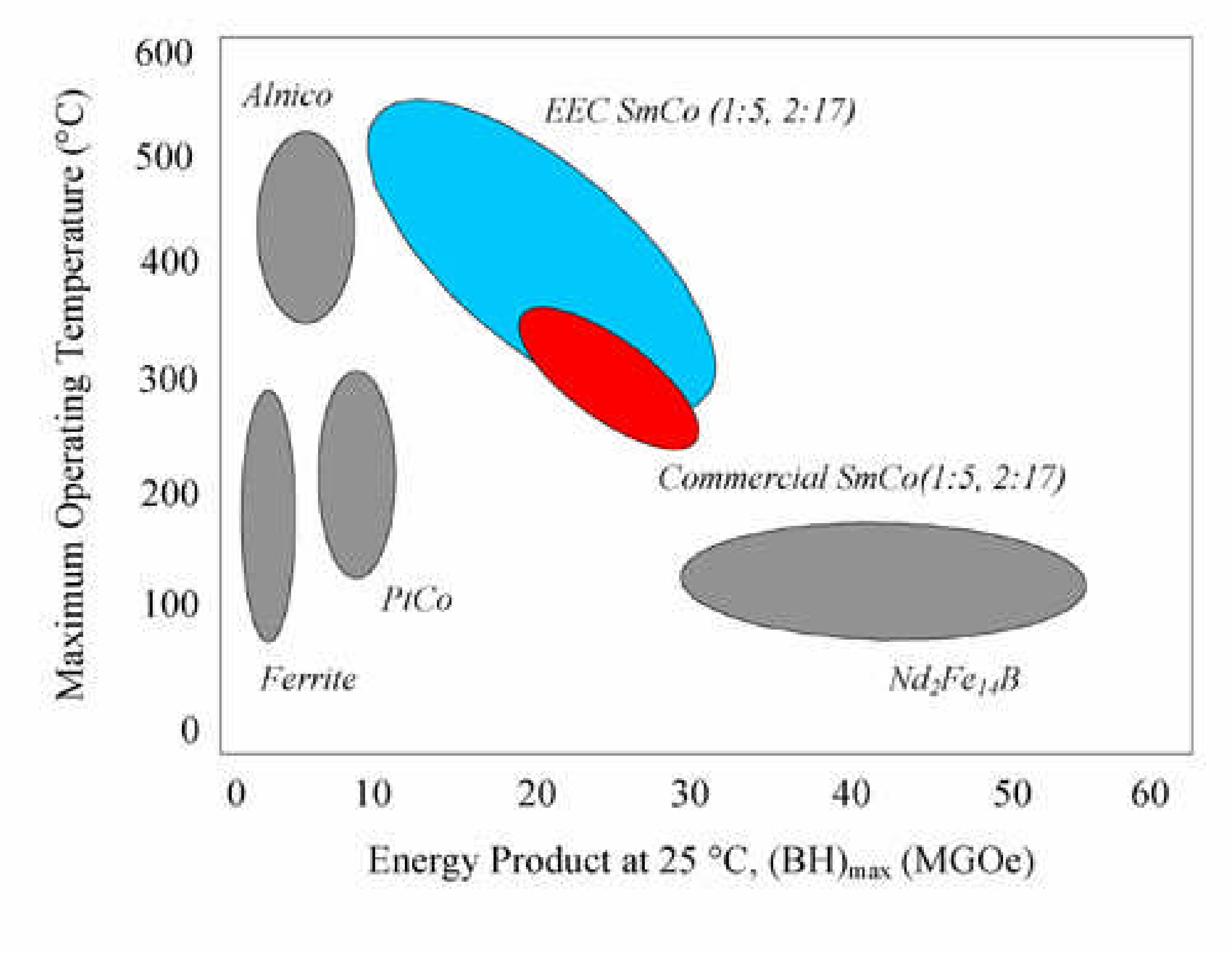
(4) Some examples

(5) Summary

Types of Commercial magnets



$(BH)_{max}$ versus Maximum Operating temperature



Rare Earth magnet ---- materials selection

Some factors to consider:

(1) Magnetic performance
(2) Maximum operating temperature
(3) Coating
(4) Temperature coefficient of Br
(5) Thermal stability
(6) Magnetization direction
(7) Manufacturability

