PRELIMINARY CONSIDERATIONS ABOUT THE DESIGN OF THE SOLENOID AND THE END-COILS FOR THE MICE COOLING EXPERIMENT

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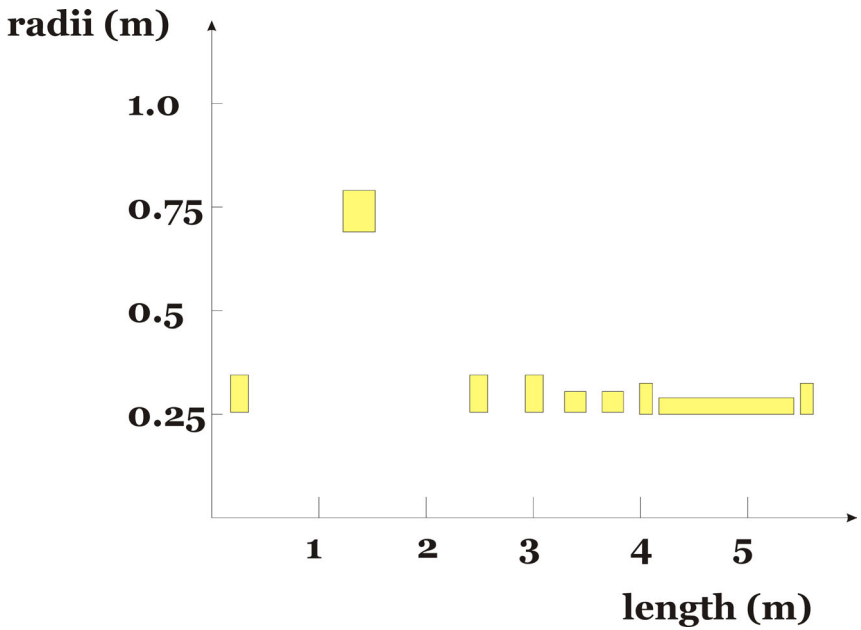
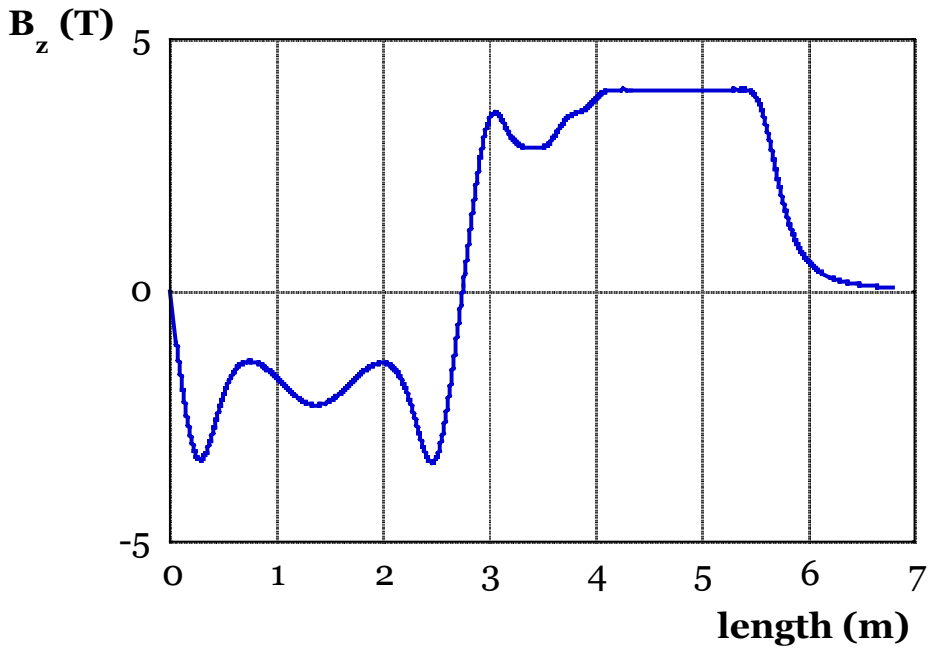
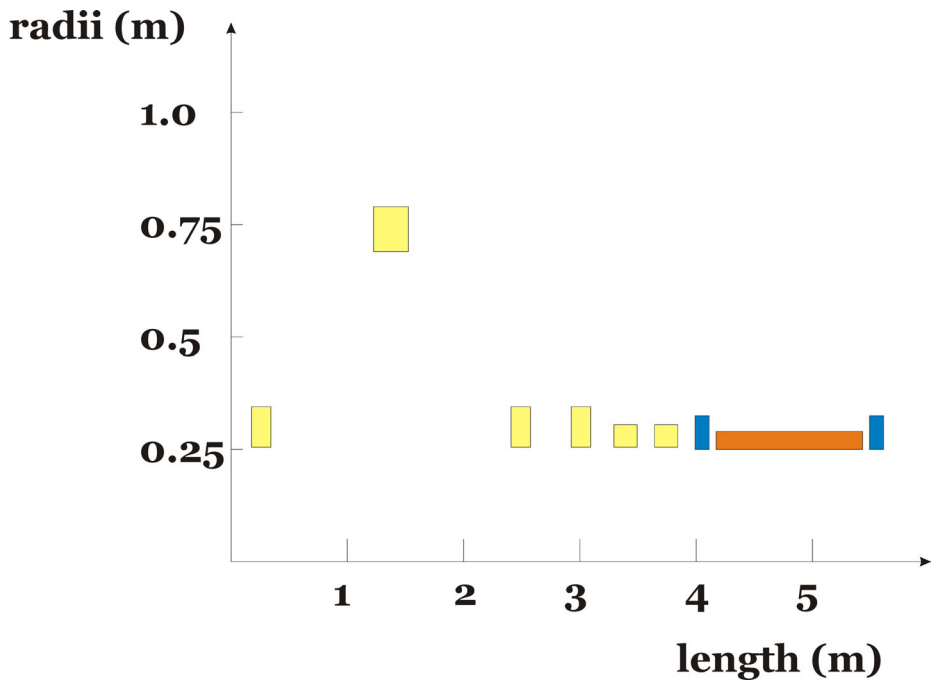
STARTING POINT: the magnetic system described by R.B. Palmer and R. Fernow in their latest Note (23 August 2002).





