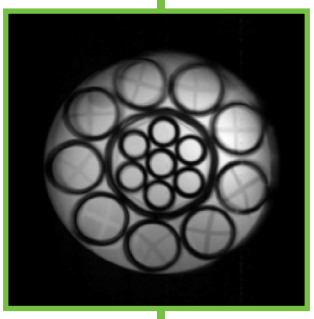
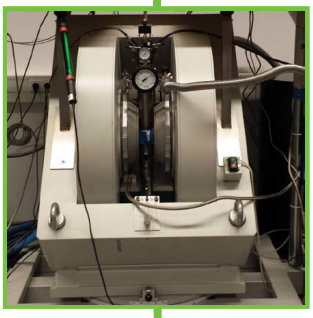
Magnetic Resonance

(MRI, EPR, NMR, DNP)





CRYOGENIC

www.cryogenic.co.uk

Magnetic Resonance Systems

Cryogenic Ltd has been a pioneer of cryogen-free superconducting magnets and cryostats for a variety of applications for more than 20 years

Taking advantage of the availability of cost effective cryocoolers, Cryogenic has been able to extend its range of cryogen-free products into the domain of magnetic resonance, including high homogeneity and high persistence magnets for high resolution solid state NMR, dissolution DNP, high field and W-band EPR and even high specification magnets for MRI.

Cryogen-Free Magnets for Solid State NMR

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Cryogen-Free Magnets for DNP

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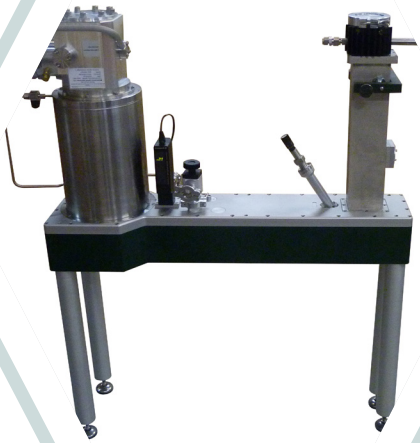
Cryogen-Free Magnets for EPR

pg.8

Cryogen-Free technology suits superconducting magnets where the ability to sweep or change the magnetic field is very important

Conventional superconducting magnets are cooled using liquid helium, which is costly, difficult to source and requires the availability of helium dewars to refill the cryostat. With cryogen-free superconducting magnets it is possible to sweep the full range of magnetic field values, as well as controlling sample temperature, without consuming any liquid helium and with the minimum of fuss. High field EPR and wide line NMR systems were the first to be built utilising this technology. In addition, Cryogenic Limited have developed W-band EPR magnets that have an integrated variable temperature insert (VTI), using a patented approach with a single cryocooler for cooling both the magnet and VTI. We have taken our expertise to the next level with our new, high resolution solid state NMR magnets, which can be swept or made persistent at any field value, making a very versatile conveniently field settable superconducting magnet.

Cryogen-Free Temperature Cryostat for EPR (CF VTC for EPR)



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Cryogen-Free 6T Split Pair Magnet System for EPR Experiments

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Mini Cryogen-Free MRI Magnets

pg.8

Cryogen-Free Magnets for Solid State NMR

NMR superconducting magnets deliver high magnetic field homogeneity and excellent temporal field stability over the sample volume. The NMR experiments are typically conducted at fixed field, in persistent mode. Our Cryogen-Free systems provide this environment, while eliminating the need for liquid cryogens.

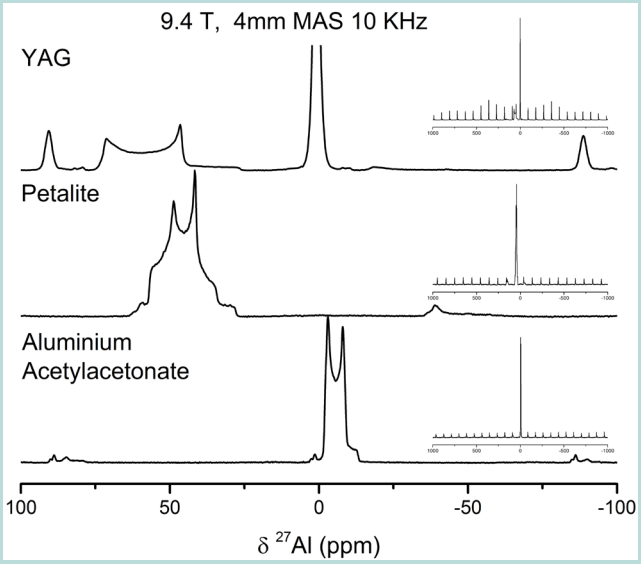
This magnet can be energised at different persistent B_0 values up to the rated maximum for full field dependent studies. In addition, the magnet can be swept through the full static quadrupole NMR spectrum making it simple and convenient to determine all of the relevant quadrupolar parameters experimentally, bringing full B_0 control to the NMR spectrometer.

