Site Planning for AVANCE Systems

750-950 MHz
User Guide

Version 002

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Introduction

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Introduction 1.1

The fundamentally superior precision of fully digital signal generation and processing was introduced and established by the precedent-setting series of Bruker BioSpin AVANCE™ NMR spectrometers. With its digital advantage, the AVANCE™ series set revolutionary standards for performance, long-term reliability and ease-of-use, whether for routine applications or the most demanding research.

The next-generation **Avance II** NMR spectrometer series features a second-generation digital receiver technology (2G-DR™), a new milestone in NMR detection fidelity. The 2G-DR provides significant benefits for the most demanding NMR applications, e.g., materials science, polymer analysis, trace analysis, LC-NMR, MR imaging and structural biology, particularly for measurements with ultrasensitive CryoProbes™.

Through its advanced modular design the AVANCE II can be optimally configured for any modern application: from classical analytical work to the most demanding structural proteomics; from high-throughput screening to high-power solids NMR to microimaging. The AVANCE II can be delivered in a variety of configurations, ranging from a minimum-footprint microbay system up to a three cabinet instrument fully equipped for high power solids NMR with four or more channels.

Site planning requirements for Avance and AVANCE II are identical, so in this manual they will be referred to as simply AVANCE systems.

Recommendations regarding site planning are based on the experience gained by Bruker BioSpin engineers through the years. Every effort has been made to make the site requirements realistic and readily achievable. It must be stressed however, that **the figures quoted are only recommendations**. Likewise, any performance values that are used are **minimum values that should be readily achievable by every system**. Predicting NMR performance is complicated by the fact that every site is unique. This manual has been written to help you plan the site, but it carries no guarantee of ultimate NMR performance.

While every effort has been made to ensure the information contained herein is accurate, Bruker BioSpin accepts no liability for consequential loss or damage arising from its use. Specifications are subject to change without notice and where a value (e.g., ceiling height) lies close to a recommended minimum value you are advised to check with Bruker BioSpin before final delivery

How to Use This Manual — *1.1.1*

This manual contains information about site planning and preparation prior to delivery of a Bruker BioSpin AVANCE system. After reading this manual you should have enough information to make an initial decision as to whether a proposed site is suitable for locating an AVANCE spectrometer and magnet. The manual should be read through carefully as mistakes made initially may be costly to remedy at a later stage.

The systems covered by this manual are AVANCE spectrometers in the range of 750-900 MHz. **A separate manual is available for 300-700 MHz systems**.

If you are considering a CryoProbe system be sure to request a copy of our latest **CryoProbe System Site Planning Guide**.

If you are considering a LC-NMR/MS system be sure to request a copy of our latest **LC-(SPE)-NMR(/MS) Site Planning Guide**.

The chapters within this manual deal with various points that need to be considered for successful system operation. They have been included to familiarize you with general principles of successful site planning.

If you have a specific question, try using the ***"Contents"*** or ***"Index"*** section of this manual.

For specific questions that may not be addressed in this manual, or for further information on a topic, do not hesitate to contact your local Bruker BioSpin office.

Units Used Within This Manual — *1.1.2*

The SI Unit **Tesla** (mT) is used throughout this manual whenever magnetic field strengths are discussed. Some readers may however be more familiar with the **Gauss** (G) Unit.

For comparison the conversion fact is: **1 mT=10 G**

Likewise the unit **kilowatt** is used for the measure of heat energy (e.g. amount of heat generated by a device per hour). Some readers may be more familiar with these measurements in **BTU/hour**:

For comparison the conversion factor is: **1 BTU/hour=0.000293 kW.**

(BTU = British Thermal Unit which is the required heat to raise 1 pound of H_2O by 1 degree Fahrenheit).

Whereever possible both the metric and American (North and South) measure units have been used throughout this manual. In most cases the weights and measures have been rounded upwards where necessary. The following table offers the common metric to American conversion factors used in this manual:

Table 1.1. Metric to American Conversion Factors

Measure	Metric Units	American Standard Units	Conversion Factor (rounded to nearest hundredth)
Linear	meter (m) centimeter (cm)	feet (ft.) inch (in.)	1 m = 3.28 ft. 1 m = 39.37 in. 1 cm = 0.394 in.
Distance	kilometer (km)	mile (mi.)	1 km = 0.62 mi.
Area	square meter (m^2)	square foot (ft^2)	1 m^2 = 10.76 ft^2
Volume	cubic meter (m^3) liter (l)	cubic foot (ft^3) quart (qt.)	1 m^3 = 35.32 ft^3 1 l = 1.06 qt. (liquid)
Weight	kilogram (kg)	pounds (lbs.)	1 kg. = 2.21 lbs.
Pressure	bar	pounds/square inch (psi) atmosphere (ATM)	1 bar = 14.51 psi 1 bar = 0.99 ATM (stan-dard)
Flow (e.g. gas flow)	cubic meter/minute (m^3/min.)	cubic feet/minute (ft^3/ min.)	1 m^3/min. = 35.32 ft^3/ min.
Temperature	degree Celius (°C)	degree Fahrenheit (°F)	F = C × 1.8 + 32

Table 1.2. Temperature Convesion Formulas

Conversion From	To	Formula
degree Celius (°C)	degree Fahrenheit (°F)	F = C × 1.8 + 32
degree Fahrenheit (°F)	degree Celius (°C)	C = (F - 32) / 1.8
degree Celius (°C)	kelvin	K = C + 273.15
kelvin	degree Celius (°C)	C = K - 273.15
degree Fahrenheit	kelvin	K = (F + 459.67) / 1.8
kelvin	degree Fahrenheit	F = K × 1.8 - 459.67

Warnings and Notes 1.2

There are two types of information notices used in this manual. These notices highlight important information or warn the user of a potentially dangerous situation. The following notices will have the same level of importance throughout this manual.

Note: Indicates important information or helpful hints

WARNING: Indicates the possibility of severe personal injury, loss of life or equipment damage if the instructions are not followed.

Contact for Additional Technical Assistance 1.3

For further technical assistance concerning site planning, please do not hesitate to contact your nearest BRUKER dealer or contact us directly at:

BRUKER BioSpin GMBH
Silberstreifen
D-76287 Rheinstetten
Germany

Phone: + 49 721 5161 0
FAX: + 49 721 5171 01
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Safety 2

Introduction 2.1

These safety notes must be read and understood by everyone who comes into contact with superconducting NMR Magnet Systems. Proper training procedures must be undertaken to educate all people concerned with such equipment about these requirements. It is essential that clear notices are placed and maintained to effectively warn people that they are entering a hazardous area. Please refer to **Bruker Biospin's General Safety Considerations for the Installation and Operation of Superconducting Magnets**, attached at the end of this manual or available from Bruker BioSpin.

The Magnetic Field 2.2

Since the magnetic field of the NMR magnet system is three dimensional, consideration must be given to floors above and below the magnet, as well as to the surrounding space on the floor the magnet resides on. The magnetic field exerts attractive forces on equipment and objects in its vicinity. These forces, which increase drastically approaching the magnet, may become strong enough to move large equipment and to cause small objects or equipment to become projectiles.

The magnetic field may affect the operation of electronic medical implants such as pacemakers, if exposed to fields greater than 5 gauss. Medical implants such as aneurysm clips, surgical clips or prostheses may also be attracted. Further care must be taken around changing fields (e.g. pulsed gradient fields). Eddy currents could be generated in the implant resulting in heat generation and/or unwanted torques.

Ensure that all loose ferromagnetic objects are outside the 5 gauss field zone of the magnet before the magnet is ramped to field. Human experience and reaction speed are totally inadequate to cope with the extremely nonlinear forces the magnet exerts on iron objects. Therefore no ferromagnetic objects should be allowed to enter the magnet room after the magnet is energized.

Exclusion Zone 2.2.1

The **Exclusion Zone** is the area inside the magnet's 5 gauss field line, extended in all directions, including rooms above and below the magnet area.

Individuals with cardiac or other medically active implants must be prevented from entering this area. The exclusion zone must be enforced with a combination of warning signs and physical barriers.

Security Zone 2.2.2

The **Security Zone** is usually confined to the room that houses the magnet.

Ferromagnetic objects should not be allowed inside the security zone to prevent them from becoming projectiles.

Standards on Health and Safety in the Workplace 2.2.3

The maximum length of time human beings can be exposed in the stray field of strong magnets is given by country-specific standards on health and safety in the workplace. It is the customer's responsibility to choose and evaluate the right country-specific regulation and to ensure that maximum doses are not exceeded by anyone with access to the system.

We strongly recommend using all the mounting devices supplied to change gradient coils or probes. Furthermore, samples should be exchanged by using the sample supports without entering the extremities inside the magnet's bore. These preventive measures minimize doses of magnetic flux and must be applied as a general rule of thumb.

Example:

In Germany, regulation BGV B11 describes the maximum exposure doses in two basic tables. ***Table 2.1.*** applies to situation under the standard precautionary conditions, whereas ***Table 2.3.*** applies to systems with field strengths above 5 Tesla and can only be applied to certain subgroups of people, which meet nonstandard precautionary conditions. Details on the different precautionary conditions and subgroups of people are given in the document BGV B11 document.

Table 2.1. BGV B11 Standards for Standard Precautions and Users

Exposure	Maximum Magnetic Flux Density
Average over 8 hours	212mT
Peak values for head and body	2T
Peak values for extremities	5T
Standards on health and safety in the workplace for standard precautions and users, according to BGV B11	

Table 2.2. BGV B11 Standards Under Special Conditions for Selected Subgroups

Exposure	Maximum Magnetic Flux Density
Average over 8 hours	4T
Peak values for head and body	***Table 2.1.*** is valid
Peak values for extremities	10T
Health and safety standard in the workplace applicable under special conditions to selected subgroups of people, according to BGV B11	

Table 2.3. shows the maximum retention periods within different stray field regions below 5 Tesla for standard precautionary situations. The corresponding spatial regions within and around the super-conducting magnet can be worked out from the stray-field plots of the magnet being used.

Table 2.3. Example of Maximum Retention Periods

Magnetic Flux	Retention Period	Parts of the Body
5T	< 20 Minutes	Extremities
4T	< 25 Minutes	Extremities
3T	< 34 Minutes	Extremities
2T	< 52 Minutes	Head/Body
1T	< 1 Hour 42 Minutes	Head/Body
0.5T	< 3 Hours 23 Minutes	Head/Body
0.3T	< 5 Hours 39 Minutes	Head/Body
We do not take any responsibility for the numbers given in this table!		

If higher field strength is accessible inside the magnet by a user's extremities, a corresponding table for non-standard situations can be worked out from ***Table 2.3.***. However, the analysis must be carried out in a more detailed and differentiated manner and a greater number of more important conditions must be strictly fulfilled.

Ventilation 2.3

A very large increase in volume accompanies vaporization of the cryogenic liquids into gas. The cryogenic gas to liquid volume ratios are approximately 740:1 for helium; 680:1 for nitrogen. Due to this large increase in volume the vapor may displace the air in an enclosed room If someone is in the room, this may lead to asphyxiation. To prevent this, adequate ventilation of the magnet room must be provided. **All doors to the magnet room should open outwards** to allow safe exit in the event the room becomes pressurized by helium gas during a magnet quench.

Regular Ventilation 2.3.1

Regular HVAC systems should be able to handle 3-5 room air exchanges per hour, and provide temperature stability of +/-0.5°C (+/-1°F). Please refer to ***"HVAC (Heating Ventilation Air Conditioning)" on page 71*** for more details.

Emergency Ventilation 2.3.2

Depending on the actual size of the magnet room, a large amount of He and/or N_2 gas could displace the air in the room. This is possible during the initial cooling of the magnet, during follow-up cryogen fills, or in case of a quench. Therefore, an emergency exhaust system may be required to avoid asphyxiation. Please refer to the section ***"Emergency Gas Exhaust" on page 72***, for more details.

Oxygen Sensors 2.3.3

Oxygen (O_2) sensors are required in the magnet room to detect low levels of O_2 due to cryogenic gases. Please refer to ***"Compressed Gas Options" on page 67*** for more details.

Safe Handling of Cryogenic Substances 2.4

Croygenic liquids are usually stored at their boiling temperature. As a result, a fraction of the liquid constantly evaporates into the gas phase, leading to a pressure build-up inside the storage dewar. A very important characteristic of cryogens is their enormous increase in volume during the conversion from liquid to gaseous phase. This conversion follows a raise in gas temperature starting at the boiling temperatures of the cryogenic liquids and going up towards room temperature. Cryogenic liquids must be handled and stored in **well ventilated areas**. Containers for cryogenic liquids must be constructed with non-magnetic materials and should be specifically designed for use with particular cryogens. Be sure to read and follow any specific instructions provided by the container manufacturer concerning their individual products.

Refill of Liquid Nitrogen 2.4.1

Keep contact with air at a minimum. When liquid nitrogen is exposed to air, it can condense and become as hazardous as liquid oxygen. The **pressure relief valve** for the nitrogen vessel should be mounted at all times, even when the vessel is being refilled.

When the vessel is being refilled, liquid nitrogen should not be allowed to spill onto the room temperature bore closure flanges. Place gum rubber or Teflon tubes on the nitrogen neck tubes during refill. The transfer should be stopped immediately when the vessel is full. Failure to observe this can lead to the freezing of the o-rings and a subsequent vacuum loss of the magnet cryostat.

The liquid cryogen transport dewars used to refill the magnet should be of the low pressure type. Never use high pressure gas-packs.

Refill of Liquid Helium 2.4.2

Avoid contact with air. Air that has been exposed to liquid helium will solidify. Vacuum insulated pipes should be used for transferring liquid helium. The helium vessel should be checked weekly for helium level and overpressure.

A one-way valve is supplied to avoid air or moisture from entering the He vessel. This is to prevent ice from building and plugging the neck tubes. The 0.2 bar valve must be mounted at all times even during a helium transfer.

Important Note: The transfer of liquid helium can be done easily and safely, provided the helium transfer line is in good condition, is handled correctly, and the transfer pressure does not exceed 3.5 psi (0.24 bar). Never connect a warm helium transfer line to the magnet as the warm helium gas could disturb the magnet temperature. Always allow the helium transfer line to cool down to helium temperature before connecting it to the short end inserted into the helium fill port. This short end is cooled down by inserting it - both ends open - into the magnet at the same time, while the long part of the transfer line is cooled from the supply vessel.

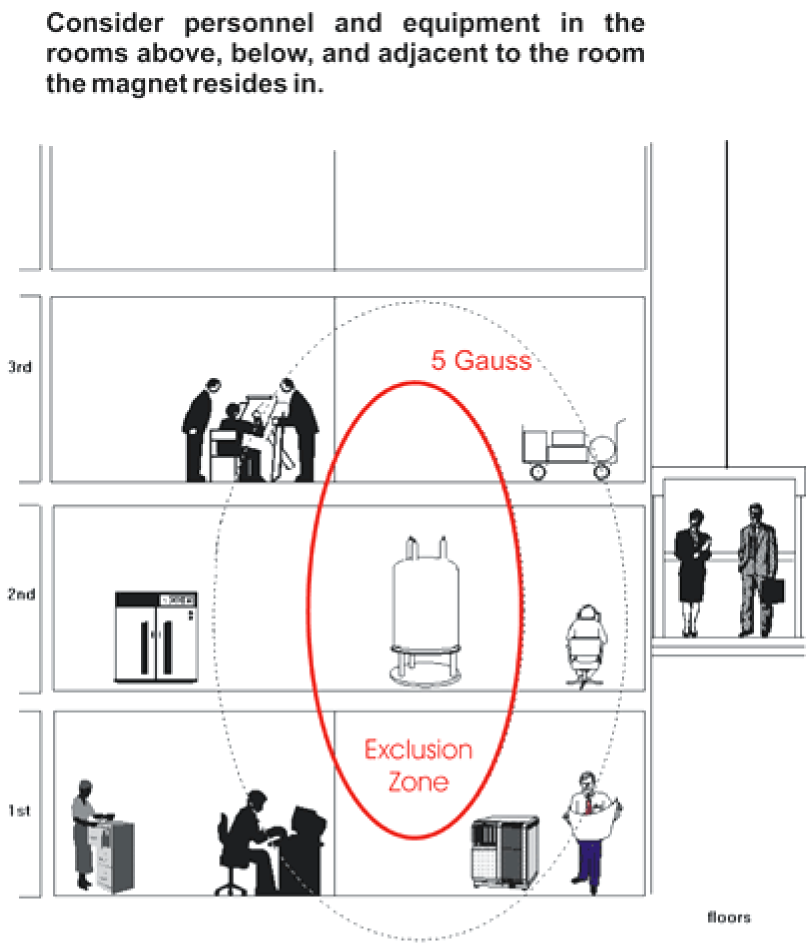

Figure 2.1. Stronger Stray Fields in Vertical Direction than in Horizontal Direction

Earthquake Safety 2.5

In regions where there is a potential risk of earthquakes, additional measures should be taken to reduce the chance of personal or property damage through movement or tipping of the magnet.

Many countries or regions have documented regulations, including building codes, regarding earthquakes. Before installing a magnet system, it is highly advisable that you check with local authorities on whether your area is prone to earthquakes and if there are any regulations in effect.

If your area is regarded as an earthquake area there are several shock absorbing measures or riggings available to reduce the likelihood of damage during an earthquake. Please contact Bruker for more information on earthquake securing equipment.

Country-specific Safety Regulations 2.6

In addition to the above safety precautions, any country-specific safety regulations for operating NMR systems must be fulfilled. These may include, for example, regulations on:

- Facilities of a controlled access area around the magnet
- Working conditions at computer stations
- Use of anesthesia gases
- Handling of laboratory and transgenic animals

Equipment 3

Introduction 3.1

This section describes the types and functions of the various sub-systems that are delivered as part of our AVANCE UltraStabilized NMR systems. These include the following:

- The superconducting magnet system.
- The console, monitoring & control unit.
- The CryoProbe^{TM} system.

Superconducting Magnet Components 3.2

This section describes the basic operation of an NMR superconducting magnet.

Purpose: The superconducting magnet is a complex system producing a very strong, homogeneous, and stable magnetic field, which is required for NMR.

Magnet temperature: The magnet uses both liquid nitrogen and liquid helium. The magnet coil is immersed in liquid helium inside a dedicated helium vessel. Liquid nitrogen fills a different vessel and reduces the helium evaporation rate.

UltraStabilized Magnets: The magnet coil is immersed in a liquid helium bath at a sub-cooled temperature (~2 K). An additional liquid helium bath operating at a standard temperature of 4.2 K is located above the sub-cooled helium section.

Magnet current: After the initial charging with electrical current, the magnet runs in persistent mode. The current runs in a closed loop inside the system and the magnet itself is no longer connected to a continuous power supply.