PRELIMINARY DESIGN: the solenoid (in orange) and the end-coils (in blue).



INVESTIGATED ASPECTS:

- choice of the conductor
- Definition of the magnetic parameter (number of turns, operative current, etc)
- load line
- temperature margin
- protection

SOLENOID DESIGN: conductor and magnetic parameters.

EUROPA METALLI CONDUCTOR CHARACTERISTICS:

Dimensions (bare):	1.52×2.28 mm²
Dimensions (insulated):	1.65×2.40 mm²
Number of filaments:	92
Filament diameter:	80 μm
Critical current:	2000 A @ 2 T 1550 A @ 3 T 1210 A @ 4 T

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PALMER NOTE PARAMETERS:

Overall dimensions:	1.26×0.04 m²
Ampere turns:	$4.08 \cdot 10^6$ A

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SOLENOID DESIGN:

Number of layers:	30
Number of turns per layer:	525
Length:	1.26 m
Winding thickness:	0.0495 m
Operative current:	260 A
Ampere turns:	$4.095 \cdot 10^6$ A
current density:	65.7 A/mm²
Volume:	0.11 m³
Weight:	715 Kg
Inductance:	48.6 H
Magnetic energy:	1.64 MJ

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LOAD LINE: If the coil were indirectly cooled, it would be better to work with a large enthalpy margin; i.e. at a current $<<I_C$.