In the case of solid state DNP NMR, the same magnet can be used for the high-resolution NMR component, as well as the full EPR spectrum of the spin label

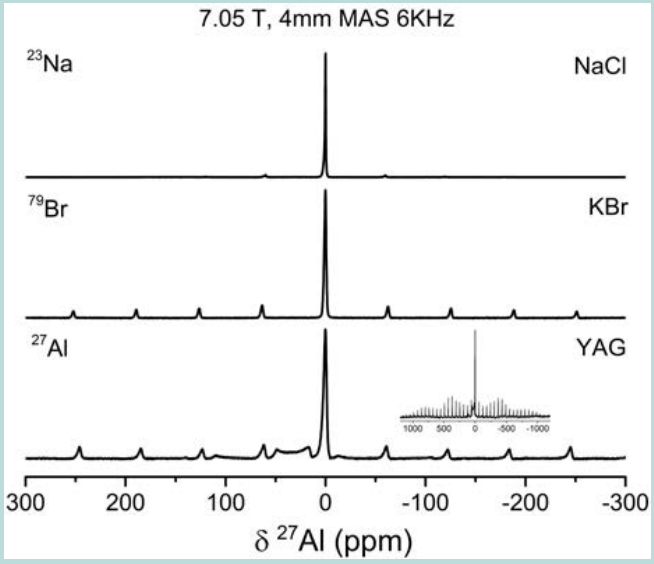
Specification

300 MHz to 600 MHz 54 mm and 89 mm bore magnets
Variable temperature inserts down to below 2 K
Superconducting shim coils
Custom magnets tailored for DNP
NMR consoles available

CF 400 MHz Narrow bore



NMR spectrum in magnetic field of 400 MHz

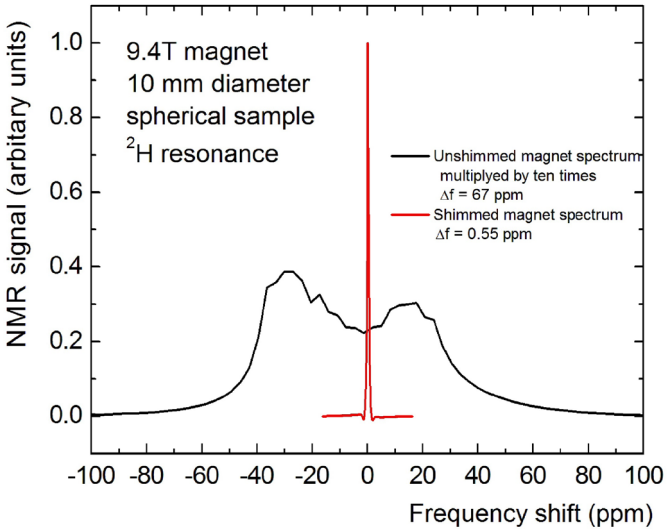


NMR spectrum in magnetic field of 300 MHz

Cryogen-Free Magnets for Solid State NMR

Product	CF 300/89	CF 400/89	CF 600/89	CF 300/54	CF 400/54	CF 600/54
Field Strength	300 MHz	400 MHz	600 MHz	300 MHz	400 MHz	600 MHz
Homogeneity (*)	1 ppm HHLW	1 ppm HHLW	1 ppm HHLW	1 ppm HHLW	1 ppm HHLW	1 ppm HHLW
Field Sweep	±7.05 T	±9.4 T	±14.1 T	±7.05 T	±9.4 T	±14.1 T
Cryo-shims	Z1, Z2, X, Y, C2, S2, ZX, ZY			Z1, Z2, X, Y, C2, S2, ZX, ZY		
Drift	< 0.1 ppm/hr			< 0.1 ppm/hr		
Room Temperature Bore	89 mm			54 mm		
Cryocooler	1 W PT	1 W PT	1.5 W PT	1 W PT	1 W PT	1 W PT
Compressor	Water cooled, 3-phase power			Water cooled, 3-phase power		
Cooldown time	100 hours			80 hours		

We now offer complete NMR spectroscopy systems, consisting of our high homogeneity and high persistence magnet, along with an NMR console supplied by our partner.



Modular Digital NMR / MRI Console

Based on many years of research and development, Cryogenic is offering the most flexible and fastest NMR spectrometer available on the market. The digital ™ is a compact, modular, Windows 10 64-bit-based NMR, MRI, and NQR system. A range of features and options are available including transmitter arrays, high power linear RF amplifiers, digital receiver arrays, gradient control system, shim unit, MAS spinspeed controller, Variable Temperature (VT) unit, digital lock system and RF probe interface. With its numerous options, the system can be configured for any NMR, NQR or MRI application in the frequency range of 2 kHz to 3.5 GHz.

Some features include:

- 2 kHz to 3.5 GHz frequency range
- 10 ns minimum pulse width and resolution
- < 10 ns phase switching with 0.0055° phase resolution
- < 20 ns phase-continuous frequency switching
- 64 Million point waveform memory for each transmitter and gradient channel
- 12.5 MHz (80 ns per complex point) digital receiver
- Up to 24-bits of digital receiver dynamic range