Magnet material selection

Typical magnetic performance of some commercial magnets

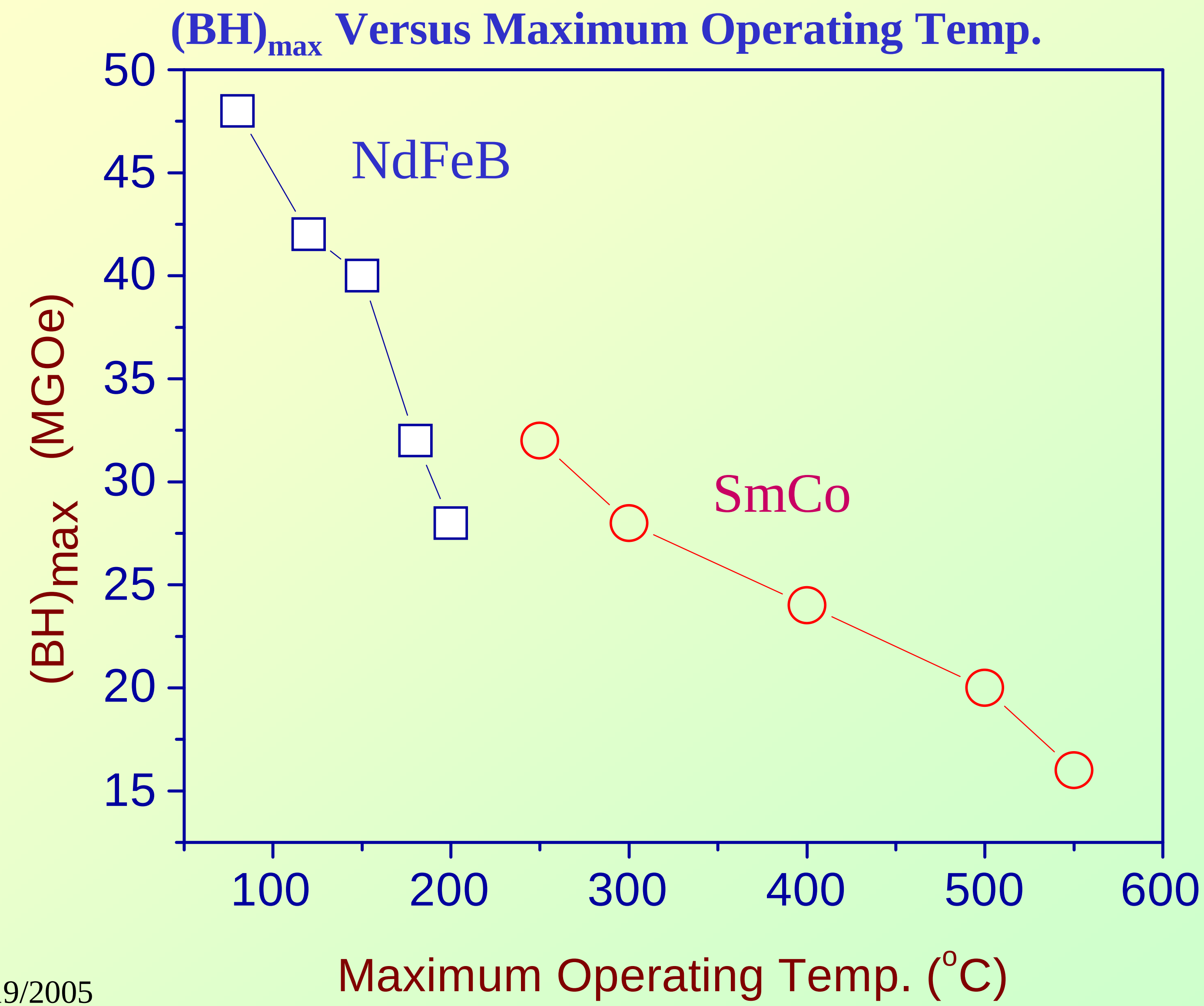
- ✓Sintered neo magnets up to 50 MGOe
- ✓Sintered Sm-Co magnets up to 32 MGOe
- ✓Isotropic bonded neo magnets up to 10 MGOe
- ✓Sintered ceramic magnets up to 4 MGOe
- ✓Cast Alnico magnets up to 9 MGOe

Rare Earth magnet ---- materials selection

Maximum operating temperature of sintered magnets

Magnets	Maximum Operating Temp.*
NdFeB with $_iH_c$ =12 kOe	80°C
NdFeB with $_iH_c$ =17 kOe	120°C
NdFeB with $_iH_c$ =20 kOe	150°C
NdFeB with $_iH_c$ =25 kOe	180°C
Conventional SmCo magnets	300°C
EEC24-T400 magnets (patented & available)	400°C
EEC20-T500 magnets (patented & available)	500°C
EEC16-T550 magnets (patented & available)	550°C