Maximum field on the winding = 4.0 T

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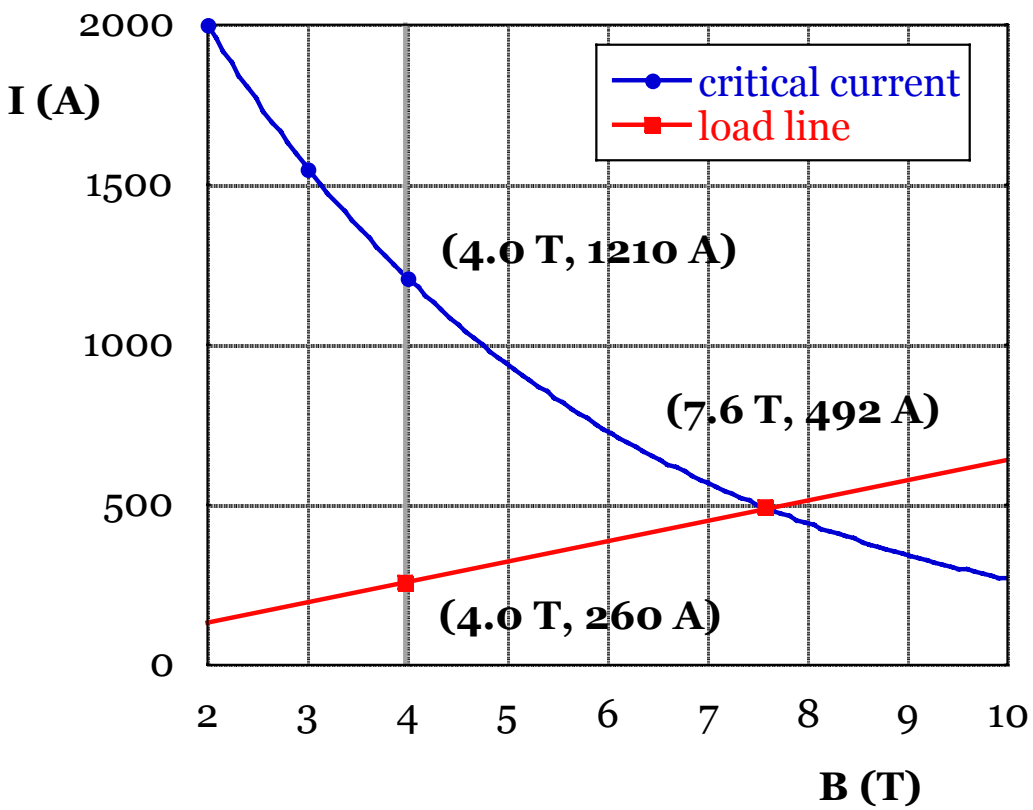
The operative current (260 A) is:

- 22% of the conductor critical current (1210 A)
- 53% of the magnet critical current (492 A)



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TEMPERATURE MARGIN ΔT:
the temperature increase needed to have power dissipation in the coil.

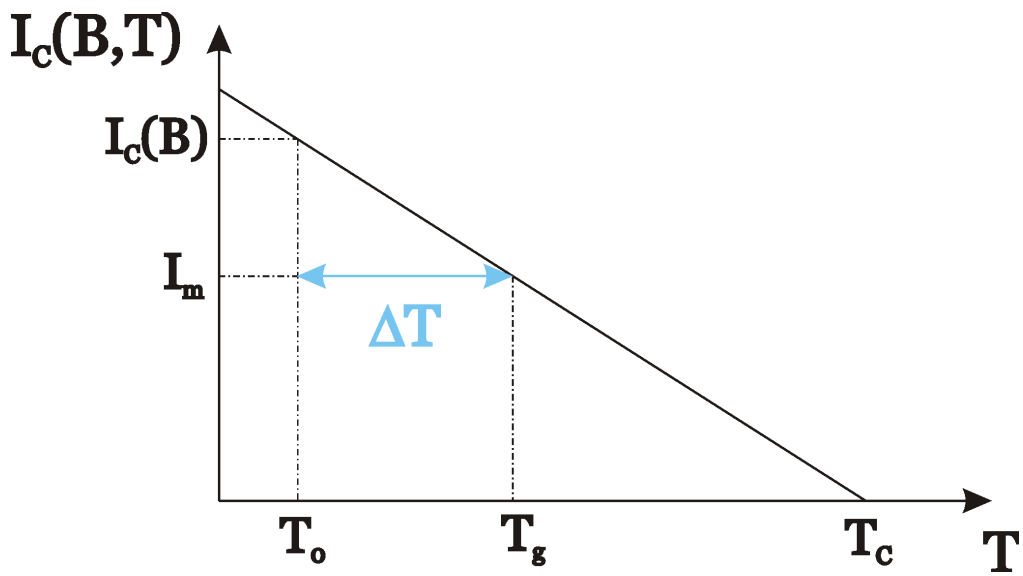
ΔT is the difference between the sharing temperature T_g and the operative temperature T_o:

T_o=4.5 K

T_C=7.6 K

Tg=6.9 K

ΔT=2.4 K



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PROTECTION: the hot spot temperature should be lower than 200 K.