Cryogen-Free Magnets for DNP

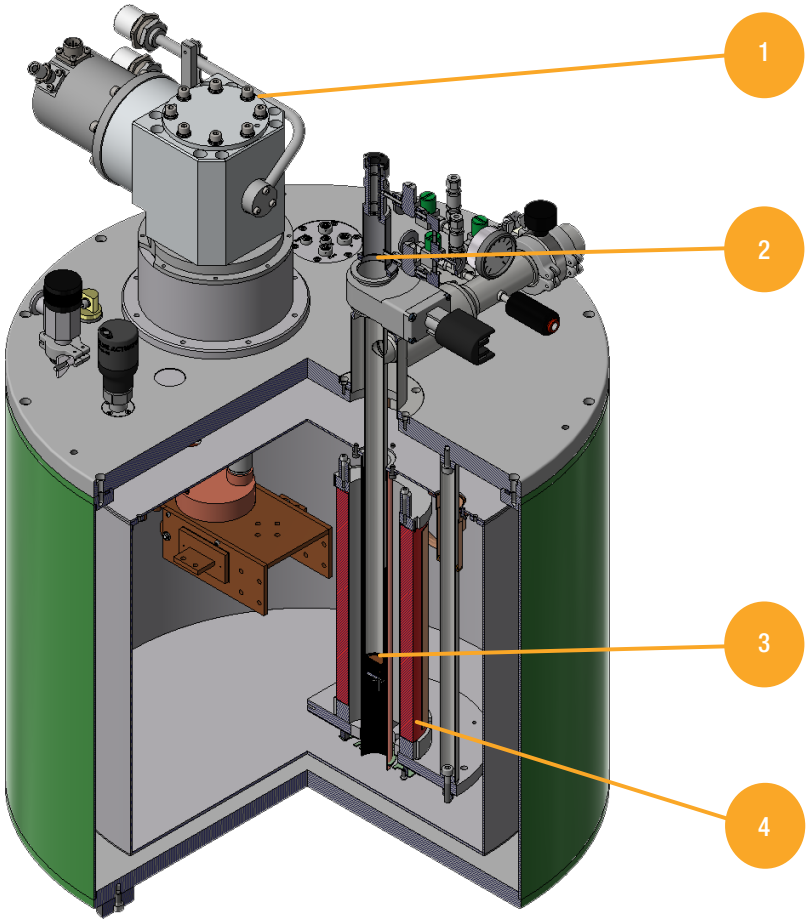
Cryogen-Free Dissolution DNP Magnets

Superconducting dissolution Dynamic Nuclear Polarisation (DNP) NMR magnets are an excellent use of cryogen-free technology. The magnets are available with maximum magnetic field up to 10.1 Tesla and an integrated variable temperature insert (iVTI) with base temperature down to below 1.3 K.

These magnets are manufactured with an integrated pulse tube cryocooler, which is sufficiently powerful to handle the heat load caused by the high repetition rate of polarised sample ejection. In addition, the magnet and the sample regions are well thermally isolated from each other, to remove any short term effects on the magnet, as witnessed by the performance of other systems.

Technical Specifications	
Product	Cryogen-free magnet system with integrated VTI for NMR/DNP
Max magnetic field	6.7 T / 9.4 T / 10.1 T
Homogeneity	50 ppm bare homogeneity over ∅30 mm DSV
Field drift in persistent mode	0.1 ppm/hr
Current at 10.1 T	110 A
Sample access bore	∅30 mm
VTI minimum temperature	< 1.3 K – 300 K
VTI operational mode	Single shot or continuous He flow
Cryocooler	1 W Pulse Tube
Cooling power	1 W @ 4K
Compressor consumption	6.6–6.9 kW @ 50 Hz, 3-phase, water cooled
Cool-down time	approximately 24 hours depending on model
Maintenance interval	30,000 hours

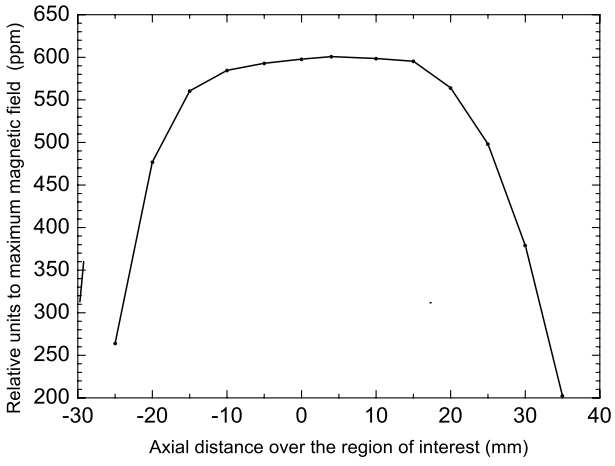
Cryogen-Free Magnets for DNP



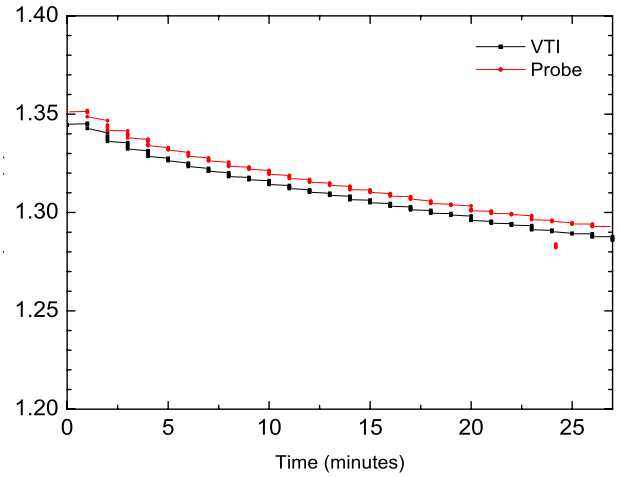
Key

1. Pulse tube cryocooler
2. Airlock for sample exchange
3. VTI sample space
4. Superconducting magnet

Magnetic Field Axial Profile of the 10.1 T magnet



VTI Base Temperature (Continuous Flow)