Pump-line: The sub-cooled systems are equipped with a special pump line in order to reduce the liquid helium temperature from 4.2 K to ~2 K. The pump line connects one port of the magnet to a set of pumps. Pumping is done on a Joule-Thompson Cooling Unit located inside the cryostat in order to reduce the temperature of the liquid helium (by using this method the large volumes of liquid and gaseous helium in both temperature zones can be kept slightly above atmospheric pressure).

Maintenance: The magnet maintenance consists of refilling the system with cryogenic fluids at defined time intervals (refer to ***"Refill Time Intervals for UltraStabilized Magnets" on page 18***).

Table 3.1. Refill Time Intervals for UltraStabilized Magnets

	750WB	800	800 US Plus	800 US^2, 850 US^2, 850WB US^2, 900, 900US^2, 950US^2
LN_2: Refill Volume Hold Time	 230 liters 10 days	 230 liters 13 days	 170 liters 14 days	 400 liters 21 days
LHe: Refill Volume Hold Time	 240 liters 45 days	 245 liters 56 days	 190 liters 56 days	 350 liters 60 days

Console, Monitoring & Control Unit 3.3

Table 3.2. lists the various parts of the console, monitoring & control units. Please also refer to the floor plan diagrams beginning on ***"Floor Plan" on page 43***. These scaled diagrams provide an idea of where the various pieces of NMR equipment should be placed.

Table 3.2. Spectrometer and Magnet Controls

Name	Function	Picture
AVANCE console main cabinet	• Performs the actual NMR data acquisition.	
Bruker Magnet Pump Control (BMPC II)	• Monitors the magnet status and cryogenic parameters. • Includes the pumps that drive the Joule-Thompson cooling unit in order to maintain the temperature of ~2K. • Interfaces between the magnet, pump system, and user.	
Uninterruptable Power Supply (UPS)	• Feeds the BMPC and provides continuous power in case of power failure. • Acts as a power conditioner. • **It is recommended to have the UPS on emergency power**.	

Table 3.2. Spectrometer and Magnet Controls

Name	Function	Picture
Workstation	• Acts as operational computer for the user. • Processes NMR data. • Sends/receives data to/from the acquisition computer in the main console.	
BCU-05 cooling unit	• Cools VT gas to allow proper sample temperature regulation. • Reduces the temperature of the air input (supplied by the variable-temperature unit) and provides cooling of the NMR sample within the magnet to at least -5 °C for a room temperature of 25 °C.	
Imaging accessory cabinet option	• Houses the gradient amplifiers for micro-imaging applications.	

CryoProbe System (Optional) 3.4

The Bruker CryoProbe™ Accessory for the AVANCE NMR Spectrometers offers dramatic increases in signal to noise ratio, stability, and ease of use. For site planning details for the CryoProbe Accessory, refer to the “CryoProbe™ Purchase and Siting Guide”.

The CryoProbe system consists of the following components:

Table 3.3. CryoProbe System

Item	Description and Function	Picture
CryoProbe™	• Represents the NMR probe inside the magnet bore. • Is cooled by cryogenic helium gas • Maximizes efficiency and reduces thermal noise, thus enhancing the signal-to-noise ratio.	
CryoCooling Unit	• Contains a cryocooler, a cryocontroller, a vacuum system, and He transfer lines. • Cools compressed helium gas by expansion. • Provides and maintains the vacuum insulation. • Supervises all CryoProbe operations.	
Buck Boost Transformer	• 1kVA transformer steps up the 208V voltage to 230V for the CryoCooling unit.	

Table 3.3. CryoProbe System

Item	Description and Function	Picture
He compressor	• Provides compressed helium gas to the CryoCooling unit. • Connects to the CryoCooling unit by means of helium gas pressure lines. • The indoor water-cooled He compressor is shown to the right. Other models, including indoor air-cooled and outdoor air-cooled, are available.	
Research Grade He gas cylinder	• Provides research grade helium gas (99.9999%) at high pressure (min. 300 psi or 20 bar) for flushing the probe prior to a cool-down cycle. • Includes a regulator, an outlet valve, and a charging hose.	
Transfer line supports	• Provides support for the probe • Isolates probe against vibrations.	

Magnet Access and Rigging

4

Introduction 4.1

Important Note: As the magnet is very heavy and fragile, the majority of this chapter focuses on movement of the magnet. The remaining crates (spectrometer, BMPC, etc..) are typically removed from the trucks with forklifts and are positioned in the NMR lab with a pallet jack.

On the morning of delivery, the magnet, the electronics, all accessories, and the required rigging equipment will arrive on 2-3 flatbed trucks. A crane will also arrive on site that morning.

The crane will unload the forklifts and pallet jacks. The forklifts will be used to unload the equipment crates, and the pallet jacks will be used to transport the equipment crates into the NMR building. (The equipment may be uncrated outside if doorway space is limited.)

The crane will be used to pick the magnet from the flatbed truck and place it on a level surface to be uncrated. Most of the time, the uncrated magnet is lifted, and placed on special **air-skates** on a slab or dock in front of the access doors/opening to the NMR building. Then, the magnet will be air-skated into place in the NMR lab. This process depends on the particularities of the loading dock, the NMR building, and the pathway to the lab. Sometimes, the magnet can be lifted by the crane directly into the NMR building through a hatch. ***Figure 4.1.*** shows this process.

Once the magnet is in place in the NMR room, a **gantry** will be erected over the magnet, in order to lift it for assembly. When the assembly is complete, the magnet will be lowered onto its legs.

The remainder of this chapter describes, in detail, how each of these steps are completed.

Figure 4.1. Unloading the Magnet

Off-loading on Site *4.2*

When planning to offload the magnet on site, the following must be considered:

- An overhead crane is required to unload the magnet off the truck and position it correctly for access into the building. The size of the crane will depend on the magnet transport weight (***Table 4.2.***) and size (***Table 4.1.***), as well as the distance of reach (horizontal and vertical) to the access point into the building (e.g. access door, airway, etc.). This detail is usually attended to by the rigging firm.
- Where will the crane and delivery vehicles park?
- Where will the magnet be uncrated?
- The entry way of the NMR building must be large enough to accommodate the magnet with any rigging equipment necessary. Please refer to ***Table 4.1.*** for minimum doorway dimensions.
- What is the load-bearing capacity of the entry-way? The loading dock or entrance into the building must be able to handle the load safely. Please refer to ***Table 4.2.*** for magnet transport weights.

Access to the NMR Room 4.3

Before delivery the customer must ensure that the system and magnet can be transported to the site. ***Table 4.1. on page 25*** gives the sizes of the crates in which the magnets are shipped. The following must be considered:

- The access clearance (height x width) and floor loading capacity must be checked along the entire route that the magnet will take from the access point into the building to the NMR room. Refer to ***Table 4.1.*** for minimum door sizes. Refer to ***Table 4.2.*** for magnet system transport weights.
- Special air-skates are often used to transport the magnet from the access point into the building to the final magnet location inside the NMR room. A large air compressor is required to operate these skates. Refer to the section ***"Rigging Equipment" on page 27***.
- Transport will also be affected by any floor irregularities and the presence of door jams and steps. Use masonite sheets with air skates to traverse floor irregularities such as cracks and door seals.
- Elevator capacity and dimensions must also be considered if the magnet must make an elevation change within the building.

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Table 4.1. Door Dimensions for Magnet Access

	Crate Size (m)			Minimum Door Dimensions (m)		
System	**L**	**W**	**H**	**Width Uncrated**	**Height Uncrated***	**Height if Crane is Used****
750 WB, 800	2.00	1.80	3.00	1.40	2.90	4.4
800 US Plus	2.00	1.80	2.50	1.40	2.50	3.9
800 US^2, 850 US^2, 850 WB US^2, 900, 900 US^2, 950 US^2	2.40	2.20	3.00	1.80	3.00	4.6

WB = Wide Bore (89 mm),
US^2 = UltraShield-UltraStabilized
* Including air skates (cushions) required to move the magnet.
** These numbers are approximate; the true number will depend on the distance between the boom of the crane and the bottom of the magnet.

Magnet Transport Weights 4.4

The transport weights for each magnet are listed below. For the weights of the rest of NMR equipment, please refer to ***"Dimensions and Weights of NMR Equipment" on page 43***.

Table 4.2. Magnet Transport Weights

Magnet Type	Approx. Transportation weights - crated (kg/lbs.)
750 WB	4,350 / 9,600
800	4,000 / 8,800
800 US Plus	4,000 / 8,800
800 US^2	6,800 / 15,000
850 US^2	6,900 / 15,200
850 WB US^2	8,200 / 18,100
900	6,800 / 15,000
900 US^2	8,200 / 18,100
950 US^2	8,200 / 18,100

Rigging Equipment 4.5

All rigging equipment must be selected to handle the size (***Table 4.1.***) and transport weights (***Table 4.2.***) of the magnet system. For Ultra High Field magnet systems, a crane is required to remove the magnet from the truck and place it on the the dock or slab in front of the access doors to the building. Air skates should be used during transport over floors and through passage ways whenever possible. For lifting during installation, hydraulic lifts are preferred.

Rigging equipment is not included with the NMR system order. The following rigging equipment will be needed for a typical delivery and installation of an UltraStabilized magnet system:

- **Crane:** A crane able to handle magnet load is required to:

  - lift the magnet off the truck,

  - place it on a flat surface for uncrating, and

  - lift it again and place it on air-skates in front of the access doors

  - or to place the magnet inside the building (e.g. roof hatch).

- **Air-Skates:** A set of four air-skates is required to transport the magnet from the access doors. The air-skates require an air-compressor capable of supplying up to ca. **1.72 bar (25 psi) at ca. 2 cu. meter/minute**.
- **Leveling Sheets:** Masonite (or other suitable material) sheets may be temporarily required to level the transport route from the access doors to the NMR room, in case of small imperfections.
- **Pallet Jack and/or Fork Lift**: For transporting system accessories to the NMR room.
- **Lifting Hook or Hydraulic Lifting System:** Lifting the magnet inside the NMR room for assembly purposes requires either a fixed lifting hook or a hydraulic lifting system capable of handling the magnet load within the given ceiling height requirements (please refer to ***"Minimum Ceiling Height Requirements and Lifting Weights" on page 30***).

Figure 4.2. Unloading the Magnet Crate and Positioning for Uncrating

Figure 4.3. Lifting the Magnet and Placing it on Air Skates in Front of the Access Doors

Figure 4.4. Air Skates

Figure 4.5. Magnet Positioned on Air Skates

Ceiling Height Requirements 5

Introduction 5.1

The assembly of the magnet system, the magnet energization, and refills with liquid helium require minimum height clearances as specified in ***Table 5.1. on page 30***.

- The ceiling height requirements do not need to be met over the entire NMR room. ***Figure 5.2.*** illustrates that the height requirements need only be met immediately above the magnet, over an area to allow for assembly of the gantry (if applicable), and over an area to allow for insertion of the helium transfer line.
- If a soffit is to be used, it is important to consider ceiling height for magnet assembly. If a hydraulic gantry is used to assemble the magnet, the horizontal beam must fit within the confines of the soffit.
- An alternate hydraulic lift system supporting the magnet at the flanges may be used in rooms with limited ceiling height.
- In lieu of a gantry, or a fixed lifting hook capable of supporting the magnet at a sufficient height can be used to assemble the magnet. However, this option is usually not ideal. See notes below.

***FIXED HOOK:* It is important to consider how the hoist system and harness will be removed from a fixed lifting hook after the magnet is installed. Removing the heavy hoist directly over the magnet can be very difficult and dangerous for both the safety of personnel and the magnet.**

Due to the additional hand chain hoist required, the minimum ceiling height to lift the magnet with a fixed lifting hook is typically greater than when using a hydraulic lifting system.

Ceiling Height Requirements

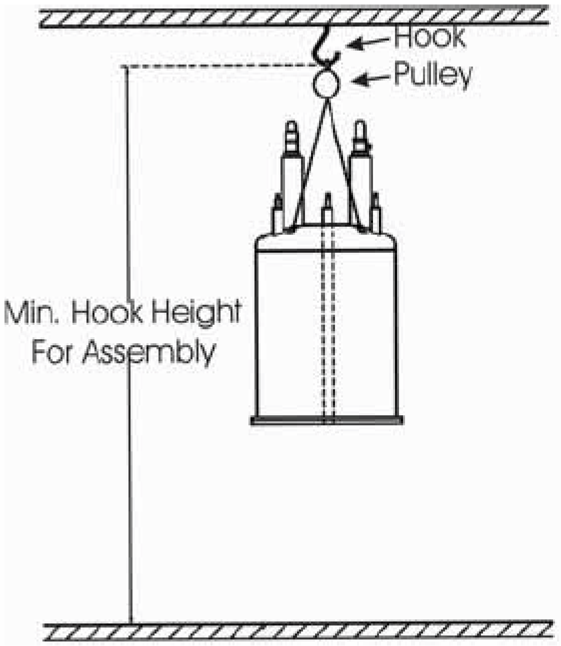


Figure 5.1. Minimum Hook Height for Assembly

Table 5.1. Minimum Ceiling Height Requirements and Lifting Weights

	Minimum Ceiling Height			
Magnet Type	**For Magnet (m)**	**For He Transport Dewar (m)**	**Minimum Hook Height (m)**	**Total Lifting Weight (kg)***
750 WB	4.95	3.6	4.25	3600
800	4.88	3.6	4.25	3400
800 US Plus	3.66	3.6	3.10	3400**
800 US^2	5.3	3.6	4.75	5300
850 US^2	5.3	3.6	4.75	5300
850 WB US^2	5.3	3.6	4.75	6600
900	5.3	3.6	4.75	5500
900 US^2	5.3	3.6	4.75	6600
950 US^2	5.3	3.6	4.75	6600
WB = Wide Bore (89 mm); US^2 = UltraShield-UltraStabilized * Lifting weight uncrated without stand. ** For 800 US Plus - lifting weight uncrated with stand.				

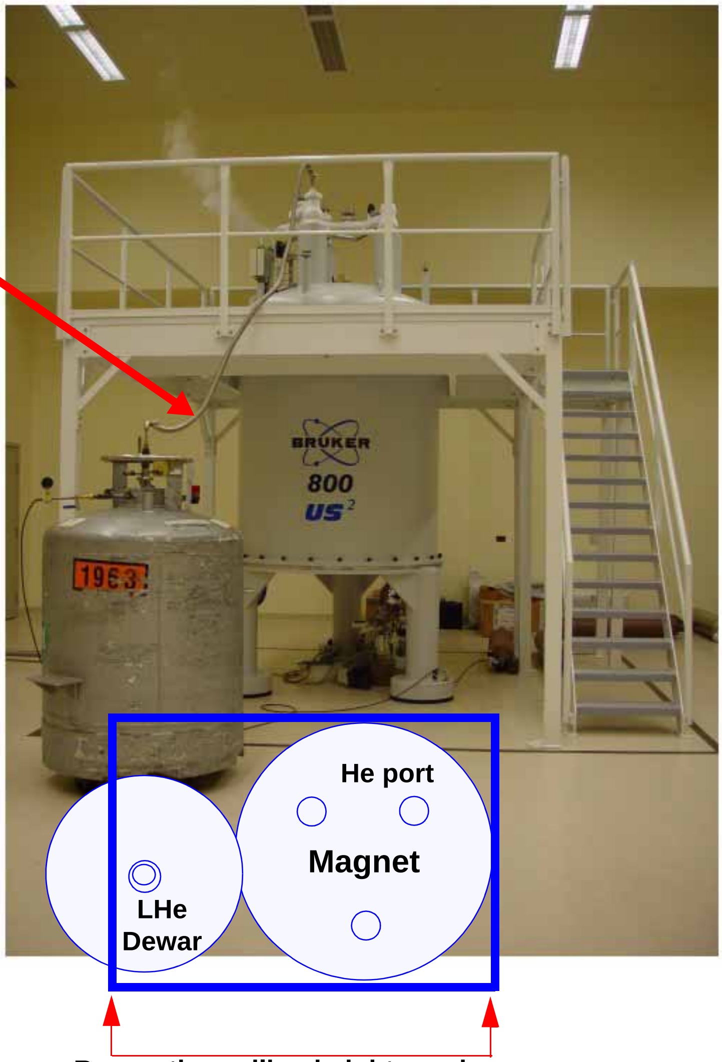


Figure 5.2. Helium Transfer Line Insertion

Magnetic Stray Fields 6

Introduction 6.1

Magnetic stray fields are three dimensional, and they extend further in the vertical direction than in the horizontal direction. ***Table 6.1.*** displays the horizontal stray fields in the radial, direction, while ***Table 6.2.*** displays the vertical stray field in the axial direction.

Table 6.1. Horizontal Stray Fields (distances are measured in radial directions from magnet center)

Magnet type	50 G	10 G	5 G	2 G	1 G	0.5 G
750 WB	2.9	4.9	6.2	8.4	10.6	13.4
800	2.8	4.8	6.1	8.2	10.3	13.0
800 US Plus	1.0	1.35	1.5	2.0	2.5	3.3
800 US^2	1.45	1.9	2.2	2.95	3.8	4.95
850 US^2	1.3	1.8	2.2	2.8	3.7	4.6
850 WB US^2	2.0	2.7	3.3	4.6	6.0	7.7
900	3.7	6.3	7.8	10.7	13.4	17.0
900 US^2	2.0	2.7	3.3	4.6	6.0	7.7
950 US^2	2.0	2.7	3.3	4.6	6.0	7.7
WB= Wide Bore (89 mm); US^2= UltraShield-UltraStabilized						

All measurements in table 6.1 and 6.2 are in meters!