If R= 2 Ω

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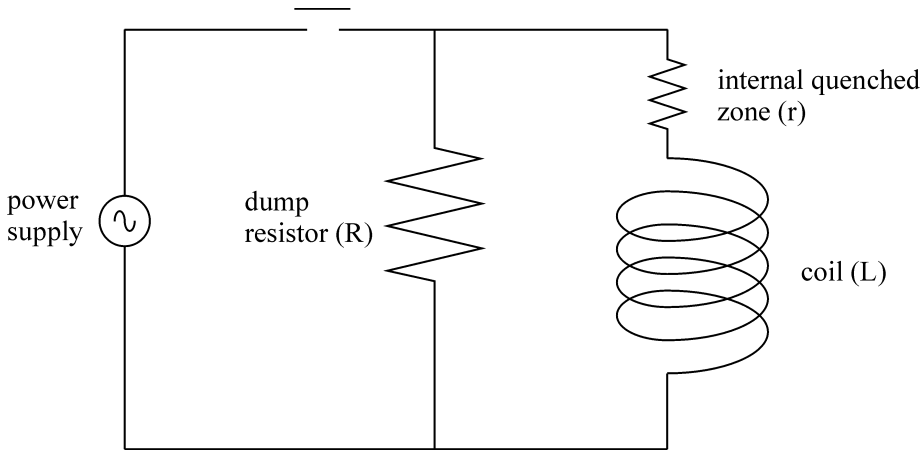
$T_{HOT\ SPOT} < 100$ K

PROTECTION CIRCUIT:



END COILS DESIGN: ANSALDO has available a conductor and a cryostat (with 60 A HT_C current leads) for a non-constructed coil.

CONDUCTOR CHARACTERISTIC:

Diameter (bare):	1.5 mm
Diameter (insulated):	1.56 mm
Number of filaments:	92
Filament diameter:	80 μm
Critical current:	543 A @ 7.52 T
	786 A @ 6.10 T
	1000 A @ 4.90 T
	1073 A @ 4.46 T
	1233 A @ 3.54 T

AVAILABLE LENGTHS:

1. 1900 m
2. 2000 m
3. 2100 m
4. 2200 m
5. 2300 m
6. 2420 m
7. 2520 m
8. 2700 m
9. 3540 m

Totally: 21.68 Km

INNER END-COIL OUTER END-COIL

PALMER NOTE PARAMETERS:

Overall dimensions:	0.12×0.075 m²	Overall dimensions:	0.12×0.075 m²
Ampere turns:	$0.9 \cdot 10^6$ A	Ampere turns:	$1.1 \cdot 10^6$ A

END-COIL DESIGN:

Number of layers:	77	Number of layers:	77
Number of turns per layer:	34	Number of turns per layer:	42
Length:	0.12 m	Length:	0.12 m
Winding thickness:	0.05304 m	Winding thickness:	0.06552 m
Total conductor length:	4.55 Km	Total conductor length:	5.08 Km
Operative current:	344 A	Operative current:	344 A
Ampere turns:	$0.90 \cdot 10^6$ A	Ampere turns:	$1.11 \cdot 10^6$ A
current density:	140 A/mm²	current density:	140 A/mm²
Inductance:	14.1 H	Inductance:	21.5 H
Magnetic energy:	0.83 MJ	Magnetic energy:	1.27 MJ