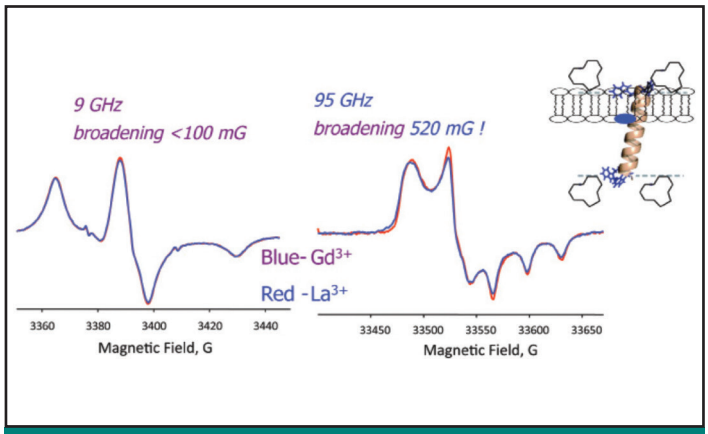
Cryogen-Free Magnets for EPR

Cryogenic offers a superconducting transverse field EPR magnet with integrated variable temperature insert (iVTI). The compact design of this magnet facilitates the use of X and Q band flexline resonators, making this a very versatile magnet. This magnet with iVTI makes use of Cryogenic Ltd's patented approach of using a single cryocooler for cooling two independent thermal circuits; one for the magnet and one for the iVTI. The magnet uses electricity more efficiently than the conventional 2 T resistive electromagnets and uses no liquid helium for performing low temperature studies.

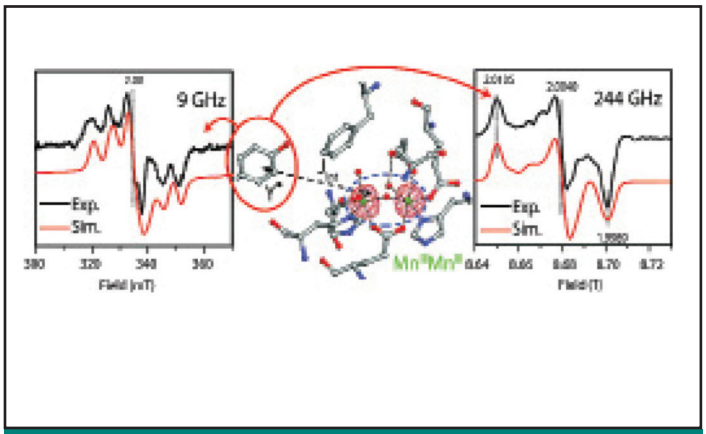
This is attractive as it allows the magnetic field to be swept between fields as required and for the field to be set at any level up to the maximum rated field. For long periods and for the best long term field stability, there is no requirement to add helium or nitrogen and no need for skilled personnel to perform this task.

- Cryogen-free magnets generating fields up to 14 T with Ø89 mm room temperature bore
- Magnetic field along or transverse to vertical bore
- Central field homogeneity 10 ppm (HHLW) over 10 mm diameter sphere volume (DSV)
- Superconducting sweep coils
- Variable temperature insert with Ø50 mm internal diameter integrated into the cryostat
- Optical access to sample region

The photo is courtesy of Professor Dariush Hinderberger, Martin Luther Universität Halle-Wittenberg



Intensity-normalized experimental EPR spectra from 6-WALP in DMPC/DMPE-DTPA bilayer in the presence of Gd^3 + ions (blue) and in the presence of LA^{3+} (red) ions. Left: 9 GHz and Right: 95 GHz.
(courtesy of Dr. A. Smirnov, North Carolina State University)



EPR spectra at 9 GHz and 244 GHz of tyrosyl radical in R2F subunit of Ribonucleotide Reductase of Corynebacterium ammoniagenes together with a representation of the crystal structure around the Mn(III)-Mn(III).
(courtesy of Dr. E. J. Reijerse and Prof. W. Lubitz, Max Planck Institute for Bioinorganic Chemistry, Muelheim; reproduced from J. Am. Chem. Soc. (2010) 132, 11197-11213)

Cryogen-Free Magnets for EPR

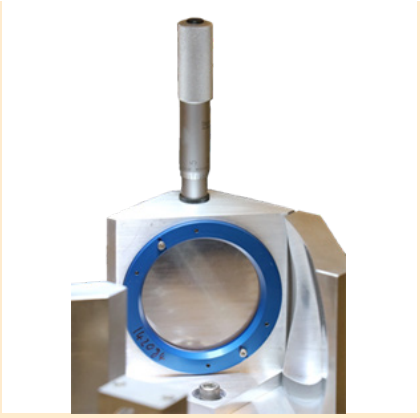
EPR systems with Ø89 mm room temperature bore

Model	CFM-7T-10ppm-89RT	CFM-14T-10ppm-89RT
Maximum central operating field @4K	7 Tesla	14 Tesla
Central magnetic field homogeneity	10 ppm over Ø10 mm sphere	
Stabilised long term drift rate	≤ 0.1 ppm/hr	
Clear room temperature bore	Ø89 mm	
Typical initial cool-down to operating temperature	24 hrs	24 - 36 hrs

EPR systems with Ø50 mm variable temperature insert (VTI)

Model	CFM-7T-10ppm-VTI50	CFM-14T-10ppm-VTI50
Maximum central operating field @4K	7 Tesla	14 Tesla
Central magnetic field homogeneity	10 ppm over Ø10 mm sphere	
Stabilised long term drift rate	≤ 0.1 ppm/hr	
VTI Temperature range	2 K - 300 K	
Typical initial cool-down to operating temperature	24 hrs	24 - 36 hrs