Table 6.2. Vertical Stray Fields (distances are measured in axial directions from magnet center)

Magnet Type	Distance from Floor to Magnet Center	50 G	10 G	5 G	2 G	1 G	0.5 G
750 WB	1.5	3.65	6.2	7.8	10.6	13.4	16.8
800	1.5	3.55	6.1	7.6	10.3	13.0	16.4
800 US Plus	1.2	1.5	2.2	2.5	3.2	3.9	4.8
800 US^2	1.6	1.95	2.85	3.4	4.35	5.25	6.45
850 US^2	1.6	2.0	2.9	3.4	4.5	5.5	6.7

Table 6.2. Vertical Stray Fields (distances are measured in axial directions from magnet center)

Magnet Type	Distance from Floor to Magnet Center	50 G	10 G	5 G	2 G	1 G	0.5 G
850 WB US^2	1.6	2.6	3.9	4.6	6.0	7.3	9.0
900	1.6	4.8	7.8	9.8	13.5	16.9	21.5
900 US^2	1.6	2.6	3.9	4.6	6.0	7.3	9.0
950 US^2	1.6	2.6	3.9	4.6	6.0	7.3	9.0
WB= Wide Bore (89 mm); US^2= UltraShield-UltraStabilized							

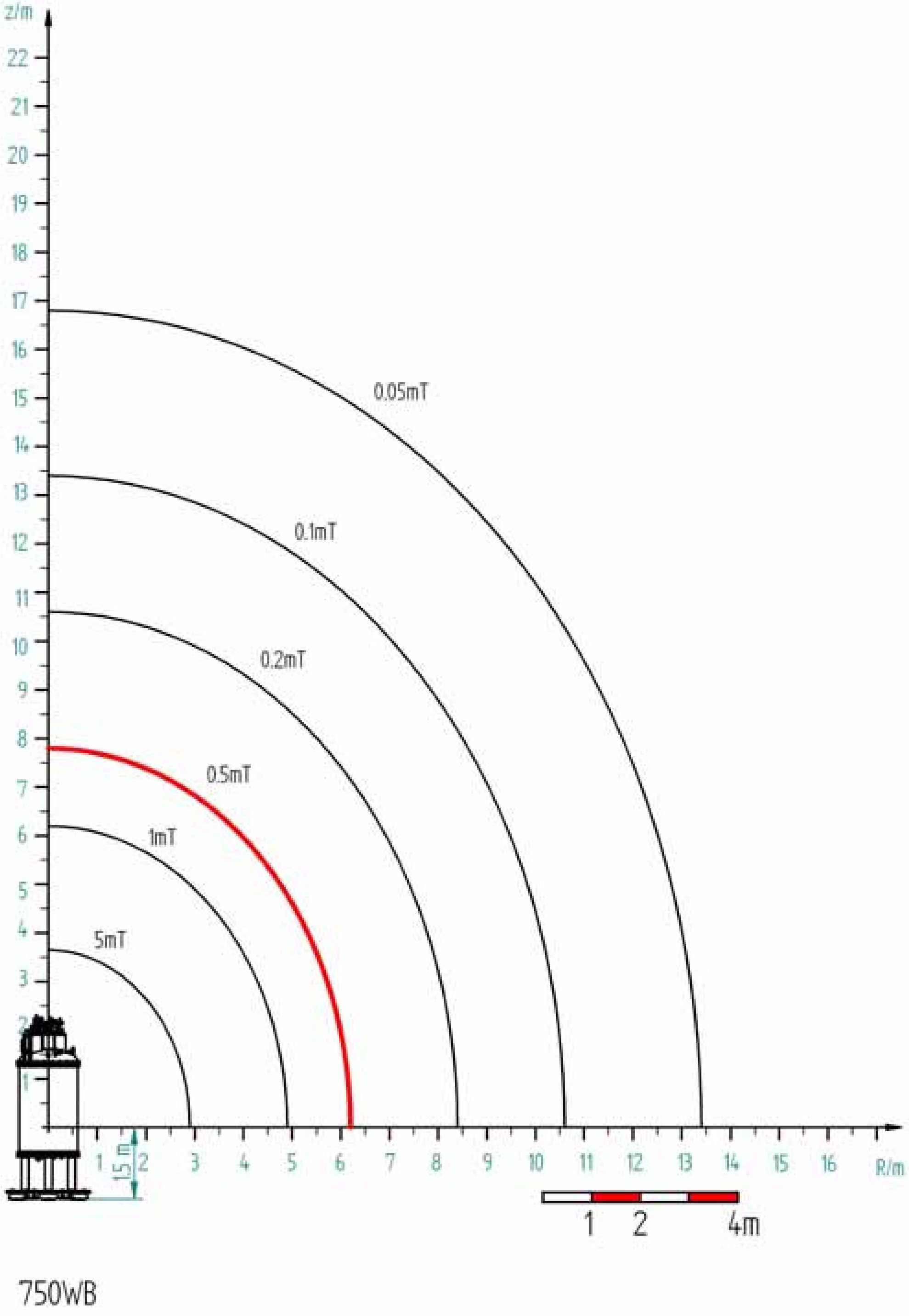


Figure 6.1. Magnetic Stray Field Plot 750 WB

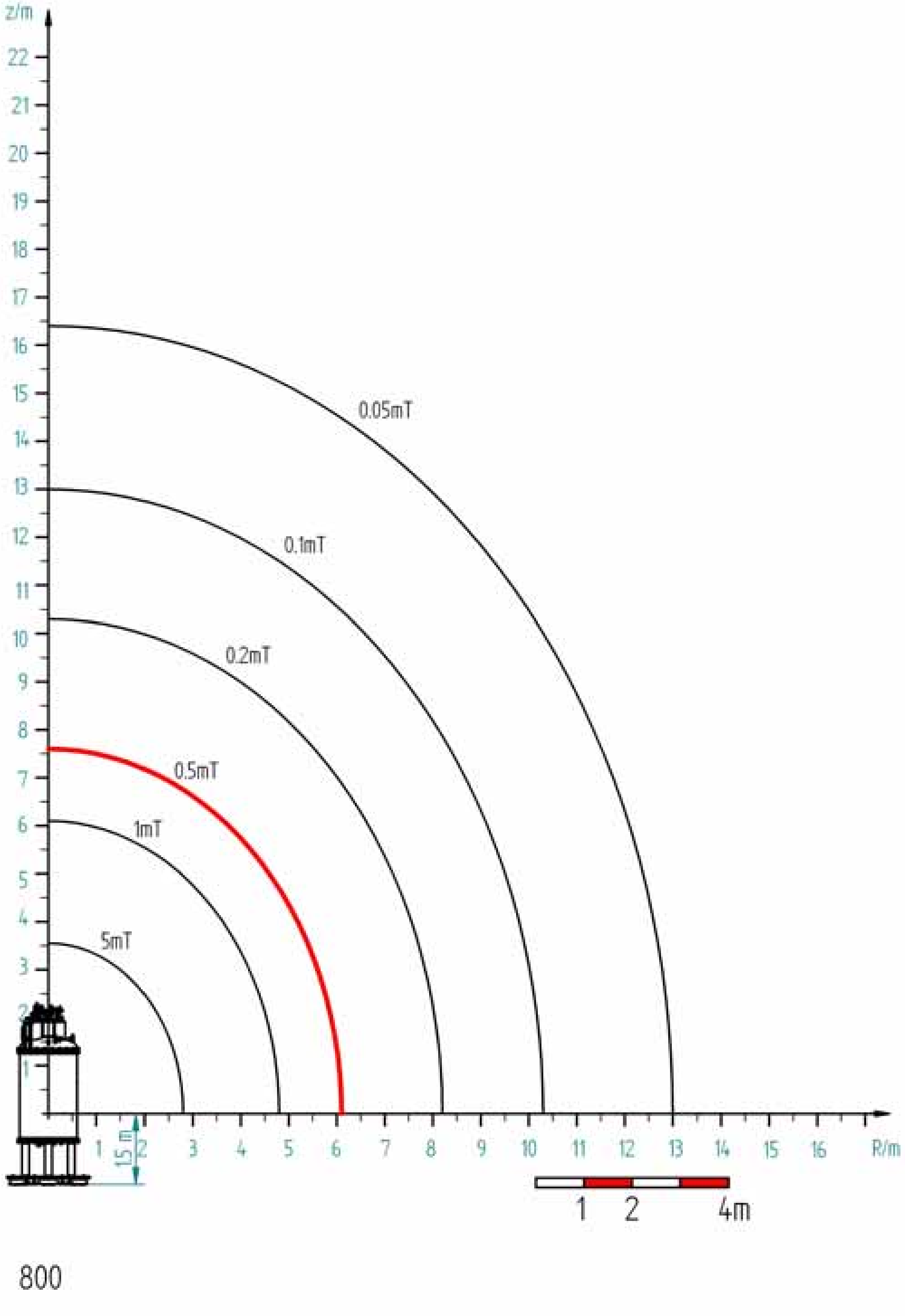


Figure 6.2. Magnetic Stray Field Plot 800

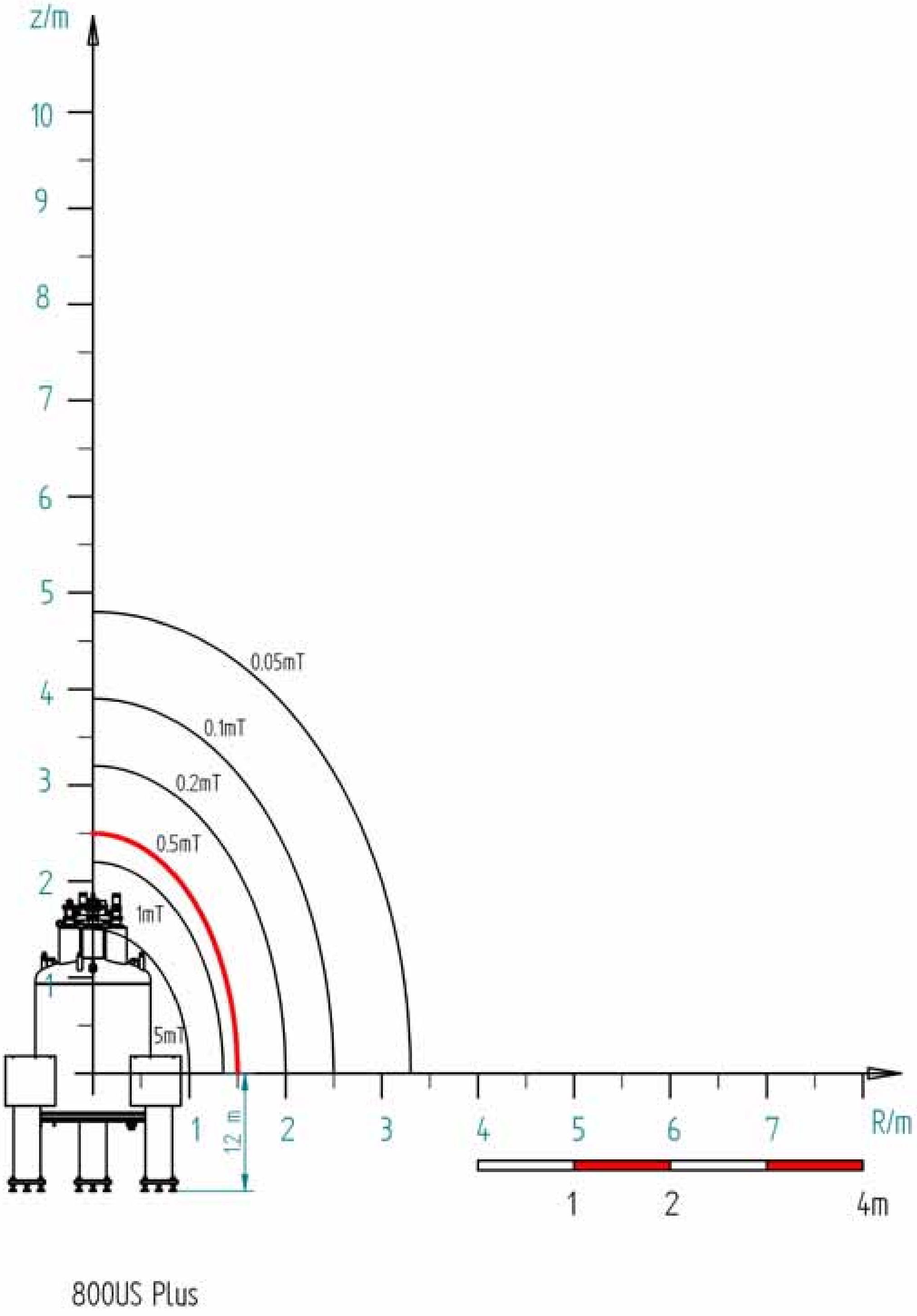


Figure 6.3. Magnetic Stray Field Plot 800 US Plus

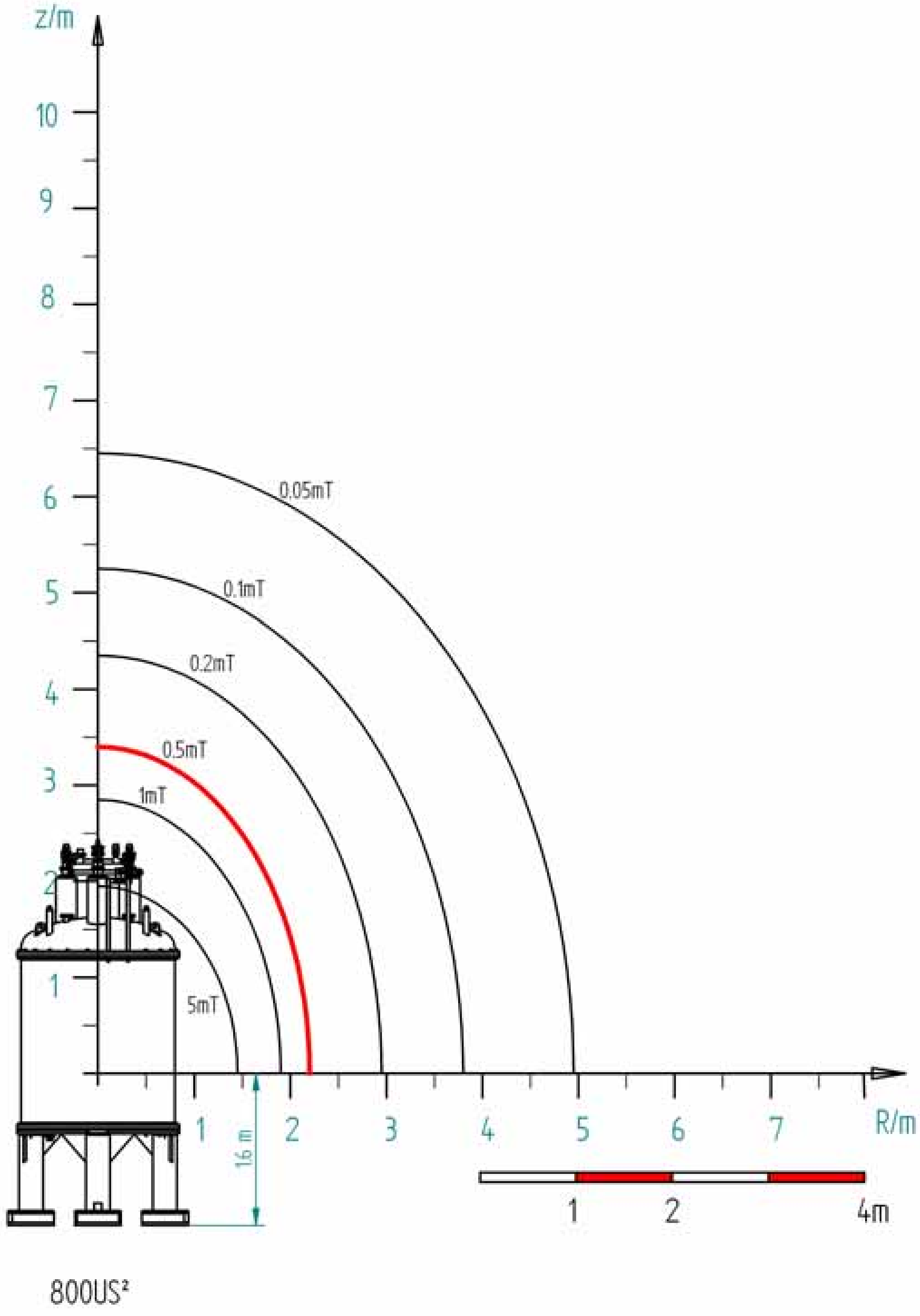


Figure 6.4. Magnetic Stray Field Plot 800 US2

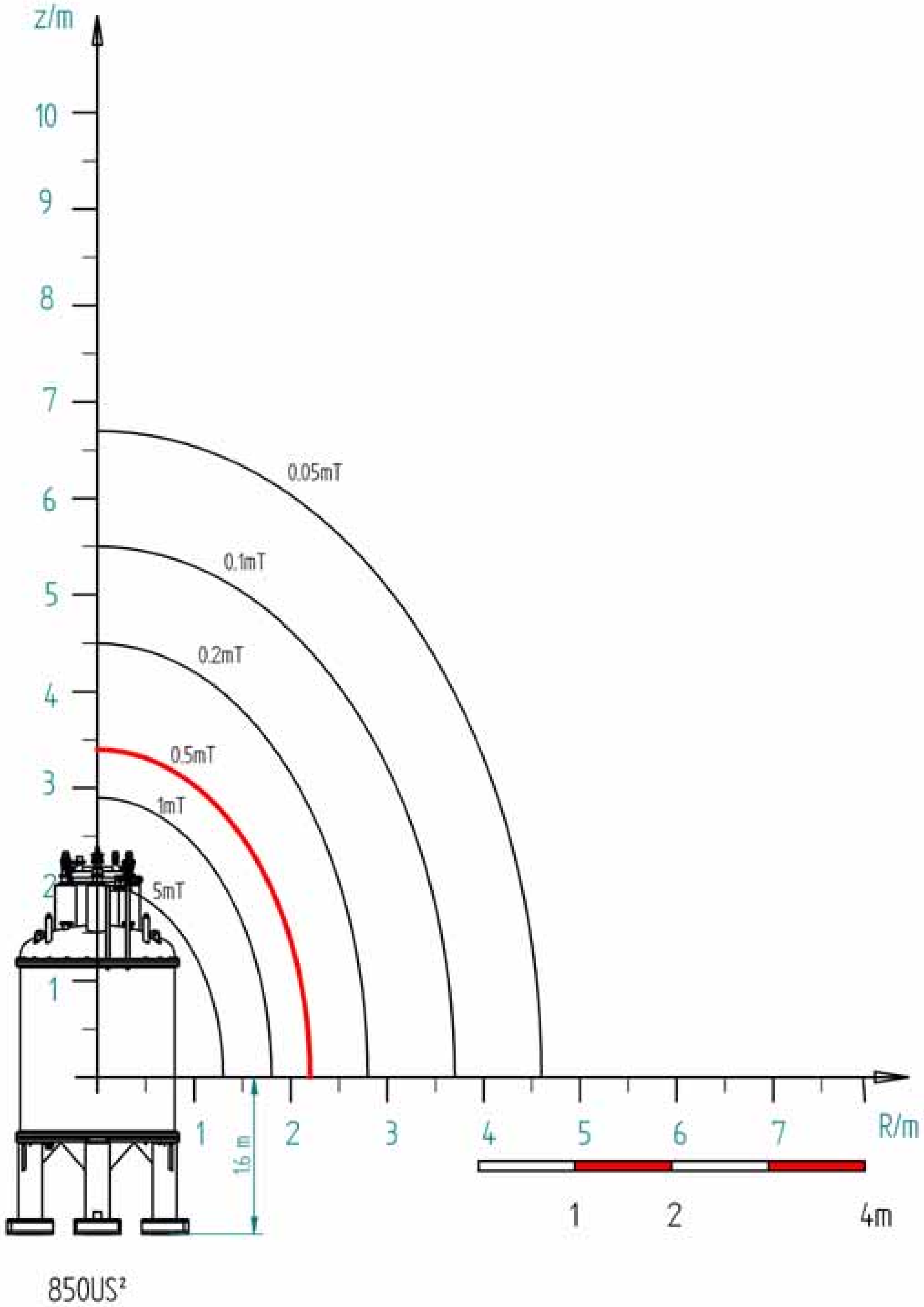


Figure 6.5. Magnetic Stray Field Plot 850 US2

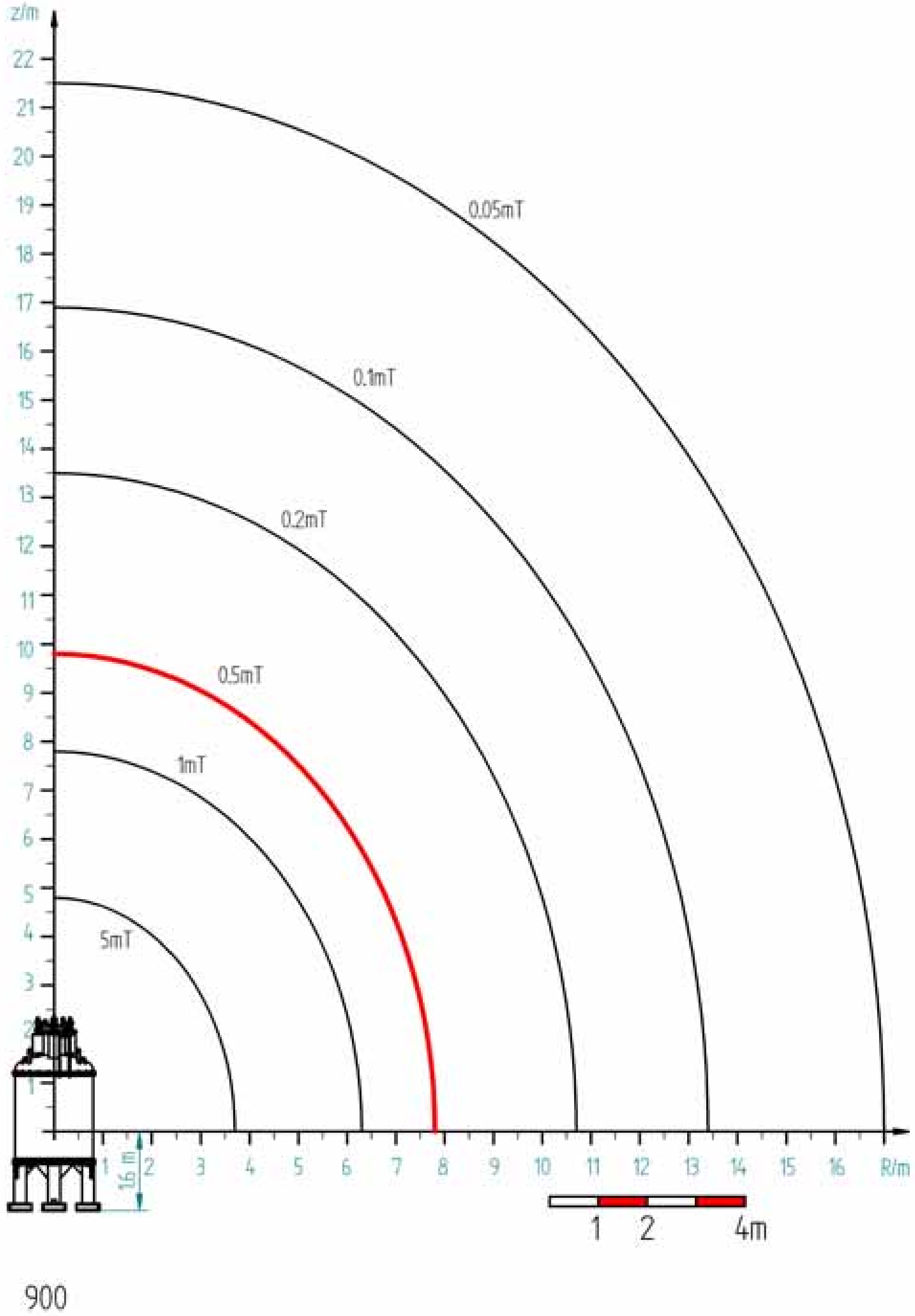


Figure 6.6. Magnetic Stray Field Plot 900

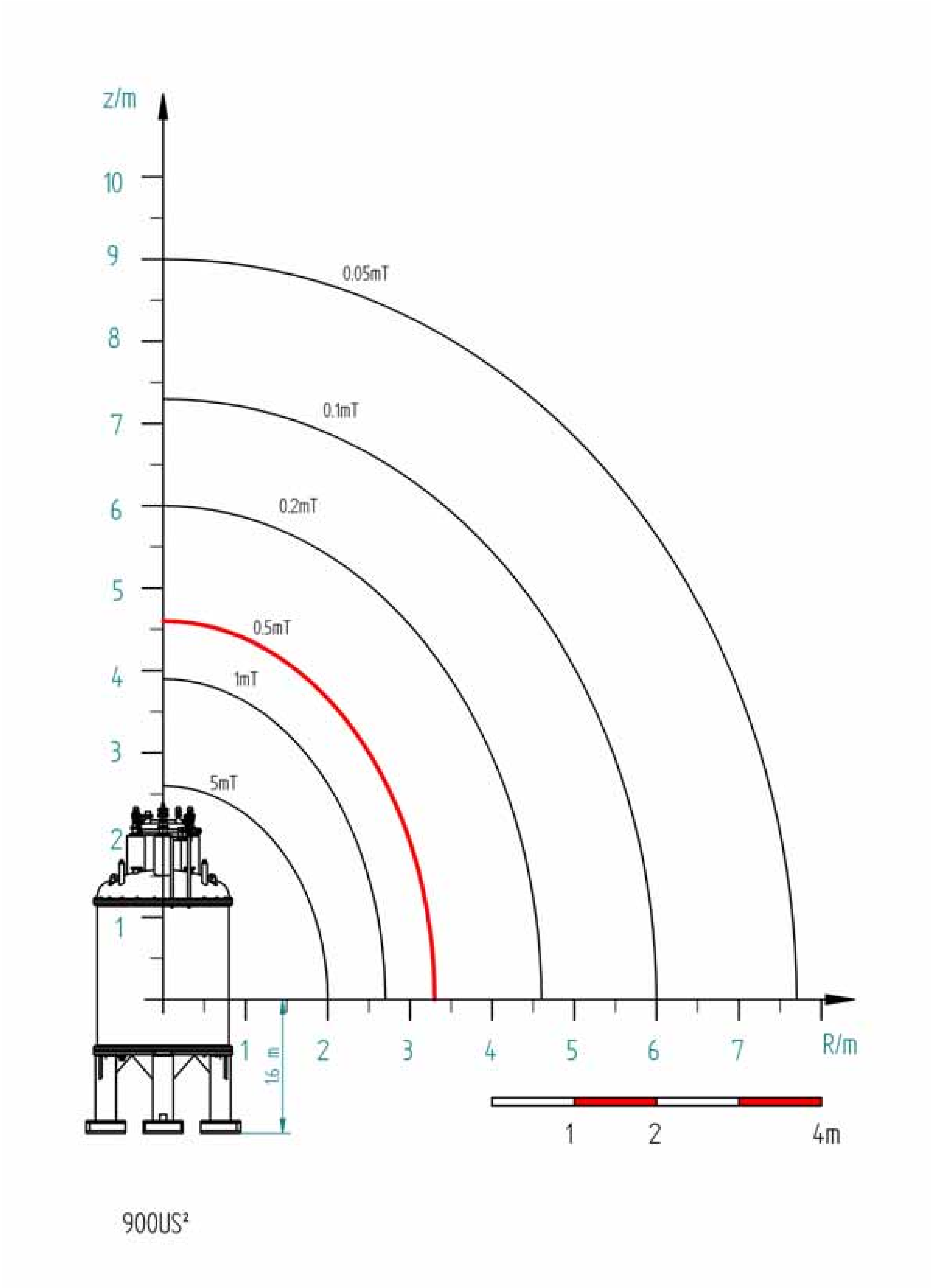


Figure 6.7.   Magnetic Stray Field Plot 850WB US2, 900 US2, 950 US2

Floor Plan 7

Size and Mass of Equipment 7.1

The floor of the NMR room must be sufficiently strong to support the console, magnet, and ancillary equipment. ***Table 7.1.*** gives the dimensions and weights of NMR equipment. ***Table 7.2.*** gives the footprint and weight of magnets (filled with cryogens and including stand). The floor should also be as rigid as possible to reduce the effect of vibrations.

Table 7.1. Dimensions and Weights of NMR Equipment

Component	Width (m)	Depth (m)	Height (m)	Weight (kg)
AVANCE Cabinet	1.31	0.83	1.55	454
Table / Workstation	1.20	1.00	0.75	68
Microimaging Cabinets	0.69	0.83	1.55	205 / 150
BMPC II	0.85	0.70	1.70	254
UPS - Main Unit - Battery Pack	0.32 0.34	0.69 0.62	0.72 0.79	165 216
B-CU 05	0.50	0.55	0.48	50
For CryoProbe Option:				
CryoCooling Unit	0.69	0.89	0.96	400
Helium Compressor Indoor Water Cooled	0.46	0.51	0.69	118
Helium Compressor Outdoor Air Cooled Indoor part Outdoor part	0.31 0.92	0.61 0.41	0.31 1.05	115 46
Helium Compressor Indoor Air Cooled	0.56	0.56	0.89	141

The values in the following table correspond to ***Figure 7.1.***.

Table 7.2. Mass of UltraStabilized Magnets

Magnets	A Maximum Magnet Diameter (m)	B Magnet Height from the Floor Including Stand (m)	C Overall Footprint Diameter (m)	Total Magnet Weight Incl. Stand and Cryogens (kg)
750 WB	1.295	3.641	1.818	4,400
800	1.295	3.641	1.818	4,200
800 US Plus	1.280	3.084	1.965	3,500
800 US^2	1.688	3.865	2.10	5,900
850 US^2	1.688	3.865	2.10	6,000
850 WB US^2	1.688	3.865	2.10	7,300
900	1.688	3.865	2.10	6,000
900 US^2	1.688	3.865	2.10	7,300
950 US^2	1.688	3.865	2.10	7,300
US^2= UltraShield-UltraStabilized; WB= Wide Bore (89 mm)				

Refer to *Table 7.2.* for the values of A, B, and C for each magnet.

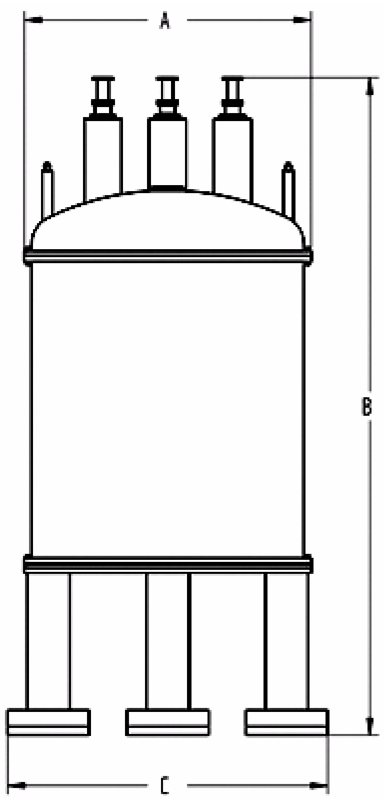


Figure 7.1. Magnet Dimensions

Magnet Location 7.2

When locating the magnet, certain considerations must be made with regards to the laboratory environment:

- To increase magnet homogeneity, the magnet should be located away from permanent iron structures such as support beams in walls and floors. Reference ***"Magnetic Environment" on page 59***
- To increase temperature stability, the magnet should not be placed in direct sunlight or near any artificial heat source. The magnet should also not be placed under or in close proximity to air-vents or in an area that experiences air drafts. Air should not be blown directly down or towards the NMR magnet.
- When possible, avoid a situation where a significant stray field (>5 G) extends into adjacent rooms.
- There should be free access to the magnet from all sides.

It is important to determine the optimal position in the NMR room, based on the following orientation elements:

- **The front of the manifold**: The front of the He manifold is defined by a U-shaped opening. The manifold connects the three He turrets at the top of the magnet.
- **The He fill port**: The left turret (when looking at the front of the magnet) is the helium fill port. It is necessary to provide a path to either the left side or the front of the magnet so liquid helium transport dewars can be rolled in place.
- **Magnet pump line**: The magnet pump line connects to the back of the manifold (see ***Figure 7.2.***).
- **The front of the stand**: The magnet stand also has a front side. The CryoProbe™ transfer lines coming from the "Cryo" unit connect to the probe on the front side of the magnet stand. The shim cable comes out through the back side, 180 degrees apart from the CryoProbe transfer lines.

NOTE: The front of the magnet stand does not necessarily have to match the front of the manifold.

Figure 7.2. UltraStabilized Magnet Orientation

Magnet Slab 7.3

In larger buildings, it is strongly recommended to design an isolated magnet slab that separates (isolates) the magnet from the rest of the floor and building. This reduces vibrations that are transmitted to the magnet from the building (electromechanical equipment, HVAC, personnel, etc.). The slab must be large and strong enough to safely support the load of the magnet.

It is important to achieve a full isolation of the slab on the sides as well as underneath it in order to reduce both vertical and horizontal vibrations.

