Development of a 1.5 Tesla whole-body MRI Magnet with a very low helium inventory

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SIEMENS Healthineers

RATIONALE

- Siemens Healthineers aims to reduce the total cost of owning an MRI scanner for our customers and to ensure availability of MRI scanners into the future.
- One challenge is the reduced availability and increasing cost of helium. Conventional MRI systems are cooled by greater than 1000 litres of liquid helium.
- A high risk/ reward programme was set-up to realise the next generation of whole-body MRI magnets with a significantly reduced inventory of liquid Helium (< 50 litres). This work is presented.

PROGRAMME

Minimisation of Helium

Magnet Technology
- Technologies to cool MRI magnets with small (<50 litre) Helium volumes.
- Must work within MR imaging system.

Logistics
- Magnets have less thermal inertia.
- Cool down at site or in hubs required.

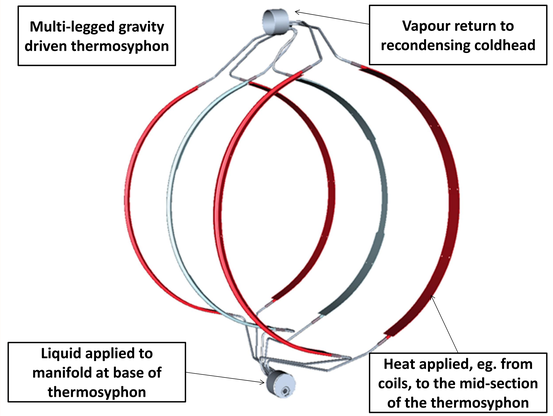
See Oral presentation by A Mortensen Thu-Mo-Or29

Infrastructure reliability:
- Customer impact of poor power and water reliability must be minimised.

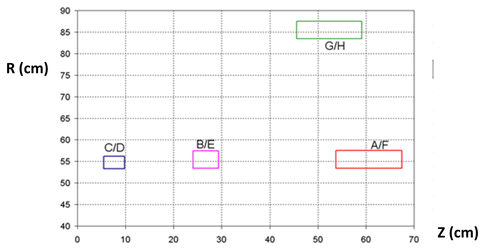
MAGNET SPECIFICATION

Parameter	Specification
Field strength at isocentre	1.494T.
Long term temporal field drift	< 0.1 ppm/hour
0.5mT Fringe field	Radial (x,y) <= 2.6m Axial (z) <= 4.6m
Magnet Length	1528mm
Magnet Bore Diameter	950mm
Liquid Helium volume	Less than 50 litres
Homogeneity	500 x 500 x 350 mm Elliptical Volume ≤30 pk to pk ppm (14.80ppm achieved)
Target shim mass	The target shim mass is <6kg (2.7kg achieved)

CRYOGENIC PRINCIPLE



MAGNET DESIGN



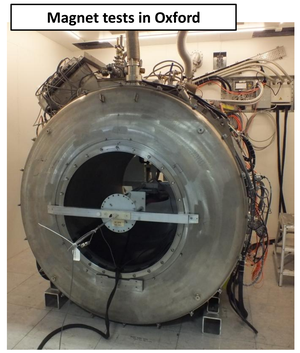
Parameter	Value
Current	468A
Stored energy	4.47 MJ
Conductor ABCDEF	Monolith. Hard insulated. Total 29km.
Conductor GH	Wire in Channel. Polyester braided. Total 18km.

INSTRUMENTATION

- 107 x calibrated Carbon Ceramic Resistor (CCR) temperature sensors were positioned on all components to obtain temperature maps.
- 34 x optical strain gauges were used to measure strains without magnetic interference, for example on the suspension rods.
- Various heaters and voltage taps were also used for thermal characterisation and measurement of quench voltages.
- A National Instruments PXI chassis including four PXI-4070 DMMs and four PXI-2530B multiplexers were used for acquiring signals.

REALISATION

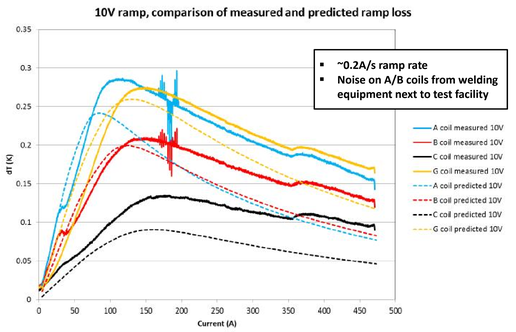
Magnet tests in Oxford



System tests in Erlangen

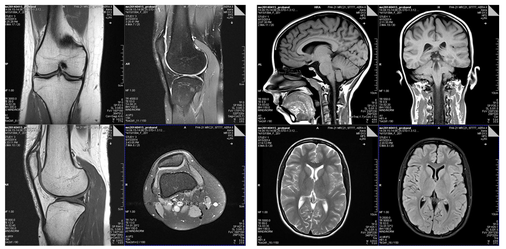
TESTING: RAMPING

- The temperature rise in the superconducting coils during ramping was measured and compared with hysteresis loss predictions.



IMAGING

- The Magnet Technology Demonstrator was fully evaluated in a Siemens MRI system in 2014.
- With an inventory of ~20 litres of liquid helium it was found to deliver comparable imaging performance to a conventional bath-cooled magnet.
- Many imaging protocols were tested including those used for Orthopedic, Neurological, Cardio, and Spectroscopy imaging.
- The magnet remained recondensing during imaging.



ACHIEVEMENTS

- ✓ Achieved intended field strength of 1.495T and field stability requirements.
- ✓ Temperature of magnet measured during all operating modes including cooldown and ramping.
- ✓ Magnet successfully tested as part of an MR system. Magnet tolerant to heating from the gradient coil and recondensing under all imaging conditions.
- ✓ This development provides a solid basis for Siemens to commercialise the technology.

ACKNOWLEDGEMENTS

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