Rare Earth magnet ---- materials selection



Corrosion resistance:

Sintered Sm-Co magnets:

Very good corrosion resistance

Plating is needed only if the operating temperature exceeds 400^{o}C

Sintered Nd-Fe-B magnets:

Poor corrosion resistance

Coating is required (typically Ni plating)

Bonded Nd-Fe-B magnets:

Coating is required (typically epoxy coating)

Temperature compensated magnets

- Some applications , such as gyro and TWTs, require stable B_r over a wide temperature range
- The reversible temperature coefficient of B_r is defined as:

$$\alpha = \frac{\Delta Br}{Br} \frac{1}{\Delta T} \text{ x } 100\%$$

- To address above requirements, EEC developed temperature compensated magnets with the reversible temperature coefficient of B_r close to zero

Temperature compensated RE-Co 1:5 magnets

Grades	$(BH)_{max}$	Reversible temp. coeff. of B_r	Comment
EEC 1:5-18	18 MGOe	-0.04 %/°C	no compensation
EEC 1:5TC-15	15 MGOe	-0.03 %/°C	some compensation
EEC 1:5TC-13	13 MGOe	-0.02 %/°C	some compensation
EEC 1:5TC-9	9 MGOe	-0.001 %/°C	full compensation

Reversible temperature coefficient of B_r of fully compensated RE-Co 1:5 magnets is 40 times smaller than the non-compensated $SmCo_5$ magnets

Temperature compensated RE-TM 2:17 magnets

Grades	$(BH)_{max}$	Reversible temp. coeff. of B_r	Comment
EEC 2:17-24	24 MGOe	-0.035 %/°C	No compensation
EEC2:17TC-18	18 MGOe	-0.02 %/°C	Some compensation
EEC2:17TC-16	16 MGOe	-0.001 %/°C	Full compensation

- ✓Higher $(BH)_{max}$ as compared to RE-Co 1:5 magnets for both compensated and non-compensated magnets
- ✓0TC material has a $(BH)_{max}$ of 16 MGOe

High temperature magnets

- A few years ago, the maximum operating temperature of Sm-Co magnets was only up to 300^{o}C
- DoD initiated the More Electric Aircraft program, which requires magnets with maximum operating temperature more than 400^{o}C
- Funded by Department of Defense, a series of sintered SmCo 2:17 magnets were developed with maximum operating temperature as high as 550^{o}C

High temperature magnets

Grades	$(BH)_{max}$	Maximum operating temp
EEC24-T400	24 MGOe	400 ^{o}C
EEC20-T500	20 MGOe	500 ^{o}C
EEC16-T550	16 MGOe	550 ^{o}C

High temperature magnets require a special coating if used above 400^{o}C continuously.

Rare Earth magnet ---- materials selection

Nd-Fe-B sintered magnets

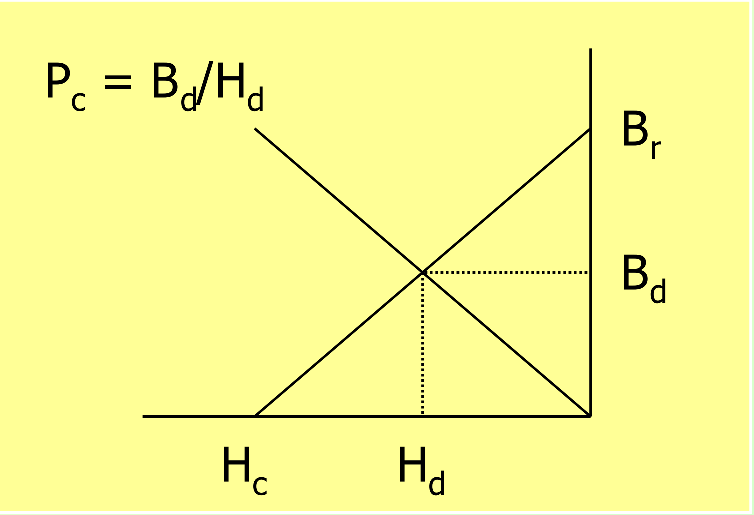
Key features:

- Highest $(BH)_{max}$ available (up to 50 MGOe)
- Less expensive than SmCo magnets
- Corrosion resistance is not good
- Special coating is required
- Maximum operating temperature is very low as compared to SmCo magnets

Some Design Considerations

Permeance Coefficient P_c

In the magnetic circuit, magnets will operate at a specific point on its extrinsic demagnetization curve:

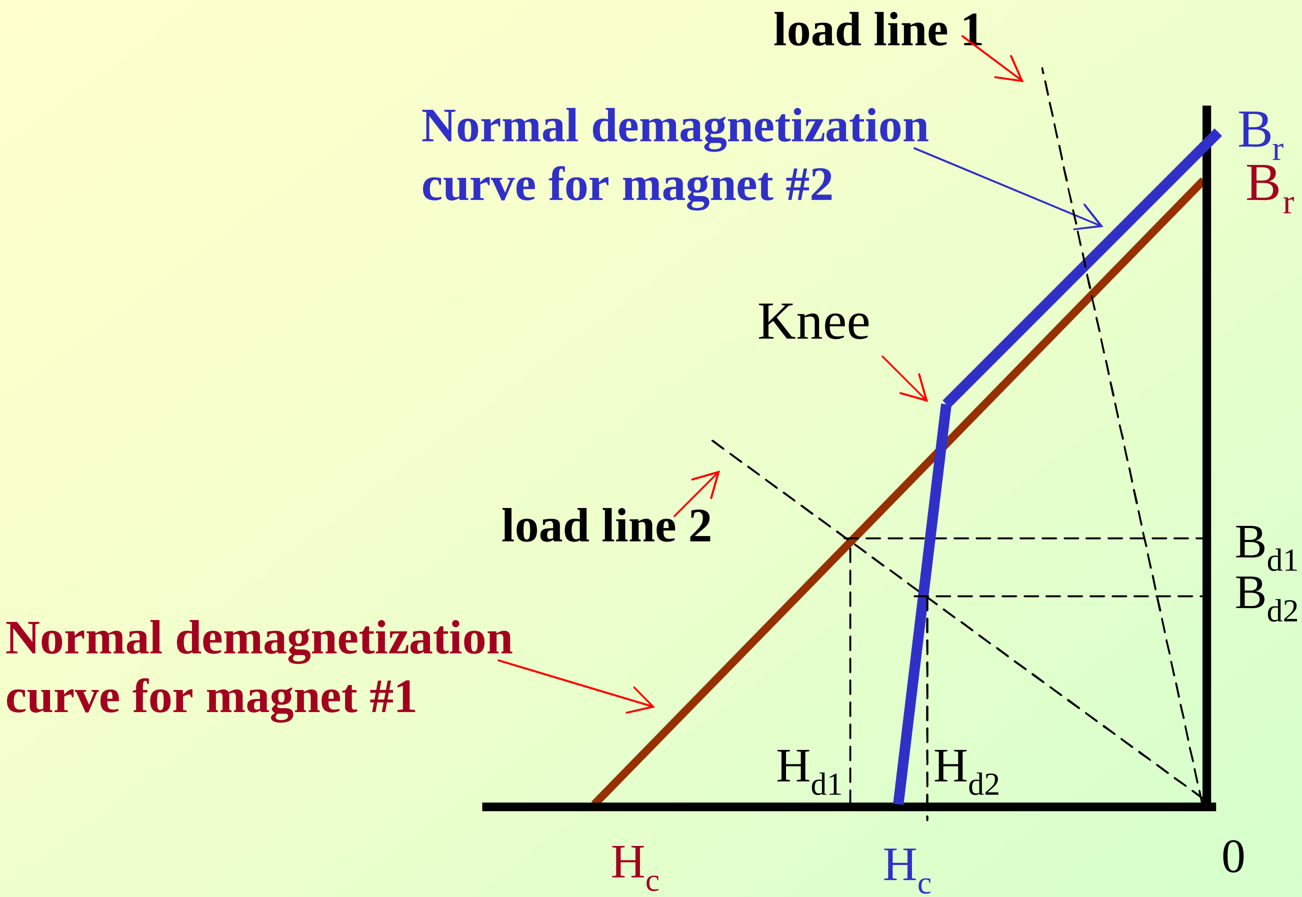


Permeance Coefficient (P_c)

$$P_c=B_d/H_d$$

- Also known as **load line, operating point**.
- It is related to the dimensions of the magnets and the associated magnetic circuit.

Why straight-line demagnetization curves?



Application with load line #1: Both magnets will be alright

Application with load line #2: Only magnet #1 is suitable

Summary

- Sm-Co magnets offer the best thermal stability, while Nd-Fe-B magnets have the highest magnetic performance at relatively lower temperatures.
- Isotropic bonded magnets can be easily manufactured for multipole configurations
- Temperature compensated SmCo magnets are the best choice for aerospace and defense applications
- High temperature magnets with maximum operating temperature up to 550^{o}C is commercially available
- FEA and magnetic design service can help reduce cost and improve performance

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