High Frequency EPR Spectrometer



Cryogenic, in collaboration with Bridge 12, offers a series of cost effective modular continuous wave and pulsed high field EPR instruments using quasi-optical components. The high field EPR spectrometers are available three main standard configurations:

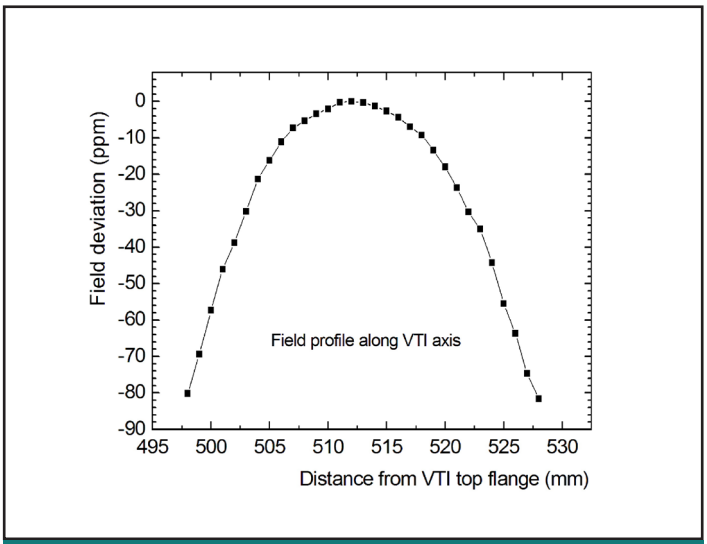
- 140 GHz cw/pulsed EPR system based on a 5.0 T cryogen-free superconducting magnet with or without integrated variable temperature insert (iVTI);
- 263 GHz cw/pulsed EPR system based on a 9.4 T cryogen-free superconducting magnet with or without iVTI;
- 395 GHz cw/pulsed EPR system based on a 14.1 T cryogen-free superconducting magnet with or without iVTI.

These systems are fully supported, integrated and complete EPR solutions. The cryogen-free magnets integrated with the system are manufactured by Cryogenic Ltd and are fully sweepable magnets (from one maximum field polarity to the other) under the Bridge12 EPR spectrometer control. EPR spectrometers operating at more than one of these frequencies are also possible (or with a bespoke frequency, see below).

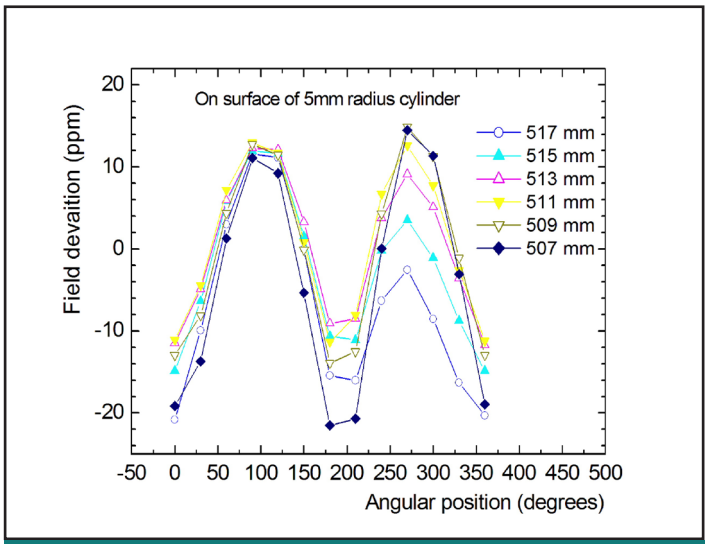
Cryogen-Free 6T Split Pair Magnet System for EPR Experiments

±6 T split pair superconducting magnet with horizontal field

- ±6 T split pair superconducting magnet with horizontal field
- 10/25 ppm homogeneity over Ø10 mm diameter sphere
- Ø50 mm variable temperature insert designed to incorporate Brüker W-Band EPR spectrometer
- 2 K – 350 K sample temperature range
- High magnetic field stability in persistent mode 0.1 ppm/hr
- Designed to minimise vibration resulting in low sample displacement
- Low stray magnetic field B < 5 G for z & r > 3 m
- No liquid cryogens
- HTS current leads from room temperature to magnet permanently connected

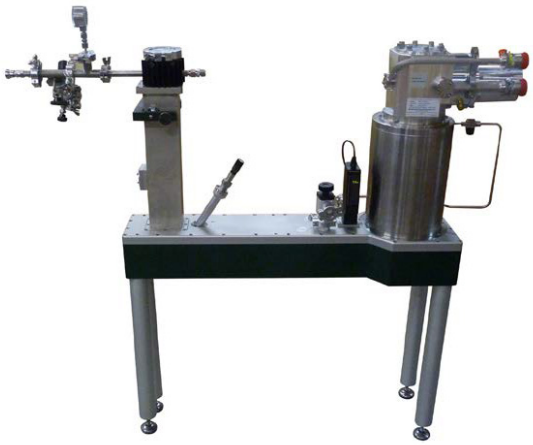


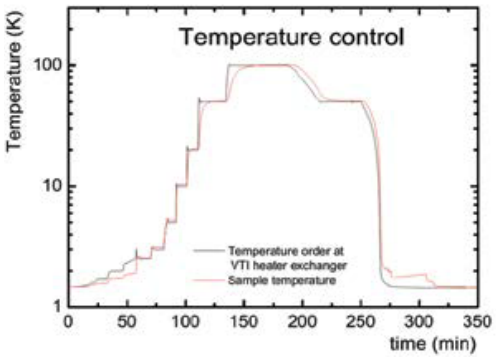
Field profile measured at low temperature as a function of axial position