END-COIL LOAD LINE

Maximum field on the winding (outer end-coil) = 6.3 T

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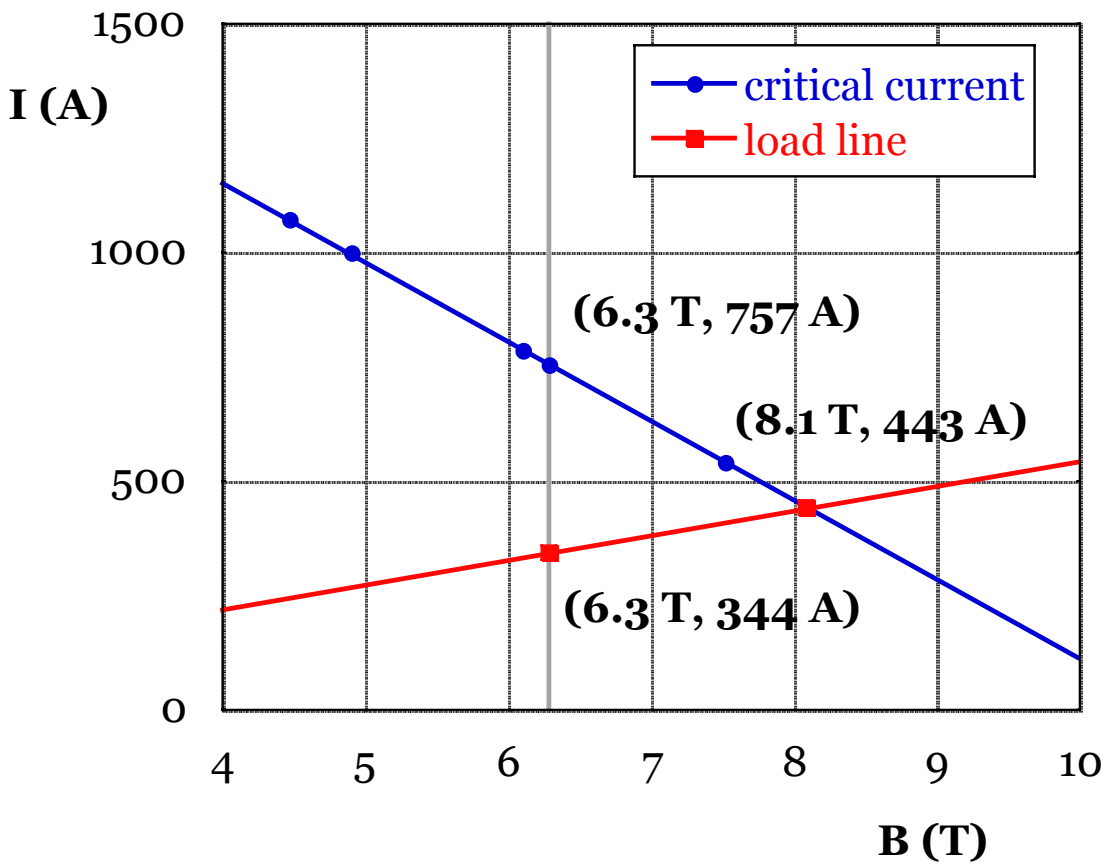
The operative current (344 A) is:

- 45% of the conductor critical current (757 A)
- 78% of the magnet critical current (443 A)



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END-COILS

TEMPERATURE MARGIN:

T_o=4.5 K

T_C=6.5 K

Tg=5.6 K

ΔT=1.1 K

PROTECTION:

If R= 2 Ω

$T_{HOT\ SPOT}$ < 200 K

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THE PROBLEM OF THE AXIAL FORCES

SOLENOID	AXIAL FORCE (ton)		
focus	123.9		
coupling	9.8		
focus	-121.1		
focus	163.5		
match	-2.0		
match	34.7		
end	40.2	}	
solenoid	0.8		-92.2
end	-133.2		

TOTALLY: 116.8 ton (=1.14 MN)

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COOLING: Indirect with 4.5 K cryocooler (1-2 W)

First stage keeps cool the thermal shields

Additional cooling for the (strong?) axial supports?

LHe cooling + 40 K cryocooler only for shield and support thermal intercepts

Longitudinal copper strips at every 5 layers

MECHANICS

The coil is relatively thin (50 mm). Hoop and axial stress and deformation shall be studied and a mechanical structure may be needed (in this case we are thinking to an anisotropic steel banding, already used in the 400 mm bore 8 T insert of our laboratory).

Coil lay-out: main and end-coils as part of the same col mass.