It is recommended to build first a thinner slab of ~15cm (6") on grade with a layer of sand underneath this slab. The main thick slab for the magnet would be added on top of the thinner slab, and could be isolated from it with a pattern of small pads made of special rubber isolation material. The main slab could be finished on top with silicon filler. The separation gap on the sides can be filled with neoprene or foam type material

The recommended dimensions are as follows:

750 WB, 800, and 800 US Plus:

Length = 3.6 m (12')
Width = 3.6 m (12')
Depth = 0.3 m (1')

800 US^2, 850 US^2, 850WB, 900, 900US^2, and 950US^2:

Length = 3.6 m (12')
Width = 3.6 m (12')
Depth = 0.6 m (1 1/2')

NOTE: These dimensions are guidelines, not specifications, and remain subject to approval by the project's structural engineer.

Reinforcement: The slab must be reinforced with non-magnetic reinforcement (e.g. fiberglass, or non-magnetic stainless steel).

An isolated slab may not be necessary if the structure contains no sources of vibrations, or if the foundation is on bedrock. In this case, it is still recommended to perform a vibration analysis. Please consult with Bruker BioSpin regarding the magnet slab and to arrange for analysis.

Please refer to ***"Vibrations" on page 57*** for more information on vibration isolation and site analysis.

Magnet Platform *7.4*

The purpose of a platform is provide safe access to the top of the magnet for sample insertion, cryogen fills, etc. The basic design requirements for the platform include, but are not limited to the following:

- **Material**: It must be non-magnetic. Wood and aluminum are used most often.
- **Height of platform deck**: The top of the deck must be located approx. at 2.44m (8') above the finished floor. The 800 US Plus does not require a platform given its compact size. An aluminum rolling ladder is sufficient.
- **Railing:** The height of the railing will be determined by local building codes. However, if the ceiling height is low it may be necessary to make a section of the railing removable. When the gantry is used to pick the magnet off the air skates, the cross-bar must not crush the railings.
- **Footprint:** The total footprint of the platform should be large enough to accommodate a person, but small enough that the helium transfer line will reach across the footprint without trouble. A footprint of 4m x 4m without taking into account the stairs is generally adequate.
- **Opening diameter**: The circular opening must be centered with the magnet and have the following diameters:
  - 750 WB and 800: 1.32m (52") diameter
  - 800 US^2, 850 US^2, 850 WB, 900, 900 US^2, and 950 US^2: 1.71m (67") diameter

    This will leave ca. 5 cm (2") clearance around the magnet cryostat, not the flanges. The diameter of the flanges is larger (please refer to the maximum magnet diameter identified with „A“ in ***Figure 7.1.*** and corresponding ***Table 7.2.***.
- **Border around the opening by the magnet and the outer platform rim**: Borders, or lips, are recommended to prevent anything from falling off the magnet platform.
- **Support posts**: Given the larger magnet diameter at the flanges relative to the opening in the platform, care should be used when designing the support post to prevent obstructons. It is recommended to have the support posts away from the magnet and closer to the outside perimeter of the platform to provide optimal access to the bottom of the magnet and allow sufficient clearances for accessories.
- **Stairs**: The access stairs shall be positioned to allow easy access to the front of the upper manifold. This facilitates sample insertion.
- **Magnet assembly time**: As stated in ***"Rigging Equipment" on page 27***, the magnet will be slid into place, and then a hydraulic gantry will be used to assemble the magnet. For this reason, it is recommended to construct the platform in two parts. The first piece can be installed before the magnet is delivered. The second piece should be installed shortly after the magnet has been assembled. Please refer to ***"Magnet Installation Stages" on page 77*** for the stages of installation.

Sample Changer Considerations *7.5*

A B-ACS (Bruker Automatic Control System) has been developed for the Ultra High Field magnet systems. This sample changer holds up to 60 NMR sample tubes and can be used the in conjunction with any of the ultra high field magnets.

This B-ACS utilizes a new kind of mechanical mounting equipment to attach the sample changer to the magnet. This allows for easy B-ACS adjustment in X, Y, and Z directions.

The mounting hardware descends along the Z-axis, down the front of the magnet. This may cause a slight interference with the decking of the magnet platform. This could be solved by either lowering the height of the deck or implementing an additional opening in the deck.

Magnet Pump Line *7.6*

This section briefly describes the purpose, fabrication, and route of the pump line.

- **Purpose**: The pump line connects the pump to the Joule Thompson cooling unit located inside the helium dewar of the magnet system.
- **Fabrication**: It is custom-made out of stainless steel to fit site requirements.
- **Route**: The pump line connects the rear side of the helium manifold to the BMPC II cabinet. Most of the time it runs across the floor, although sometimes it is partially elevated:

  - Keeping the pump line at floor level is the preferred route as it is the most efficient way to prevent vibrations from entering the magnet. The pump line runs down to the floor near the magnet stand, then continues across the floor to the wall. It runs along the wall to the BMPC II. A 15cm x 15 cm (6” x 6“) trench would be sufficient to conceal the pump line and sensor cable.

  - It is always important to design the route to avoid tripping and obstructions, and to protect the pysical integritity of the pump line at all times.