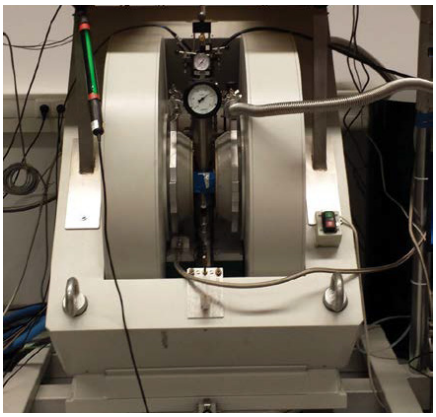


Field deviation as a function of angular position on the surface of a cylinder of 5 mm radius

Cryogen-Free Temperature Cryostat for EPR (CF VTC for EPR)



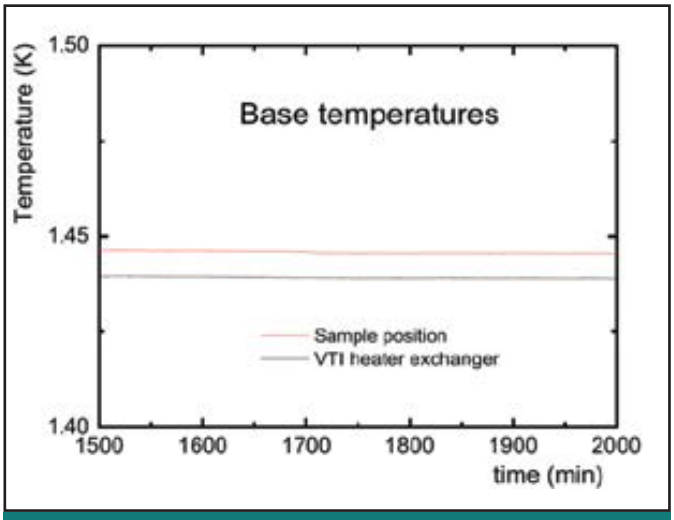




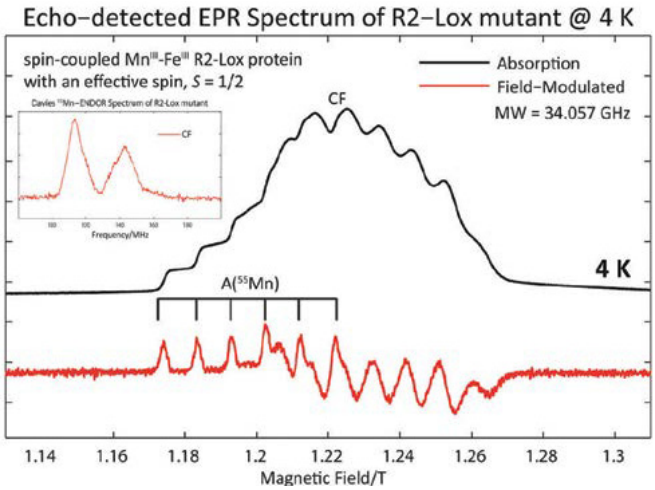
The CF VTC is a replacement for the CF 935 flow cryostat with a temperature range of 2 K to 300 K (typically with a lower base temperature). It allows the user to make experimental scheduling much more efficient and convenient.

- Continuous run times over several weeks
- No dependence on liquid helium availability, avoiding significant scheduling and potential safety problems in addition to the reduced cryogen costs
- Routinely achievable low and stable base temperature (~1.6 K), allowing more systems to be investigated

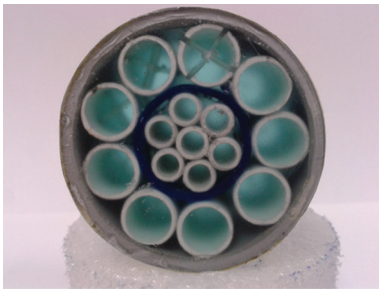
Parameter	Model CF-VTC-1.0W
Cryocooler nominal power at 4.2K	1.0 W
Sample environment	Flowing gas or liquid
Sample space access	Ø40 mm
Sample height below top flange	310 mm
Sample column external width between electro-magnet pole pieces	55 mm
System cool-down to operational readiness	6-9 hours
Sample cool-down time 300 K to 10 K	40 mins
Operating temperature range	1.6 K to 300 K
Typical base temperature with EPR probe installed*	< 4K operation (2 K expected)
Typical temperature stability	± 10 mK from 2 K to 10 K
Operating time	Continuous
Optional optical window	Ø15 mm outer window / Ø12 mm inner window



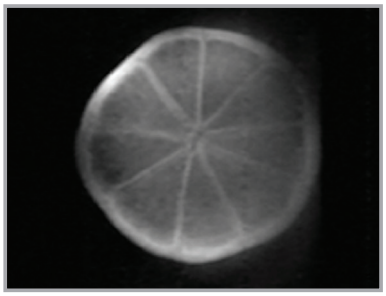
The plot above demonstrates the small difference between the set temperature and the actual sample temperature at below 1.4 K operation (achievable base temperatures will vary, cryostat to cryostat) and demonstrates the temperature stability at base temperature. This measurement was made by placing a cernox sensor into an EPR tube, making the EPR glass and placing in a MD5 flexline resonator.