Magnet Pits *7.7*

If the ceiling height is not sufficient, and/or the stray fields in the room above are beyond the acceptable range, then a magnet pit may be an option. Important issues that need attention include but are not limited to the following:

- Special rigging equipment and a temporary platform to support and lower magnet inside the pit.
- Continuous ventilation and emergency exhaust inside the pit (please refer to special notes related to pits in sections ***9.6*** and ***9.8*** for HVAC and Emergency Gas Exhaust).
- Magnet refills and access for transport dewars.
- Cable lengths.
- Tuning and matching the probe.
- Siting the BCU05 cooling unit.
- Siting the CryoPlatform^{TM}.

Consult your local Bruker Installation Engineer for pit design and construction details.

Figure 7.3. Magnet in Pit with Customized Platform

Maximum Field Strengths for NMR Equipment 7.8

Once the location of the magnet has been decided, it is time to determine where the remainder of the equipment will be placed. Protection of motors and electronics from magnetic stray fields is crucial.

Table 7.3. Maximum Field Strength for NMR Equipment

Unit	Maximum Field Strength
Computers e.g. NMR workstation, PC	0.5 mT (5 G)
Printer Plotter	0.5 mT (5 G)
Gas cylinders	0.5 mT (5 G)
Heavy metal office furniture e.g. filing cabinet**	0.5 mT (5 G) - not recommended in magnet room
LC-NMR System & Accessories	0.5 mT (5 G)
He Compressor (CryoCooling)	0.5 mT (5 G)
Gilson	0.5 mT (5 G)
AVANCE cabinet	1.0 mT (10 G) line
TFT computer monitor	1.0 mT (10 G)*
BMPC II	1.0 mT (10 G)
BCU 05	5.0 mT (50G) - max. 2.7m from magnet center
CryoCooling unit	5.0 mT (50 G)
Movable metal chair	not recommended in magnet room
* *The working place for personnel should be outside the 0.5 mT (5 G) line. An additional TFT monitor and keyboard can be located at the 1.0 mT (10 G) line for probe adjustments etc.* ** *Use wooden furniture if access during critical measurements is required.*	

Worktable Position 7.9

Magnetic storage devices are sensitive to the stray field and attention must be given to their position relative to the magnet.

- The flat LCD panel should be turned (or able to be turned) towards the magnet to facilitate tuning and matching.
- The workstation and additional disks, CD-ROM drives, etc., which are normally placed on the worktable, should not be exposed to fields greater than 1.0 mT (10 G).
- For convenience of operation, no direct light should fall on the LCD panel, nor should there be a strong light source at the back of the panel. A separate dimmer or at least partial switching is recommended for the lights in the worktable area.

Layout Examples 7.10

The following layout examples of an 800 US Plus, 850 US^2, and 900 US NMR system include the equipment and utilities. A description of each of the NMR system components is presented in the chapter ***"Equipment" on page 17***, while the details regarding the utility requirements are presented in the chapter ***"Utility Requirements" on page 65***.

The next table refers to the numbered items in the sample site layouts that follow.

Table 7.4. Utility Requirements

Device	Number	International	America	Purpose/Comments
UPS	#1	230V, 50/60Hz 50A 1-Ph	208V, 60Hz, 60A, 1-Ph	Disconnect, on emergency generator.
BMPC II	#2	230, 50/60Hz, 32A 1-Ph	208V, 60Hz, 30A, 1-Ph, L6-30R	For installation and service.
	#3	Distribution box for wire-in conduit (230V, 50/60Hz, 32A from BMPC to AVANCE),	J-box termination for wire-in conduit (208V, 60Hz, 30A from BMPC to AVANCE),	For providing power from BMPC to AVANCE.
	#4	Analog fax modem line.		
AVANCE	#6	230V, 50/60Hz, 32A, 1-Ph	208V, 60Hz, 30A, 1-Ph, L6-30R	For installation and sevice
	#7	Cekon connector, 1-Ph. Wire-in conduit coming from #3	L6-20R termination of wire-in conduit coming from #3	
	#8	Cable with Cekon male plug for wire-in conduit (to plug into Avance and feed BCU-05)	Cable with L6-20P termination for wire-in conduit (to plug into Avance and feed BCU-05)	Power from Avance
	#9	Regulated compressed gas 6.9 bar (100 psi).		
BCU-05	#10	Cekon connector, 1-Ph. Wire-in conduit coming from #8	L6-20R termination of wire-in conduit coming from #8	
Cryo Cooling Unit	#11	230V, 50/60Hz, 16A, 1-Ph	208V, 60Hz, 20A, 1-Ph, L6-20R	For buck-booster 208V/230V on separate UPS.
	#12	Regulated compressed gas 4.1 bar (60 psi).		
He Compressor	#13	400V, 50Hz, 30A (fused), 3-Ph or 480V, 60Hz, 30A (fused), 3-Ph	208V, 60Hz, 60A (fused), 3-Ph	Disconnect, on emergency power.
Workstation	#14	230V, 50/60Hz, 16A, 1-Ph	110V, 20A, 1-Ph	On separate UPS
	#15	Telephone port		
	#16	Data port		
Imaging Accessory		230, 50/60Hz, 32A, 1-Ph	208V, 60Hz, 40A, 1-Ph	Optional cabinet.

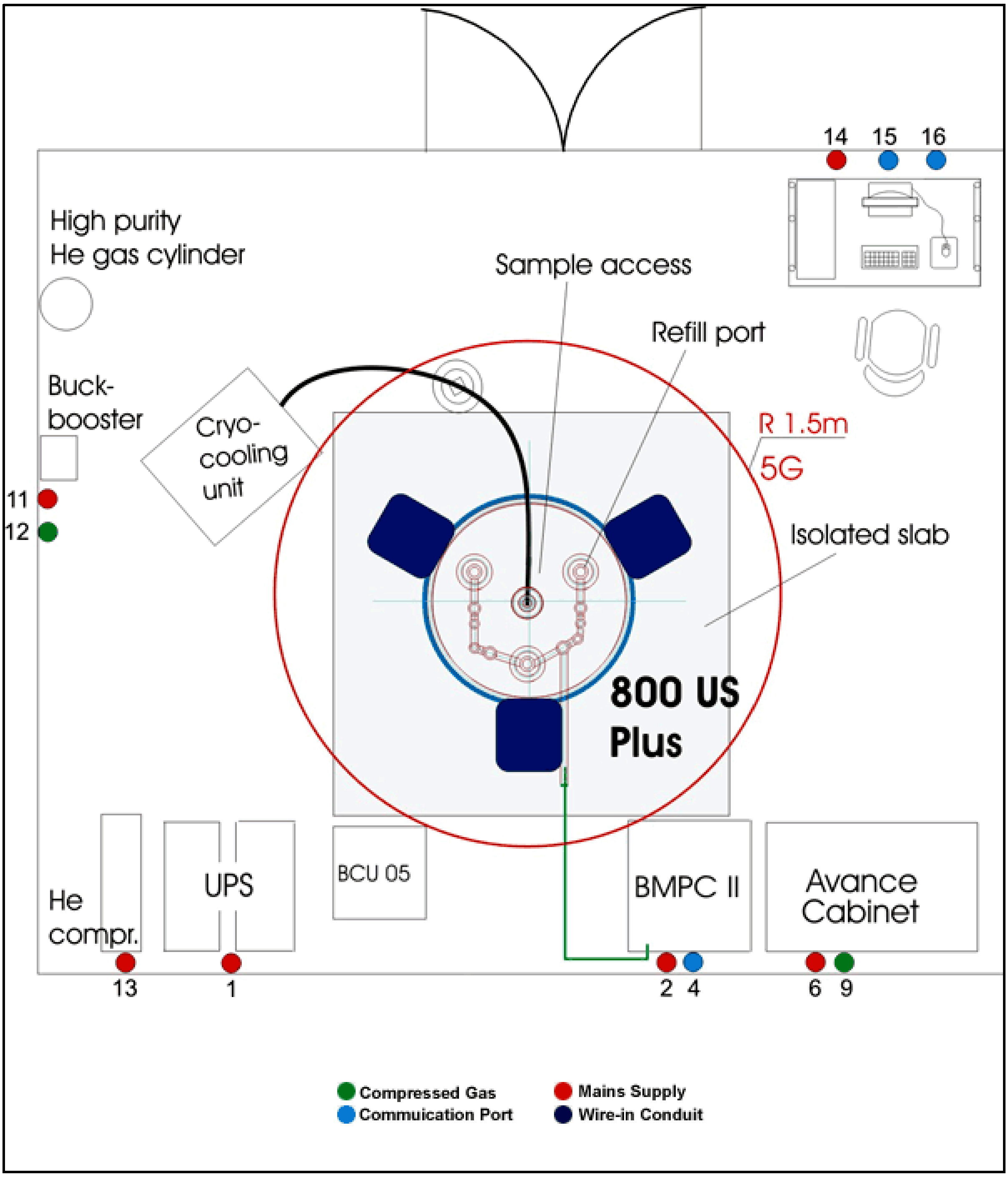


Figure 7.4. AVANCE 800 US Plus NMR Layout Example

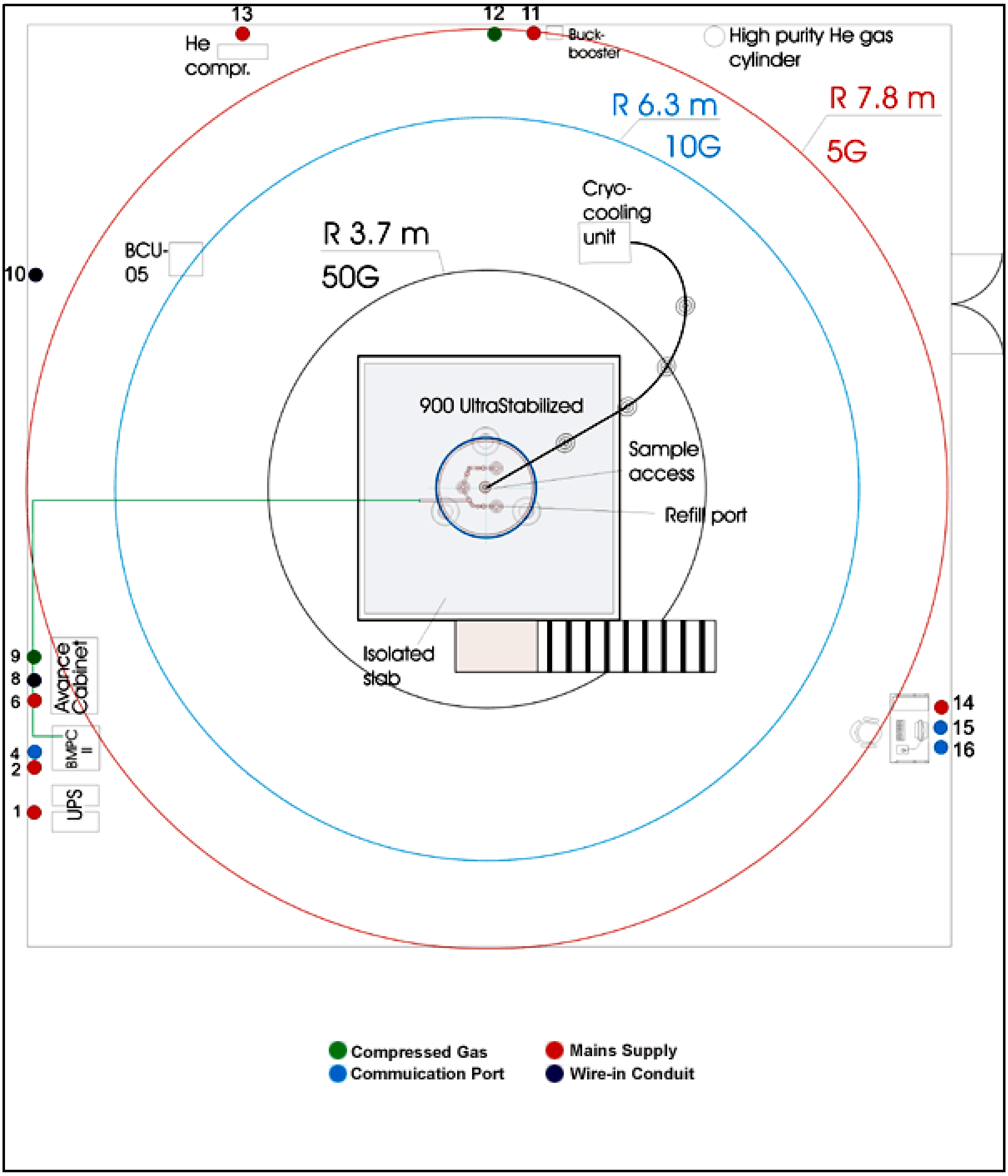


Figure 7.5. AVANCE 900 UltraStabilized NMR Layout Example

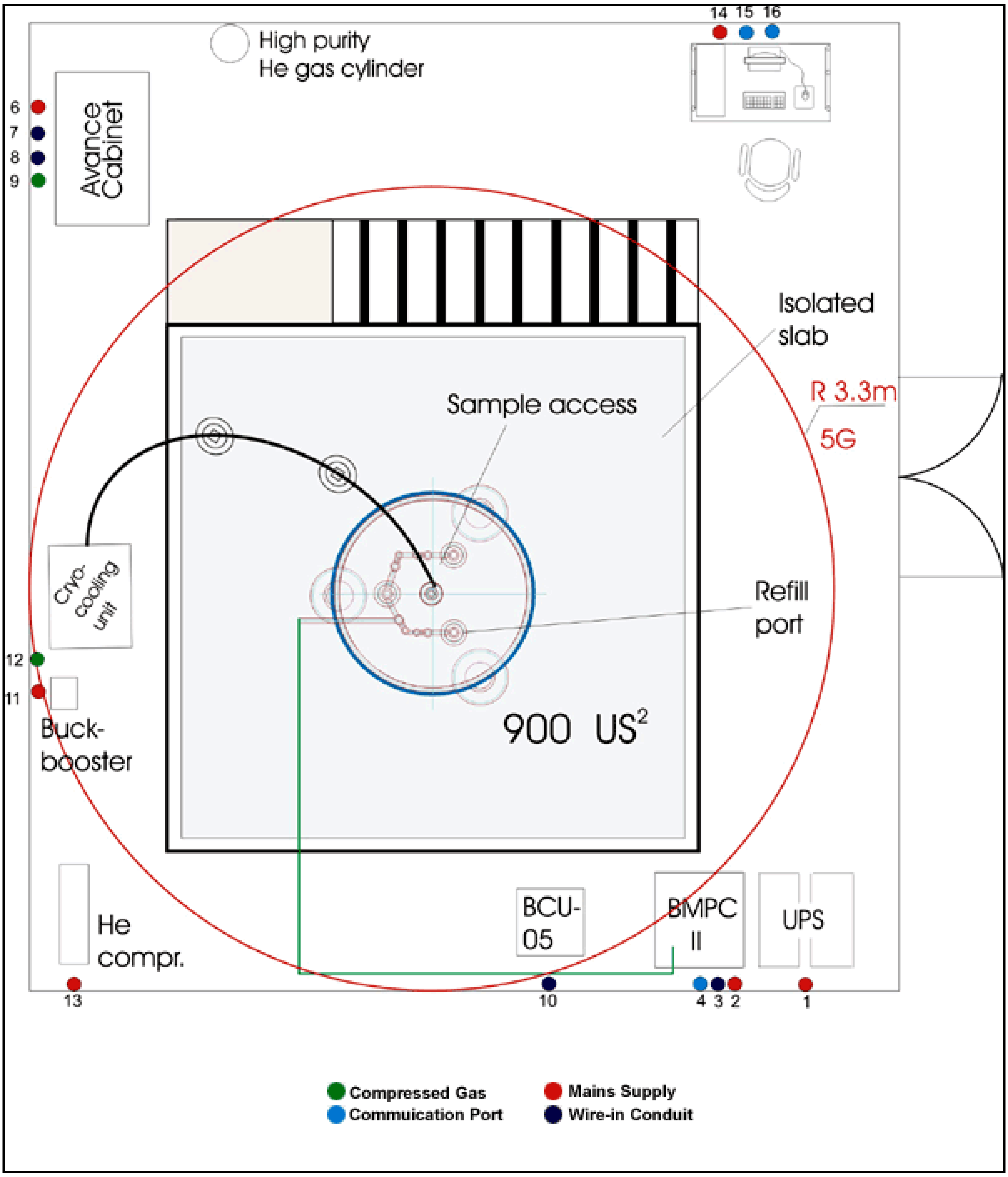


Figure 7.6. AVANCE 900 US2 NMR Layout Example

Environment and Site Survey Measurement 8

Introduction 8.1

This chapter covers the various site survey topics related to the NMR laboratory. The measurements and associated guidelines include:

- Vibrations
- Magnetic Environment
- Electromagnetic Interference: DC and 60Hz AC EMF
- RF Interference

The results of measurements carried-out during a site survey only reflect the specific conditions that were present during the survey. Although these results are useful as a reference, they would not be conclusive for the after-the-installation system performance if one or more site conditions change. These changes may be related but not limited to sources of vibrations and electromagnetic field and RF interference like electro-mechanical equipment (HVAC, motors, pumps, freezers, etc.), elevators, car/bus/train traffic, power lines, transformers, radio/TV stations and other possible RF sources, etc.

Vibrations 8.2

External vibrations may cause field modulations in the sample cavity. This could result in vibration sidebands, matched NMR signals that appear on either side of a main signal peak.

- Ideally the site should be at basement level to minimize building vibrations.
- Possible sources of vibrations are generators, compressors, fans, machinery etc. Vibrations from external sources such as cars, trains, airplanes, and construction sites can also cause problems.

- Measuring the extent of vibrations at the magnet location is a relatively simple matter; if you suspect that a problem you should contact your local Bruker Biospin office.
- Various measures to dampen floor vibrations are available. Please refer to ***"Vibration Damping Measures" on page 58***.

Vibration Guidelines *8.2.1*

Measurements of floor accelerations (mm/sec^2) are required in both vertical and horizontal directions over a minimum frequency range of 0 to 100 Hz. Recording both average and peak-hold values is recommended.

All magnets are equipped with vibration dampers in order to reduce vibrations on the magnet. The isolation performance is given by a transmissibility characteristic for the specific dampers integrated within the magnet. The higher the frequency of floor vibrations, the better the damping (less of the vibration is transmitted). Also, the smaller the natural frequency of the dampers and the smaller their “Q” (amplification factor at the natural frequency), the higher the isolation performance.

The acceleration peaks measured directly on the proposed magnet floor must be multiplied by the transmissibility factor of the dampers at the specific frequencies at which these acceleration peaks have been recorded. The results must then be compared to the **maximum 0.1 mm/sec^2** that can be tolerated at the magnet.

Vibration Damping Measures *8.2.2*

All UltraStabilized magnet systems are equipped with pneumatic vibration dampers (vibration isolation units). Two options are available:

- Air-Spring dampers have a natural frequency of ~2.5 Hz and become effective at floor vibration frequencies above 4 Hz.
- Advanced dampers - vibration isolation columns having a natural frequency below 1.5Hz, and become effective at floor vibration frequencies above 2.5 Hz. This superior isolation solution is suitable for very low frequency vibrations (vertical and horizontal).

It is strongly recommended to design an isolated magnet slab that separates (isolates) the magnet from the rest of the floor and building. This should reduce the magnitude of vibrations that are transmitted to the magnet from the building (electromechanical equipment, HVAC, personnel, etc.). For guidelines on the magnet slab please refer to the section ***"Magnet Slab" on page 46***.

Magnetic Environment 8.3

The presence of any ferromagnetic materials in the immediate vicinity of the magnet will decrease the magnet´s homogeneity and may degrade overall performance. Although minimum requirements for routine NMR are not stringent, the magnetic environment must be optimized if more sophisticated experiments are being carried out. Usually, the effect of metal pipes, radiators, and other such objects can be “shimmed out”, but whenever possible, this should be avoided.

To assist in site planning two sets of guidelines are given below: “**minimum requirements**” and “**acceptable environment**”.

If minimum requirements can not be met, the customer should consider a different site because NMR performance is likely to be reduced. By acceptable environment we mean an environment with which most customer sites comply. This is a situation which is desirable, though not always achievable.

Minimum Requirements 8.3.1

Static Iron Distribution

Any iron within the confines of the NMR lab should be located at least 3.66m (12’) from the center of the magnet. Removal of iron piping in this vicinity should be considered prior to installation. If the magnet must be located close to iron or steel support beams proper alignment is important; support beams should pass through or be symmetric to the magnet axis.

Any static iron mass (0-227kg/0-500lbs.) must be at least at 3.66m (12’) from the magnet center. For heavier masses, the limiting area must be extended accordingly. The presence of static magnetic material near the magnet assumes that these masses are firmly secured e.g. radiators, pipes.

Moveable Magnetic Material

No moveable masses should be located within a ~6.1 m (20’) radius. Potential sources of moving iron are metal doors, drawers, tables, chairs etc. For larger iron masses (> 227 kg/500 lbs.) distorting effects may be experienced when those masses are moving as far as 12.2 m (40’) or more from the magnetic center.

For high precision work (e.g. NOE difference experiments) increasing the exclusion zone for moveable magnetic material may be justified.

Acceptable Environment 8.3.2

Static Objects

Table 8.1. gives a list of common sources of magnetic interference. These items should be located according to the recommendations below. It must be emphasized however, that such recommendations represent a situation that may not be achievable. Please consult with Bruker BioSpin for possible solutions if one or more of these recommendations cannot be satisfied.

Table 8.1. Recommendations for Static Magnetic Objects

Object	Actual distance from magnetic center (m)
Iron or steel Beams	4
Steel reinforced walls	4
Radiators, Plumbing pipes	4
Metal table, metal door	4
Filing cabinet, steel cabinet	4
Massive objects e.g. Boiler	4

Moving Objects

The table below serves as a guideline for moveable magnetic material.

Table 8.2. Recommendations for Moveable Magnetic Objects

Object	Actual distance from magnetic center (m)
Steel cabinet doors	6
Large metal door, hand trolley	9
Elevators*	12
Cars, Fork-lifts	12
Trains, Subways, Trams*	30

** Note that D.C. operated elevators, trains, and trams may cause disturbances over much larger distances (see* ***Table 8.3.****). In addition, these may also cause vibrational disturbances.*

Electromagnetic Interference 8.4

Possible sources of interference are power lines which may carry fluctuating loads, heavy duty transformers, large electric motors, air conditioning systems, power transformers, etc. The fluctuating electromagnetic fields arising from such devices can interfere with the magnet homogeneity. Of particular concern are sudden changes in load as may be produced by elevators, trams, subways etc. Some laboratory equipment such as mass spectrometers and centrifuges will also give rise to fluctuating fields. Other sources of interference include radio and television stations, satellites and other RF transmitters that may operate in the vicinity of NMR frequencies of interest.

If you suspect that you have a source of interference located near the proposed magnet site then you should contact Bruker Biospin for a site survey.

Types of EMF Interference

- DC Interference
- 50/60 Hz Interference
- RF Interference

DC EMF Interference 8.4.1

DC interference generally comes from devices operated on DC, such as elevators, trains, subways, trams, etc. The locations of both the device and its power supply & lines relative to the proposed NMR site are essential to the amplitude and orientation of DC fields and how they may interfere with the NMR system. DC feeder lines are just as disturbing as a subway, and they do not run necessarily parallel to the track.

Measuring DC Fluctuating Fields

DC EMF measurements should be conducted using a **fluxgate magnetometer**. The fluxgate sensor is capable of accurately measuring magnetic field changes below 1mG. The sensor is connected to a magnetometer, and the voltage output from the meter is then converted into digital form. The magnetic field is recorded and plotted on a computer display in real time.

Reducing DC Interference

The amplitude of the “full external perturbation” (peak-to-peak) is measured with the fluxgate magnetometer at the proposed magnet location but in the absence of magnet. There are two levels of compensation against these external DC field perturbations:

1. First, the magnet screens itself against external perturbations, hence only a fraction of the full perturbation is left at the magnet center. We call this *residual field perturbation after magnet screening*. It’s value is relevant to NMR experiments *without lock*, relevant to many solids experiments and high resolution experiments using gradients which require lock hold.
2. Second, the advanced digital NMR lock further minimizes the interference after magnet screening. The digital lock is less susceptible to field perturbations than the older analog lock. The final response may depend on the lock substance and concentration.

Guidelines: DC Interference

When determining the effect of fluctuating magnetic fields, two parameters are important: the size of the fluctuation and the rate of change.

- Field changes of up to 5 mG, regardless of the rate of change, are generally considered harmless for standard NMR work.
- Field changes larger than 5 mG will be compensated by the digital NMR lock, as long as their rate of change is less than 10 mG/sec.
- Field changes faster than 10 mG/sec need to be addressed in more detail along with the types of NMR experiments to be performed, in order to better assess whether the NMR performance will be affected. **Please consult with Bruker Biospin to assess the level of interference and explore solutions**.

Table 8.3. lists the minimum distances between the source of interference and the magnet center.

Table 8.3. Minimum Distances from Sources of DC EMF Interference

Source of Interference	Recommended Minimum Distance from Magnet Center (m)
DC Trains, subways, trams*	150
DC Elevators*	12
Mass Spectrometer (slow ramp)	12
Mass Spectrometer (sudden flyback)	30

** Elevators, trains, subways, and trams are also a source of vibrational interference.*

50/60 Hz EMF Interference 8.4.2

The 50/60 Hz interference generally comes from electrical wiring, transformers and fluorescent lights located in the vicinity of the magnet as well as near the NMR cabinet and workstation. The magnetic field further modulates this interference, increasing the likelihood of disturbances.

Measuring 50/60 Hz Fluctuating Fields

The amplitude and orientation of the 50/60 Hz fluctuating fields should be mapped within the proposed NMR room. The sources of such fields should be identified. Specific locations that must be checked carefully include:

- Magnet area
- Console area
- Along the wall inside the NMR room at 5 cm (~2”) from wall, and 3.8 cm (4”) from wall
- Approximately 5 cm (~2”) below the existing lights in the room
- Near the main outlets 230V (USA - 208V) locations in the room.

Guidelines: 50/60 Hz Interference

The amplitude at which interference is likely is **~ 1.8mG RMS**. Since this amplitude is based on laboratory tests, ideal values should be well below 1.8 mG RMS.

The magnet should not be placed within a 6.1 m (20’) radius of a normally-sized transformer. If there is a large transformer adjacent to the proposed magnet location, measurements will be required to determine if the transformer will adversely affect NMR spectra.

The magnet should not be placed directly under fluorescent lights. Fluorescent lighting may cause interference, and may switch off temporarily during a quench.

RF Interference *8.4.3*

The NMR instrument is effectively a very sensitive radio frequency receiver. Possible sources of interference are local radio or television broadcasts, low Earth orbit satellite systems, and signals emitted by personal paging systems. Of particular concern will be interference at frequencies at which NMR experiments are carried out. Although the interference effects will depend greatly on the strength of the transmitter, as a rule of thumb only broadcasting transmitters located within a radius of approximately 5 kilometers (3 miles) are likely sources of interference.

RF interference may also occur between two or more spectrometers located in close proximity and operating at the same nominal 1H resonance frequency.

Measuring RF Fluctuating Fields

Radio Frequency Interference measurements should be conducted using a spectrum analyzer. The analysis should be done for the resonance frequency of each of the nuclei of interest (proportional to the 1H resonance frequency of the spectrometer). The minimum frequency sweep is 400 kHz. Any peaks with RF fields above -80 dBm should be recorded, as well as any broad frequency ranges with any level of RF signals.

"Table 8.4." on page 64 contains a list of the most common studied nuclei at the corresponding frequencies for the 750, 800, 850, and 900 MHz NMR systems.

Guidelines: RF Interference

As a general guideline the level of any RF interference should be less than an electrical field strength of -65 dBm at the side of the magnet. However, past experience has shown that broadband RF fields having smaller intensity (about -80dBm) may interfere with the NMR experiments. Therefore, it is important to make a note of any measurements exceeding -80 dBm.

Reducing RF Interference

Screening a site for possible RF Interference is complicated and expensive. Shielding of the NMR room with a Faraday cage is a possible solution, though having to take such measures is quite rare.

When designing and manufacturing the Bruker BioSpin spectrometers, care is taken to provide adequate shielding and the instruments rarely suffer from interference in normal RF environments. Furthermore, the advanced BSMS digital lock system - included with all Bruker BioSpin AVANCE spectrometers - allows a shift in the 2H lock frequency with certain limits. This may allow enough variation in the absolute magnet field strength to shift the NMR signal away from that of local broadcasting frequencies.

RF interference may occur between two or more spectrometers located in close proximity and operating at the same nominal 1H resonance frequency. These problems can be avoided by energizing the different magnets at slightly different fields, such that their operational frequencies are separated by ~ 200 kHz of the nominal 1H resonance frequency.

Table 8.4. List of Most Commonly Studied Nuclei and Corresponding Resonance Frequencies

Nuclei	NMR Frequency (MHz)			
Magnets	**750**	**800**	**850**	**900**
1H	750.131	800.131	850.131	900.131
2H	115.151	122.827	130.502	138.177
11B	240.697	256.740	272.786	288.828
13C	188.631	201.204	213.777	226.350
15N	76.145	81.221	86.285	91.372
19F	705.948	753.003	800.055	847.113
27Al	195.603	208.647	221.687	234.718
29Si	149.202	159.147	169.094	179.037
31P	303.963	324.224	344.488	364.745

Utility Requirements

9

Electrical Power Requirements 9.1

The Bruker UltraStabilized systems operate at a reduced temperature which can only be maintained by uninterrupted power to one helium pump. These systems will stay operational for several hours, but it requires a knowledgeable person to bring them back to normal operating conditions. A longer failure of the cooling system will inevitably result in a quench. In such a failure, the system may be down for several weeks and will require reinstallation.

The standard system is equipped with 9 hours of backup capacity for the magnet pump assembly. If power failures longer than 9 hours are likely in the area of installation, it is the responsibility of the customer to take appropriate provisions.

The power for the AVANCE UltraStabilized NMR systems is exclusively controlled by the BMPC (Bruker Monitoring and Pump Control) Unit. This unit provides the required power to the main AVANCE two-bay cabinet, the cooling pumps, and ancillary units such as the BCU-05 cooling unit.

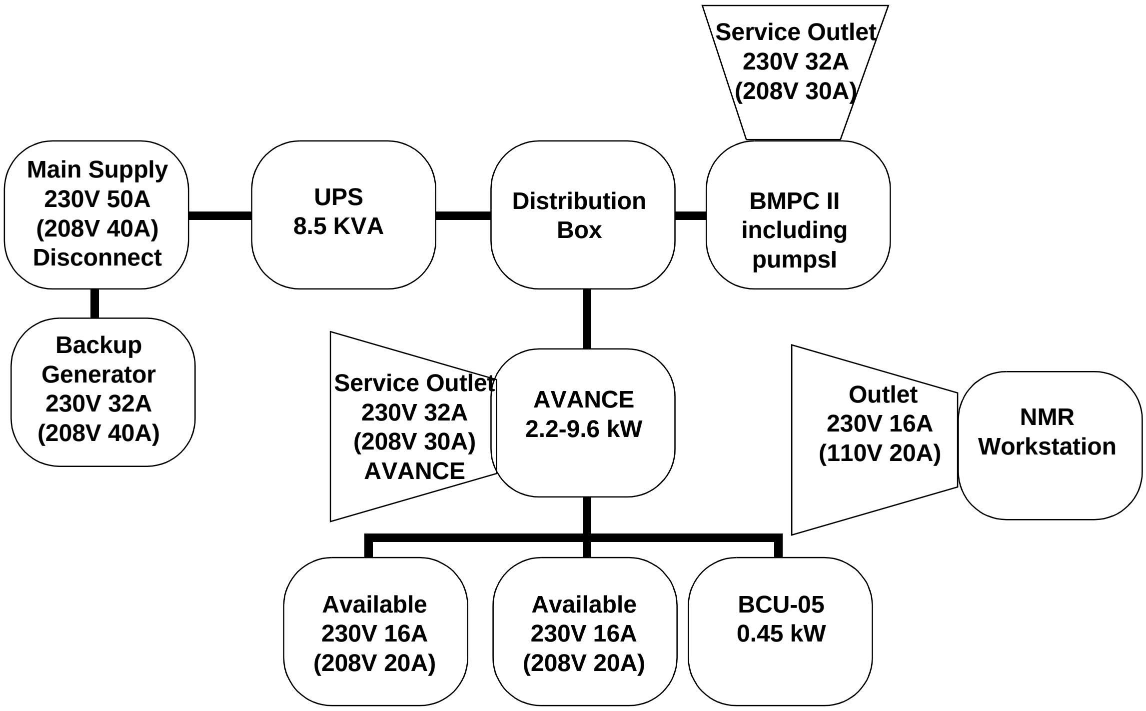
Table 7.4. includes the electrical power requirements.

Figure 9.1. displays the BMPC and the various units to which it distributes power.

Other important considerations include:

- All power is routed through the UPS which also has the advantage of serving as a line conditioner. In the event of a power failure, the power source automatically switches to the UPS batteries.
- Though the UPS is hard wired to a distribution box which feeds the BMPC and the Avance console, the power for the Avance console is still exclusively controlled by the BMPC.
- If the power failure exceeds 6 minutes, the supply to the two-bay cabinet will be cut off automatically. This will enable the UPS to power the helium pump for about 9 hours. As most (more than 90%) power failures are much shorter than 6 minutes, this compromise reserves most of the battery capacity for the magnet and allows NMR measurements to run undisturbed in case of short power interruptions.

- If the power failure exceeds 9 hours, it is recommended to provide backup emergency power to maintain the operation of the helium pumps. This power can come from the building's emergency generator or from a small, dedicated generator. If a power failure continues for more than 4 hours, the customer will be alarmed by telephone through the Bruker Monitoring System (BMS).
- Standard-length power and communication cables are provided with the instrument. If the placement of the NMR cabinets does not allow for the use of these cables, the customer may be required to provide electrical power conduits.



Notes:
- Values in parathesis are for America.
- 230V 16A (208V 20A) outlets should be plentiful.
- The AVANCE console has 3 outlets that may be used for Bruker equipment.
- Service outlets are used for matintenance purposes.

Figure 9.1. Main Electrical Power Requirements Flowchart

The AVANCE cabinet comes supplied with four electrical outlets (230V/16A - European Shuko receptacles) which can be used to power standard ancillary equipment. Two outlets are designed to power the NMR Workstation and (optional) Imaging Cabinet. This leaves two outlets free for accessories such as the BCU-05 or Automatic Sample Changer etc.

Telecommunication 9.2

Please refer to the AVANCE UltraStabilized NMR layout in ***"Layout Examples" on page 51***. The following ports are required:

- Telephone/data ports behind the workstation

- Dedicated analog modem (telefax) port behind the monitoring unit (BMPC).

Compressed Gas 9.3

General Requirements

Compressed gas line: The standard AVANCE system requires one compressed gas line with two regulated outputs. Two additional secondary connectors are perferred.

Regulators: Watts Regulator R119-03C (Watts Fluid Air Company), pressure range 0-8.6 bar (0 - 125 psi), with gage head included.

- Compressed nitrogen gas needed for temperature control with VT experiments in order to achieve optimal NMR performance. The BCU-05 cooling unit requires a DEW point of -51°C (-60°F) for the compressed gas.
- Compressed air or nitrogen gas for spinning.
- Compressed air or nitrogen gas for sample ejection, and for the magnet's vibration isolation units.
- Compressed air or nitrogen gas for the optional CryoProbe system.

Compressed Gas Options 9.3.1

Option 1 (preferred):

Nitrogen gas only: 57 l/min. (2 scfm) for non-MAS experiments, or 227 l/min. (8 scfm) for MAS experiments. The pressure should be 6-8 bar (80-120 psi).

Option 2:

Nitrogen gas for VT work only: flow 5.7-34 l/min. (0.2 - 1.2 scfm), minimum pressure 4.2 bar (60 psi). This can be provided by a nitrogen separator or using boil-off from a LN2 dewar.

Dry air for the rest: 22.7-51 l/min. (0.8-1.8 scfm) for liquid NMR experiments, 193-221 l/min. (6.8-7.8 scfm) for MAS experiments. Pressure 6-8 bar (80-120 psi).

Option 3 (not recommended unless exclusive use of a CryoProbe is expected)

Dry air only: minimum flow 85 l/min. (3 scfm) for non-MAS experiments, 255 l/min. (9 scfm) for MAS experimetns. The pressure should be 6-8 bar (80-120) psi.

Note:

A nitrogen separator (supplied by Bruker BioSpin) can be built into the AVANCE cabinet as an available solution for option 3. This will produce the nitrogen gas required for VT work. However, this is not suitable for larger flow rates required by MAS experiments.

The nitrogen separator is suitable for use with the BCU-05 cooling unit. However the nitrogen output from the separator is not pure enough and this unit should not be used with a N2 exchanger or BCU-X cooling unit for low temperature work.

Gas Requirements For Accessories 9.3.2

- If use of a Bruker Automatic Sample Changer (BACS) in high throughput mode is planned, a secondary regulator, T-split from the supply line, is recommended.
- For MAS (Double Bearing) a second regulator is mandatory. Make sure the supply line cross-section is sufficient to deliver the necessary volume at the required pressure.
- If a CryoCooling unit is to be installed, a secondary regulator, T-split from the supply line is recommended.
- If the Emergency Sample Protection Device is to be used in conjunction with the CryoProbe System, a cylinder of air or nitrogen gas is required.