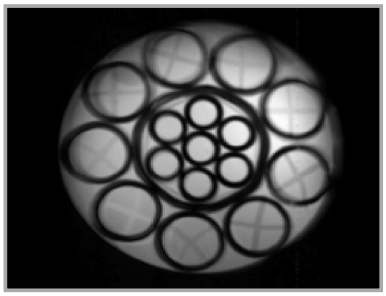
Mini Cryogen-Free MRI Magnets



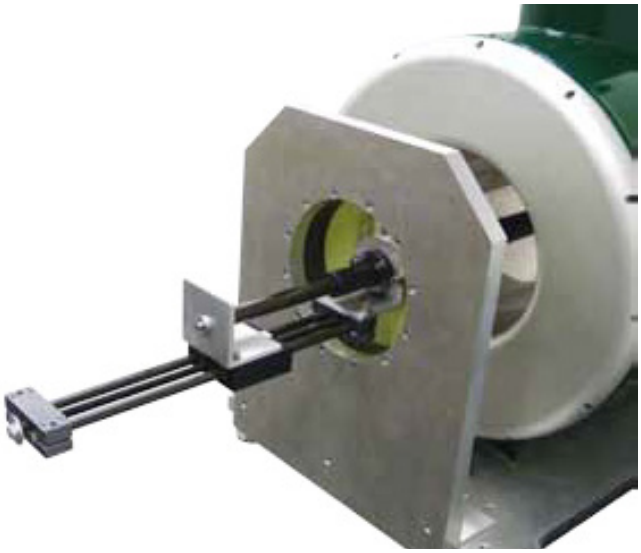
A collection of 10 mm diameter plastic tubes filled with copper sulphate solution, with perspex crosses at regular heights. Overall diameter 55 mm by 50 mm long.



SE image of lime fruit. Slice thickness 8 mm, TE = 3 ms, TR = 200 ms.



Spin Echo (SE) image of phantom. Collected using home built RF bird cage coil and home built gradients. No slice selection, 50 mm thick, TE = 3 ms, TR = 100 ms.



- Persistent-mode switches and joints located in vacuum
- No liquid cryogens
- No quench ducts
- Cool-down in a few days
- Compressors run on single or 3-phase electricity

Applications

» Pre-clinical imaging

» Laboratory MRI studies

1.0 Tesla Cryogen-Free MRI Magnet Specifications

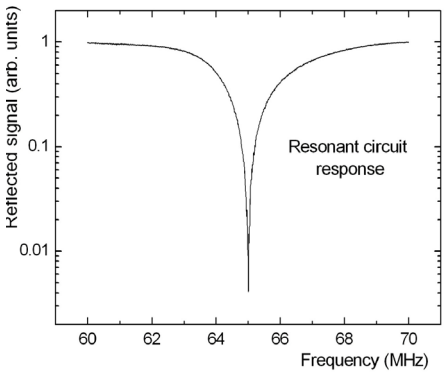
Field	1.0 T
Current	30 A
Homogeneity	10 ppm over 8 cm DSV
Drift	0.1 ppm/hr
Bore	Ø15 cm
Dimensions	330 mm OD / 314 mm long / 775 mm high
Cold-head cooling power	0.125 W at 4 K 5 W at 60K
Compressor consumption	1 kW single phase
Maintenance	10,000 hours
Stray field	5 G at $Z = 1.6$ m / $R = 1.3$ m

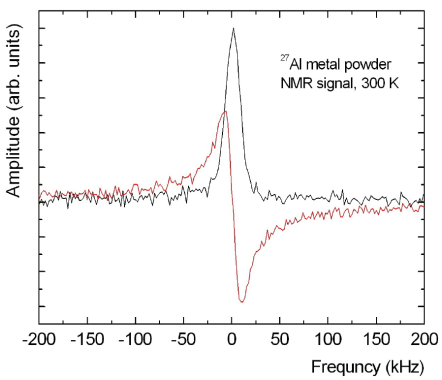
Static Broad Band NMR Probe for Variable Temperature Experiments

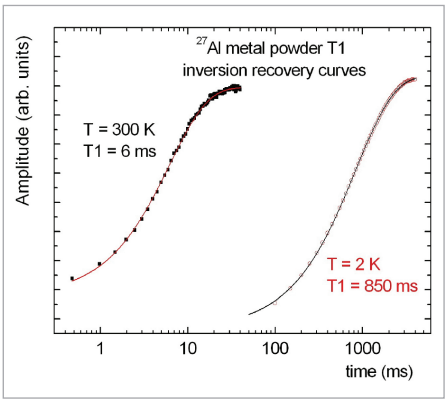
- Can be inserted into a cold cryostat
- Probe equipped with calibrated Cernox thermometer and heater for fine temperature control
- Tuning and matching rods accessible at top of probe
- Compatible with all Cryogenic cryostats with Variable Temperature Insert (VTI)
- Can be used directly in VTI gas flow, in separate static gas column or in vacuum