Compressed Gas Specifications 9.3.3

Oil Content:

< 0.005 ppm (0.005 mg/m^3)

Water Content

For the BCU05 cooling unit the compressed gas should have a DEW Point of -51°C (–60°F). For the BCU-X cooling unit, the DEW Point requirement is -100°C (-148°F).

For room temperature work and higher: DEW Point of < 4°C (39.2°F)

For low temperature work: The DEW Point must be at least 20°C (68°F) below the operating temperature.

If a cooling unit is used, then the DEW Point of the compressed nitrogen should be at least 10°C (50°F) below the temperature at the heat exchanger output.

Solid Impurities

Use 5 micron filters for high resolution NMR. For MAS probes use 1 micron filters. The filters should retain a minimum of 99.99% of the specified particles.

Table 9.1. Compressed Gas Requirements

System	Operating Pressure	Average Consumption	Recommended Minimum Gas Supply***
Two-Bay	6-8 bar (80-120 psi)	45 l/min. (~1.6 cfm)	57 l/min. (~2 cfm)
Two-Bay + BACS* or NMR CASE	6-8 bar (80-120 psi)	52 l/min. (~1.8 cfm)	57 l/min. (~2 cfm)
Two-Bay + MAS (DB**)	6-8 bar (80-120 psi)	220 l/min. (~8 cfm)	300 l/min. (~11 cfm)

* Bruker Automatic Sample Changer
** DB= Double Bearing
*** This is the actual consumption and minimum needed at the instrument input after the N2 supply (either a bulk tank, or a N2 separator).

For non-MAS work, if a an air-compressor and N2 separator are used, the flow requirements are 50% higher, i.e. 3 cfm. It is recommended to use a dual unit oil-less air-compressor rated at min. double capacity of the specified requirement. Please refer to the next section on air compressors.

Air Compressors — *9.3.4*

When choosing an air compressor the following points should be considered:

1. Ideally the compressor should be installed in a dust free, cool and dry place.
2. The compressor must be oil-free. This can be achieved by using membrane or Teflon coated piston compressors. The compressor should be fitted with a fine dust inlet filter.
3. The compressor must be capable of delivering the required flow rate and pressure suited to your particular system (see ***Table 9.1.***). Generally the compressor should be large enough so it does not run continuously (e.g. > 50% of the time), which will cause overheating.

   The extra cost of choosing an oversized system may often be justified. The reduction in duty cycles will lower maintenance costs and extend the life of the system. A suitable compressor coupled to an adequate buffer will ensure a more **constant flow rate** leading to better performance. When spinning, the system uses a constant flow of air, but surges will occur during sample lift. When referring to ***Table 9.1.*** you should add on 10 l/min. to the average consumption if the system is fitted with anti-vibration devices such as pneumatic dampers or a VIP system.
4. Take into account the pressure loss along the line between the compressor and the final gate valve. The pressure drop depends on the pipe diameters. An internal diameter of 8 mm has been found to be suitable. The plastic tubing used to carry the supply from the final gate valve to the console has an outside diameter of 8 mm and is supplied by Bruker BioSpin.
5. Some types of dryers, e.g., absorption dryers can use up to 25% of the air flow to regenerate the drying material. If this type of dryer is used then the output capacity of the compressor must be sufficient to supply this requirement.

6. Many compressors are fitted with dryer and a tray to collect excess water. Regular checking of the dryer and emptying of the water collector will ensure trouble free operation. This arrangement is quite satisfactory in environments with normal humidity (< 80%). However in areas of higher humidity (> 80%) a cooling coil with an *automatic* water drain must be fitted to the compressor outlet. This will ensure that filters do not become overloaded.
7. Although not directly concerned with air quality, compressors are a source of vibrations which may interfere with NMR performance. You should consider using a compressor fitted with a vibration damping housing if it is to be situated close to the spectrometer. The output noise level should be < 75 dBA.

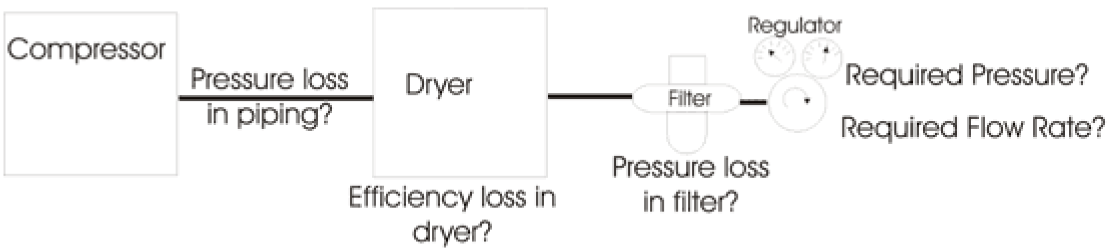


Figure 9.2. Losses in a Typical Dryer/Filter System Setup

Water *9.4*

If the system is equipped with the CryoProbe option and the compressor is water cooled, then cooling water is needed to remove the ca. 7.5 kW of heat output from the water-cooled type He compressor used in conjunction with the CryoProbe.

The cooling water requirements are found in the **CryoProbe Site Planning Guide**, which is available from your local Bruker Representative.

Lighting *9.5*

Operation is most convenient when the computer monitor(s) may be viewed under subdued lighting. However, normal office lighting will be needed in other areas of the NMR room. The most convenient arrangement is to have separately switchable lights using standard light bulbs. Make sure that reflections from strong artificial light do not fall upon the monitor screen. Care should also be taken to minimize reflections from sources such as windows.

- Please do not direct spotlights toward the magnet; this could change the surface temperature.
- Consideration should be given to the relative placement of lights to the air conditioning inputs, which mostly contain the temperature sensors for the air conditioners. Otherwise the switching of lights might result in a system overreaction and a considerable temperature change.
- Lights are generally not recommended within a radius of 3m (~10’) from the magnet.

HVAC (Heating Ventilation Air Conditioning) 9.6

Constant temperature and humidity is crucial for high performance operation.

Room temperature should be kept between 63 and 77°F.

Room temperature should not fluctuate more than **+/-0.5 °C (1°F) per hour**. Near the magnet or cabinets, the temperature fluctuation should not exceed +/-0.5°C (1°F). Air drafts, particularly those created from air conditioning or heating systems, can have negative effects on the magnet.

The location and orientation of air-diffusers must prevent the air from blowing towards the magnet and spectrometer cabinet, since this would have a negative impact on the system stability and its performance.

The heat output of the standard AVANCE UltraStabilized system for high resolution work is about 4.6 kW (18,000 BTU/hr.). This includes the main AVANCE cabinet, the BMPC, the BCU-05, and the workstation.

The heat output of the AVANCE UltraStabilized system equipped with High Power amplifiers for solids NMR is between 6 kW (25,000 BTU/hr.) to 10 kW (40,000 BTU/hr.) depending on the high power configuration.

Humidity should be kept between **30% and 80%**. Conditions other than these may warrant the installation of an air conditioner with appropriate humidity controls.

Magnet Stability: The heat output is constant and it is essential to minimize or avoid short term oscillations of the HVAC system, and provide a continuous slow flow of air that in turn reduces the speed of any temperature changes. In other words, it is recommended to have a continuous and slow exchange of air in the NMR room, hence minimizing fluctuations.

Most of the heat is generated in the AVANCE cabinet, the magnet pump assembly and the BCU05. The magnet itself does not dissipate any heat. Special care should be taken so the air does not blow towards the magnet and spectrometer cabinet.

Pits: When a magnet is installed in a pit, it is important to ensure there is continuous air-flow (or exhaust) within the pit. This is done to prevent any buildup of nitrogen gas in the confines of the pit, not to reduce the temperature stability of the magnet. If more circulation is required, emergency exhaust will be discussed in ***Section 9.8: "Emergency Gas Exhaust"***

Fire Detection System and Fire Extinguishers *9.7*

Rooms containing NMR magnets should be equipped with **temperature sensors** for fire detection. These must respond *only* to a sudden rise of temperature, and not be triggered by a quench (sudden drop of temperature).

Optical sensors cannot discriminate between smoke from a fire and fog caused by a quench so these may not be used.

Fire extinguishers in the vicinity of the magnet room must be **non-magnetic** (stainless steel or aluminum). It is the obligation of the customer to inform the local fire department about the dangers of magnetic fields. These magnets stay at field for a long time even in a most blazing fire!

Ceiling sprinkler heads should be made of metal instead of glass. A quench could falsely trigger the alcohol-filled glass vials, which can shatter in the presence of cold helium gas. Sprinklers should not be located directly over the magnet.

Any sprinkler lines or other metal pipes located above the magnet should be thermally-insulated to prevent O2 condensation or water freezing in the line from the large amount of cold He gas following a magnet quench.

Emergency Gas Exhaust *9.8*

Due to the large amount of liquid He contained in the magnet, an emergency exhaust system may be required to prevent O_2 depletion during a magnet quench. ***Table 9.2.*** lists the amount of LHe and He gas after a quench for the UltraStabilized magnets.

Table 9.2. He Gas After a Quench

UltraStabilized magnets	Amount LHe (liters)	He gas after a quench (per minute)
750 WB	~ 450	333 m^3 (~11,800 ft^3)
800	~ 450	333 m^3 (~11,800 ft^3)
800 US Plus	~ 350	296 m^3 (~10,500 ft^3)
800US^2	~ 1,200	888 m^3 (~31,400 ft^3)
850 US^2	~ 1,200	888 m^3 (~31,400 ft^3)
850WB US^2	~ 1200	518 m^3 (~18,300 ft^3)
900	~ 800	518 m^3 (~18,300 ft^3)
900 US^2	~ 1300	518 m^3 (~18,300 ft^3)
950 US^2	~ 1300	518 m^3 (~18,300 ft^3)

Regarding the emergency gas exhaust, important considerations include, but are not limited to, the following:

- **Amount of liquid He**: Taking the 850 US^2 magnet as an example, the total amount of liquid He is 1200 liters. In case of a quench, the liquid transforms into gas and expands by a factor of 740. Therefore, the total amount of He evaporated gas in case of a quench will be ca. 888 m^3 (31,400 ft^3).

- **Maximum He gas flow**: The maximum flow of He gas is calculated on the assumption that half of the volume of liquid evaporates in 1 minute, thus the maximum flow would be 444 m^3 (15,700 ft^3) for the 850 US^2 magnet. The gas should be removed from the room immediately through an emergency exhaust system.
- **O_2 level sensors**: Oxygen level sensors are required to detect low O_2 levels within the NMR room for each system. One sensor is needed above the magnet for detecting low O_2 levels due to He gas exhaust in case of a quench or during He fills. An additional sensor is needed close to the floor for detecting low O_2 levels due to N_2 gas exhaust during magnet cooling or regular N_2 fills. In case of placing the magnet inside a pit, a third sensor is needed inside a pit to detect low O_2 levels from N_2 gas.
- **Emergency exhaust solutions**: The following exhaust solutions are recommended:

Passive exhaust: This system is based on louvers in the ceiling, or upper parts of outside walls, that open up due to the pressure of He gas.

Active exhaust: In addition, an active system based on a motorized fan in, or close to, the ceiling is recommended. This way, adequate exhaust of cryogenic gases will be provided not only during a quench, but also during the initial cooling of the magnet and regular cryogen refills.

Normally it is sufficient to operate this fan manually, as the probability of an unattended quench after the installation is rather low.

If desired, this fan can be operated with an automatic switch:

a) it should be installed in addition to a manual switch.

b) measures should be taken to prevent it from being turned on during a fire.

Quench pipes: This solution may be required when the NMR room is small and any of the other options are not sufficient to ensure safety after a magnet quench.

This solution is based on a pipe connected directly to the magnet, which is then routed to the outside of the building. It is important to note the following:

- The helium exhaust from the magnet should be vented directly to the outside of the building.
- The ducts should have sufficient diameter to avoid excessive pressure build-up due to the flow impedance of the duct.
- The location of the exit end of the duct must not be accessible to anyone other than service personnel. In addition the exit opening should be protected from the ingress of rain, snow, animals, etc.
- It is also essential that any gas which vents from the exhaust duct cannot be drawn into the air conditioning or ventilation system intakes. The location of the duct's output should be carefully sited to prevent this from happening during any adverse atmospheric conditions and winds.

- Insulation of accessible exhaust piping should also be provided to prevent cold burns during a quench.

Pits: As discussed in ***Section 9.6: "HVAC (Heating Ventilation Air Conditioning)"*** , continuous air flow is required within the confines of a magnet pit. Emergency ventilation may also be necessary, particularly if the pit is >1.09m (3.5') deep (average mouth-height of a person). Since nitrogen gas cannot be detected by the human senses, an oxygen sensor mounted in the pit will trigger an increased rate of exhaust.

Figure 9.3. Emergency Quench Pipes

Please contact Bruker BioSpin for further information.

Oxygen Monitor and Level Sensors *9.9*

Oxygen monitors or level sensors are required inside the magnet room. The minimum number of oxygen sensors follows:

Above the magnet on the wall:	One oxygen level sensor should be above the magnet, to detect low oxygen levels caused by high He gas levels.
Close to the floor on the wall:	One oxygen level sensor approx. 30 cm off the floor of the magnet room.
Down in the pit:	One additional oxygen level sensor approximately 30 cm off the bottom of the pit, in case the magnet is located inside a pit.

Installation 10

Introduction 10.1

Please fill out and return the Site Planning Checklist prior to the delivery of the magnet system. If this checklist was not provided, please contact your Bruker BioSpin representative immediately.

All general requirements such as power supply, compressed air supply, etc. must be installed before the system can be delivered. Installation requirements such as cryogen supplies are totally separate from normal operation requirements. The system can only be delivered and installed after the completion of all construction work in the lab. The lab must be cleaned from all remaining dirt, dust, particles, etc.

The magnet transport crates should be kept indoors out of direct sunlight. The crates should not be opened until a Bruker BioSpin magnet engineer arrives. Failure to do so may invalidate the warranty. The crates are shipped with Shockwatch™ and Tiltwatch™ indicators.

Overview 10.2

The spectrometer system will arrive at the site in crates. The crates should only be opened by the Bruker BioSpin service engineer. The commissioning of the magnet involves several stages as outlined in ***Table 10.1.***. The installation timeline given below is an approximation; each site is slightly different.

Table 10.1. Magnet Installation Stages

Days	Procedures
Day 1	Delivery of the magnet
Days 2 - 5	Assembly of the magnet
Days 6 - 12	Flushing, vacuum, leak detection, installation of the pump line
Days 13 - 17	Precooling with liquid N_2
Days 18 - 19	Cooling with liquid He
Days 20 - 23	Subcooling to reduced temperature
Days 24 - 38	Energizing and Cryoshimming
Days 38 - 48	Running NMR experiments to demonstrate standard specifications.

Accessibility 10.3

Before the arrival on site, the customer must ensure the equipment can be delivered, and transported safely to the final location inside the NMR room. Please refer to ***"Magnet Access and Rigging" on page 23*** for the details.

Checklist of Installation Requirements 10.4

For the installation the customer must provide the following:

- Lifting equipment and minimum ceiling height as outlined in ***Table 10.2.***
- Pallet jack and/or fork lift for transporting system accessories.
- Two cylinders of N_2 gas 50l/200 bar (~2 cu.ft, 3000 psi) with reducing regulator valves to deliver pressure of 0.5 bar (~8 psi), as specified in ***"Compressed Gas Specifications" on page 68***.
- Six cylinders of He gas 50l/200 bar (~2 cu.ft, 3000 psi) with reducing regulator valves to deliver a pressure of 0.2 bar (~3 psi), as specified in the section ***"Compressed Gas Specifications" on page 68***.
- Quantities of liquid helium and nitrogen as specified in ***Table 10.2.***.
- Liquid helium and nitrogen transport dewars as specified in ***"Compressed Gas" on page 67***.
- One power outlet 230V/16A (USA 208V/30A) single phase and two more 230V/16A (USA 208V/20A) single phase power outlets are needed to run a vacuum pump, a heat gun, and a power supply unit. These power outlets must be available in addition to the main power source used to run the spectrometer.
- Minimum two standard doublet outlets 230V/16A (USA 110V/20A); ideally, these should be plentiful around the laboratory.
- Step ladder (non-magnetic e.g. aluminum, fiberglass, or wood).
- Platform to access the top of the magnet with opening suitable for magnet placement. Please refer to ***"Magnet Platform" on page 47*** for more details.

Where possible the customer should provide the following:

- Heat gun or hand held hair dryer (min. 1200 W)
- Roughing pump 10^{-2} mbar (14.5 x 10^{-5} psi)
- Pair of insulated gloves
- Electric screwdriver

Installation Procedure 10.5

The various steps and procedures mentioned in ***Table 10.1.*** will be discussed in detail.

Magnet Assembly 10.5.1

Once the magnet is lifted off the delivery truck using a suitable overhead crane, it will be uncrated by the Bruker BioSpin magnet engineers outside the building.

It will then be transported using special air-skates to the NMR room. Or, if access is through a hatch in the roof, the crane will be used to lower it safely inside the room to its final position. The crane will then be used in lieu of a gantry during the magnet assembly phase.

A hydraulic lifting device (when access is NOT through hatch in the roof above the magnet location) or a fixed lifting hook must be provided to lift the magnet for assembly. The assembly area should be clean, dry and free of dust. Under certain circumstances, hydraulic lifting equipment may be provided by Bruker Biospin. ***Table 10.2.*** lists the minimum ceiling height, minimum hook height, and the weight for each magnet.

When arranging suitable lifting gear, the customer is asked to ensure a safety margin of at least 100%.

Magnet Evacuation and Flushing with Nitrogen Gas 10.5.2

Once the magnet has been assembled and placed in the magnet room, rough pumping of the cryostat can begin. At the same time the cryostat is flushed through with dry nitrogen gas. The customer must provide a 50l/200 bar (~2 cu.ft, 3000 psi) cylinder of dry nitrogen gas (99.9999% purity). The cylinder should be fitted with a secondary regulator valve to deliver a pressure of 0.5 bar (~8 psi).

For some installations the customer is asked to provide a roughing pump, e.g. rotary pump capable of reducing pressures within the cryostat to 10^{-3} mbar. Further pumping of the cryostat is then carried out to reduce the internal pressure to 10^{-6} mbar. It is convenient, if the customer can provide a suitable pump such as a diffusion or turbo pump. If such a pump is available the customer should contact Bruker Biospin to confirm its suitability. Where no such pump is available then it will be supplied by Bruker BioSpin.