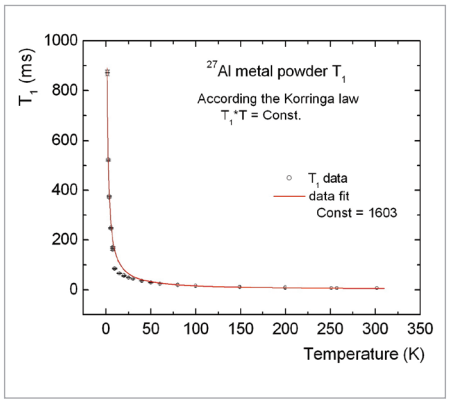
Key Benefits

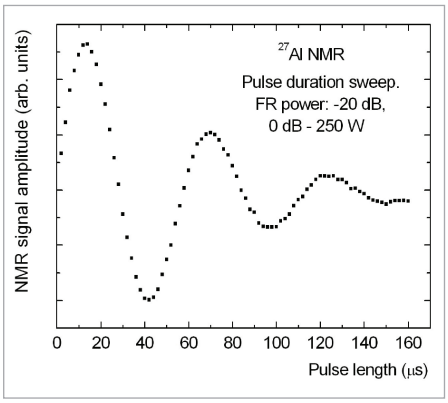
- No cryogenic experience required
- Turn-key operation
- Overnight cool-down
- Low cost of ownership
- Minimal maintenance
- Minimal quench hazards











Customer Support

The Cryogenic Customer Support team is committed to quickly and effectively addressing and resolving questions regarding your system. Customer Support staff are available Monday through to Friday from 9:00 AM to 6:00 PM to answer calls and respond to your emails. Cryogenic Ltd uses skills-based routing to ensure that specialized technical engineers are available to address your question. Free Technical support service is also available by e-mail to respond to your concerns and provide support needed for successful running of your system.

Pre-Sales Technical Support

For customers with special requirements our team of experienced physicists and engineers can design and build complex and very sophisticated Cryogenic magnet systems.

Our experienced sales team and technical design staff are always happy to discuss customer requirements in this specialised technology based on our more than 30 years in-depth experience.

Service and Maintenance

Cryogenic has a philosophy to ensure that the systems delivered are installed and used correctly in order to safeguard the customer's investment. Cryogenic's dedicated installation team, based in key locations around the world and at our Head Quarters in the UK, are hugely experienced and boasts detailed knowledge of the complete running of the system.

We have a service team in many international regions, including China, India, Japan, USA and Germany.

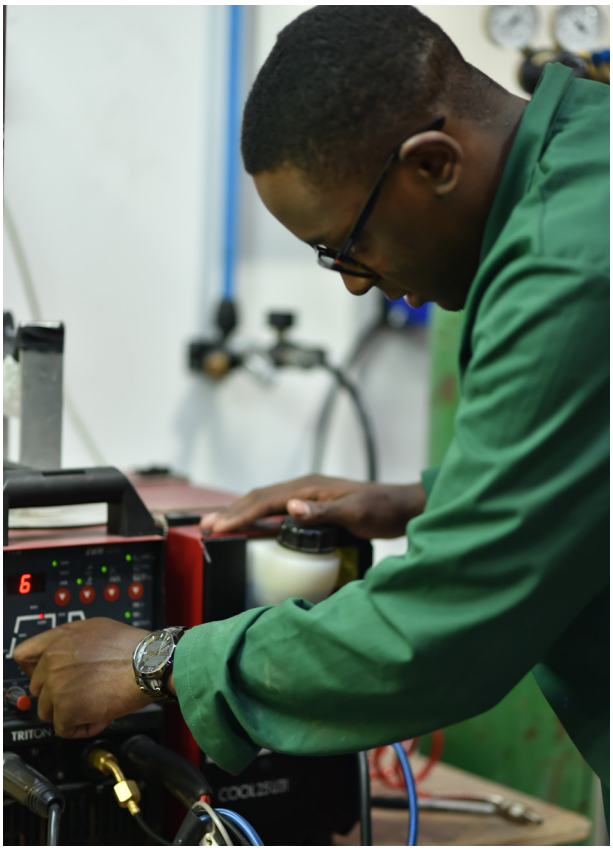
Once installed, the user is trained on how to operate the equipment and, of equal importance, how to carry out basic maintenance, thereby reducing service call-outs and prolonging the life of the equipment. Cryogenic has a dedicated training team which takes on these tasks and has vast experience suitable training methods, staff issues and potential pitfalls.

Remote Assistance

All critical parts of our systems are fitted with diagnostic sensors, and the diagnostic information is automatically logged in the background as the system operates. If a customer has difficulties running the system, or has questions about particular measurements or experiments, our engineers can use remote connection to the system computer in order to perform a comprehensive check of the system's performance, and to provide advice and assistance.

Software Upgrades

We continually work on improving the functionality of the system control software. If you wish to check for updates, please contact the software team for support and assistance.



Please contact our customer service team if you have any concerns using sales@cryogenic.co.uk or complete the customer service form on our website at www.cryogenic.co.uk.

Cryogenic World Wide Network

For locations of our global agents, please visit - www.cryogenic.co.uk/contacts/worldwide-agents-and-partners

CRYOGENIC

www.cryogenic.co.uk

Unit 6 Acton Park Industrial Estate, The Vale, London W3 7QE, United Kingdom
Tel: +44 (0)20 8743 6049 **Fax:** +44 (0)20 8749 5315 **Email:** sales@cryogenic.co.uk