Cooling the Magnet to Liquid Nitrogen Temperatures 10.5.3

This next stage involves filling the magnet with liquid nitrogen. The quantity of liquid nitrogen required is listed in ***Table 10.2.***. The transfer dewars used for precool generally have a capacity of 250 - 500 liters with a fixture for pressuring and transferring via a rubber hose of 10 mm (~3/8”) diameter.

Cooling the Magnet to Liquid Helium Temperatures 10.5.4

For this procedure, the customer must provide the following:

- Six cylinders of helium gas: 50l/200 bar (~2 cu.ft, 3000 psi), 99.996%, with secondary regulator value to deliver pressure of max 0.2 bar (~3 psi).
- Quantities of liquid helium as specified in ***Table 10.2.***.
- Liquid helium dewar: 250 - 500 liter capacity, with NW25 flange or suitable outlet compatible with the 12.7mm (1/2“).

When ordering the helium the customer should arrange to have it delivered immediately before cooling the magnet to liquid helium temperature. If delivered to the site much earlier, losses due to evaporation will occur and must be taken into account (usually 1% of nominal volume/day).

Sub-cooling and Charging the Magnet 10.5.5

The final stage involves sub-cooling the magnet to reduced temperature (~2K) and bringing the magnet to field. During the charging there is a possibility for the magnet to experience a quench. The quantities of liquid helium for final cool down and energization/cryoshimming as well as extra liquid helium required after one quench are specified in ***Table 10.2.***. The customer is required to provide the cryogens needed for the complete installation including up to two training quenches.

The values of liquid nitrogen and helium in ***Table 10.2.*** are the minimum requirements. An extra 20-30% of each is advisable, particularly as many suppliers will take back unused cryogens.

Table 10.2. Installation Requirements for the UltraStabilized Magnets

Magnet Type	Min. Ceiling Height (m)	Min. Hook Height (m)	Total Lifting Weight (kg)	LN_2 needed for precool (L)	LHe needed for cool down and charging (L)	LHe after a training quench (L)
750 WB	4.95	4.25	3,600	2,500	2,500	750
800	4.88	4.25	3,400	2,500	2,500	750
800 US Plus	3.66	3.10	3,400*	2,700	2,000	1,000
800 US^2	5.3	4.75	5,300	5,000	4,000	1,500
850 US^2	5.3	4.75	5,300	6,000	4,200	2,000
850 WB US^2	5.3	4.75	6,600	6,000	4,150	2,000
900	5.3	4.75	5,500	6,000	4,000	1,500
900 US^2	5.3	4.75	6,600	7,000	5,000	2,000
950 US^2		4.75	6,600	7,000	5,000	2,000
WB= Wide Bore (89 mm); US^2= UltraShield-UltraStabilized * For 800 US Plus - This is the lifting weight uncrated with stand.						

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General Safety Considerations for the Installation and Operation of Superconducting Magnet Systems

Revision 1.1.
Last updated: March 29, 2002

List of Contents

1. Introduction

1.1 Read this first!

Please read it carefully and make it accessible to everybody working with the magnet system.

- A superconducting NMR Magnet System can be operated easily and safely provided the correct procedures are obeyed and certain precautions observed.
- These notes must be read and understood by everyone who comes into contact with a superconducting NMR Magnet System. They are not for the sole information of senior or specialist staff.
- Proper training procedures must be undertaken to educate effectively all people concerned with such equipment with these requirements.
- Since the field of the NMR magnet system is three dimensional, consideration must be given to floors above and below the magnet as well as to the surrounding space at the same level

1.2 Warning areas

The installation and operation of a superconducting NMR magnet system presents a number of hazards of which all personnel must be aware. **It is essential that:**

- Areas, in which NMR magnet systems are to be installed and operated, are planned with full consideration for safety.
- Such premises and installations are operated in a safe manner and in accordance with proper procedures.
- Adequate training is given to personnel.
- Clear notices are placed and maintained to effectively warn people that they are entering a hazardous area.
- All health and safety procedures are observed.

These notes outline aspects of operation and installation which are of particular importance. However, the recommendations given cannot cover every eventuality and if any doubt arises during the operation of the system the user is strongly advised to contact the supplier.

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2. Magnetic Field

2.1 Overview

Superconducting NMR magnets pose numerous hazards related to the forces caused by the strong magnetic fields associated to these magnets. Precautions must be taken to ensure that hazards will not occur due to the effects of a magnetic field on magnetic materials, or on surgical implants. Such effects include, but are not limited to:

- Large attractive forces may be exerted on equipment in the proximity of the NMR magnet system. The force may become large enough to move the equipment uncontrollably towards the NMR magnet system. Small pieces of equipment may therefore become projectiles.
- Large equipment (e.g. gas bottles, power supplies) could cause bodies or limbs to become trapped between the equipment and the magnet.
- The closer a ferromagnetic object gets to the magnet, the larger the force. Also, the larger the equipment mass, the larger the force.

2.2 Shielding

Most of the newer NMR magnet systems are actively shielded. The following must be understood when installing or working with such a shielded magnet:

- The active shielding of the superconducting coil reduces the stray magnetic fields, and therefore its effects.
- Nevertheless, the magnetic field gradient is much stronger compared to non-shielded magnets, hence the distance interval between various stray field contour lines (for instance distance between 5G and 50G) is much smaller, and caution must be taken to avoid bringing ferromagnetic objects close to the magnet.
- In spite of the active shielding, the stray magnetic field directly above and directly below the magnet is very high and the attractive forces on ferromagnetic objects are very strong!

2.3 Electronic, electrical and mechanical medical implants

The following must be understood concerning the effects on electronic, electrical and mechanical medical implants and devices:

- The operation of electronic, electrical or mechanical medical implants, such as cardiac pacemakers, biostimulators, and neurostimulators may be affected or even stopped in the presence of either static or changing magnetic fields.
- Not all pacemakers respond in the same way or at the same field strength if exposed to fields above 5 gauss.

Continued on next page

2.4. Surgical implants and prosthetic devices

The following must be understood concerning the effects on surgical implants and prosthetic devices:

- Besides electronic, electrical, and mechanical medical implants, other medical surgical implants such as aneurysm clips, surgical clips or prostheses, may contain ferromagnetic materials and therefore would be subject to strong attractive forces near to the NMR magnet system. This could result in injury or death.
- Additionally, in the vicinity of rapidly changing fields (e.g. pulsed gradient fields) eddy currents may be induced in the implant, hence resulting in heat generation and possibly create a life-threatening situation.

2.5 Operation of equipment

The operation of equipment may be directly affected by the presence of strong magnetic fields.

- Items such as watches, tape recorders and cameras may be magnetized and irreparably damaged if exposed to fields above 10 gauss.
- Information encoded magnetically on credit cards and magnetic tapes may be irreversibly corrupted.
- Electrical transformers may become magnetically saturated in fields above 50 gauss. The safety characteristics of equipment may also be affected.

2.6 Before ramping the magnet to field

Prior to start energizing the magnet system, one must:

- Ensure all loose ferromagnetic objects are removed from within 5 gauss field of the NMR magnet system.
- Display magnet warning signs at all points of access to the magnet room.
- Display warning signs giving notice of the possible presence of magnetic fields and of the potential hazards in all areas where the field may exceed 5 gauss.

2.7 After ramping the magnet to field

After energizing the magnet to field, one must:

- Not bring ferromagnetic objects into the magnet room.
- Use only nonmagnetic cylinders and dewars for storage and transfer of compressed gas or cryogenic liquids.
- Use only non-magnetic equipment to transport cylinders and dewars

Continued on next page

2.8 General safety precautions

To prevent situations as described above to occur, the following precautions are provided as guidelines, and they should be regarded as minimum requirements.

- Every magnet site location should be reviewed individually to determine the precautions needed to be taken against these hazards.
- Consideration must be given to floors above and below the magnet as well as the surrounding space at the same level, since the magnetic field produced by the NMR magnets is three dimensional.

3. Magnet Zones

3.1 Introduction

The FDA requires that the hazards listed above are prevented by establishing two secure and clearly marked zones, as follows:

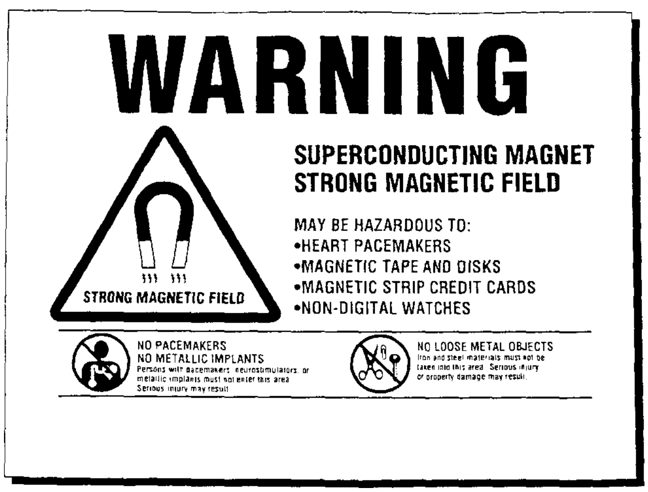
- The exclusion zone, and
- The security zone.

3.2 Exclusion Zone

The following must be understood concerning the exclusion zone:

- **Definition**: The exclusion zone comprises the area (rooms, hallways and so on) inside the magnets 5-gauss line. Individuals with cardiac or other mechanically active implants must be prevented from entering this area.
- **Extension of magnetic field**: The magnetic field surrounds the magnet in a three dimensional fashion. Access must be limited and warning given to individuals who are potentially at risk, not only at the same floor as the magnet, but also at the levels above and below the magnet.
- **Warning signs**: The exclusion zone must be enforced with a combination of warning signs and physical barriers. Figure 1 shows the recommended layout of the warning sign

Figure 1 Warning Sign



3.3 Security Zone

The security zone is usually confined to the room that houses the magnet. The security zone is established to prevent ferromagnetic objects from becoming projectiles. ***Ferromagnetic objects shall not be allowed inside the security zone.***

4. Safe Handling of Cryogenic Substances

4.1 Overview

A superconducting magnet uses two types of cyrogens, liquid helium and liquid nitrogen. Cryogenic liquids can be handled easily and safely provided certain precautions are obeyed.

The recommendations in this section are by no means exhaustive, and when in doubt the user is advised to consult the supplier.

- **Types of substances**: The substances referred to in these recommendations are nitrogen, helium and air. Contact your cryogen supplier for the appropriate MSDS sheets for these cryogens.
  - **Helium**: This is a naturally occurring, inert gas that becomes a liquid at approximately 4K. It is colorless, odorless, non-flammable and non-toxic. In order to remain in a superconducting state the magnet is immersed in a bath of liquid helium.
  - **Nitrogen**: This is a naturally occurring gas that becomes liquid at approximately 77K. It is also colorless, odorless, non-flammable and non-toxic. It is used to cool the shields, which surround the liquid helium reservoir.
- **Cryogen transport dewars**: During normal operation, liquid cryogens evaporate and will require replenishment on a regular basis. The cryogens will be delivered to site in transport dewars. I***t is essential that these cryogen transport dewars are non-magnetic***.
- **Physical properties**: Safe handling of cryogenic liquids requires some knowledge of the physical properties of these liquids, common sense and sufficient understanding to predict the reactions of such liquids under certain physical conditions.

4.2 General safety rules

General safety rules for handling cryogenic substances include, but are not limited to:

- Cryogenic liquids remain at a constant temperature by their respective boiling points and will gradually evaporate, even when kept in insulated storage vessels (dewars)
- Cryogenic liquids must be handled and stored in well ventilated areas.
- Passengers should never accompany cryogens in an elevator. There is a risk of asphyxiation.
- The very large increase in volume accompanying the vaporization of the liquid into gas and the subsequent process of warming up is approximately 740:1 for helium and 680:1 for nitrogen.

Continued on next page

4.3 Cryogen transport dewars

The rules concerning the cryogen dewars used to transport cryogenic liquids include, but are not limited to:

- All cryogen dewars transporting cryogenic liquids must not be closed completely as this would result in a large build up of pressure. This will present an explosion hazard and may lead to large product losses!
- All cryogen transport dewars must be constructed of non-magnetic materials.

4.4 Health hazards

Main health hazard related rules include, but are not limited to:

- Evacuate the area immediately in the event of a large spillage
- Provide adequate ventilation in the room to avoid oxygen depletion. Helium can displace air in the upper area of a room and cold nitrogen can displace air in the lower area. Please see the "Ventilation" section for detailed information.
- Do not come in direct contact with cryogenic substances in liquid or vapor form (or as low temperature gases), since they will produce "cold burns" on the skin similar to burns.
- Do not allow insufficiently protected parts of the body to come in contact with non-insulated venting pipes or vessels (see "Ventilation" section), since the body parts will immediately stick to them. This will cause the flesh be torn if the affected body part is removed.

4.5 First aid

First aid rules include, but are not limited to:

- If any of the cryogenic liquids come into contact with eyes or skin, immediately flood the affected area with large quantities of cold or tepid water and then apply cold compresses.
- Never use hot water or dry heat.
- Medical advice should be sought immediately!

Continued on next page

4.6 Protective clothing

Protective clothing rules include, but are not limited to:

- Protective clothing must be worn mainly to avoid cold burns. Therefore dry leather or cryogenic gloves must be worn when handling or working with cryogenic liquids.
- Gloves must be loose fitting so that they can be removed easily in case of liquid spillage.
- Goggles must be worn to protect the eyes.
- Any metallic objects (e.g. jewelry) should **not** be worn on those parts of the body, which may come into contact with the liquid.

4.7 Others

Other rules of handling cryogens include, but are not limited to:

- Handle the liquids carefully at all times. Boiling and splashing will always occur when filling a warm container.
- Beware of liquid splashing and rapid flash off of cryogens when immersing equipment at ambient temperature into the liquid cryogens. This operation must be carried out very slowly.
- When inserting open ended pipes into the liquid, never allow open ended pipes to point directly towards any person
- Use only metal or Teflon tubing connected by flexible metal or Teflon hose for transferring liquid nitrogen. Use only gum rubber or Teflon tubing.
- Do not use tygon or plastic tubing. They may split or shatter when cooled by the liquid flowing through it and could cause injury to personnel.

4.8 Smoking

Please obey the following basic rules concerning smoking:

- Do not smoke in any rooms in which cryogenic liquids are being handled
- Designate all rooms in which cryogenic liquids are being handled as "No Smoking" areas, using appropriate signs

Additional facts and precautions:

- While nitrogen and helium do not support combustion, their extreme cold dewar causes oxygen from the air to condense on the dewar surfaces, which may increase the oxygen concentration locally.
- There is a particular fire danger if the cold surfaces are covered with oil or grease, which are combustible. **Self-ignition could occur!**

Continued on next page

4.9 Properties of cryogenic substances

Properties	**Nitrogen**	**Helium**
Molecular weight	28	4
Normal boiling point [^oC] [^oK]	-196 77	-269 4.2
Approximate expansion ration (volume of gas at 15'C and atmospheric pressure produced by unit volume of liquid at normal boiling point).	680	740
Density of liquid at normal boiling point [kg m^{-3}]	810	125
Color (liquid)	none	none
Color (gas)	none	none
Odor (gas)	none	none
Toxicity	very low	very low
Explosion hazard with combustible material	no	no
Pressure rupture if liquid or cold gas is trapped.	yes	yes
Fire hazard: combustible	no	no
Fire hazard: promotes ignition directly	no	no
Fire hazard: liquefies oxygen and promotes ignition	no	no

5. Refill of Liquid Nitrogen

5.1 Read this first!

Please read this carefully and make it accessible to anybody working with the magnet system.

- A shielded superconducting NMR Magnet System can be operated easily and safely provided the correct procedures are obeyed and certain precautions observed.
- The recommendations in this section cannot cover every eventuality and if any doubt arises during the operation of the system, the user is strongly advised to contact the supplier.

5.2 Condensing oxygen

Minimize contact with air. Be aware of the following facts and precautions, contact with air occurs:

- Since liquid nitrogen is colder than liquid oxygen, the oxygen in the air will condense out.
- If this happens for a period of time, the oxygen concentration in the liquid nitrogen may become so high that it becomes as dangerous as handling liquid oxygen. This applies particularly to wide necked dewars due to the large surface area.
- Therefore, ensure that contact with air is kept to a minimum.

5.3 Nitrogen flow system

A pressure relief valve is provided for the nitrogen vessel to ensure that at least the rear neck tube cannot be blocked by the ingress of air or moisture. **This valve shall be mounted at all times even when the vessel is being refilled.**

5.4 Refill of liquid nitrogen

Other general rules include, but are not limited to:

- Do not allow liquid nitrogen to spill onto the room temperature bore closure flanges when the refilling the nitrogen vessel
- Place gum rubber tubes or Teflon tubes on the nitrogen neck tubes during refill!
- **Stop the transfer immediately when the vessel is full.** Failure to observe this can lead to the freezing of the o-rings and a subsequent vacuum loss of the magnet cryostat.

6. Refill of Liquid Helium

6.1 Read this first!

Please read this carefully and make it accessible to anybody working with the magnet system.

- A shielded superconducting NMR Magnet System can be operated easily and safely provided the correct procedures are obeyed and certain precautions observed.

The recommendations in this section cannot cover every eventuality and if any doubt arises during the operation of the system, the user is strongly advised to contact the supplier.

6.2 General rules when handling liquid helium

Be aware of these general rules including, but not limited to:

- Liquid helium is the coldest of all cryogenic liquids.
- Liquid helium will condense and solidify any other gas (air) coming into contact with it.
- Liquid helium must be kept in specially designed storage or transport dewars.
- Dewars should have a one way valve fitted on the helium neck at all times, in order to avoid air entering the neck and plugging it with ice.
- Only vacuum insulated pipes should be used for liquid helium transfer. Breakdown of the insulation may give rise to the condensation of oxygen.

6.3 The helium vessel

The superconducting NMR magnets contain an inner vessel with liquid helium.

- The helium vessel should be checked weekly for boil-off and helium level.
- Use a helium flow meter or a helium gas counter!
- A one way valve is supplied to be mounted on the helium manifold to ensure that the helium neck tubes cannot be locked by the ingress of air or moisture. This valve should be mounted at all times except during a helium transfer

Continued on next page

6.4 Refill of liquid helium

Please follow the following instructions concerning the refill of NMR magnets with liquid helium:

- Refill the helium vessel within the specified hold time period and certainly before the level falls below the allowed **minimum** level listed in the magnet manual.
- **Important Note: Transfer of liquid helium can be done easily and safely, provided:**
  - the handling of the helium transfer line is correct,
  - the helium transfer line is not damaged, and
  - the transfer pressure does not exceed 2 psi.
- Never insert a warm helium transfer line into the cryostat, since the warm helium gas could lead to a quench of the magnet!
- Always allow the helium transfer line to cool down to helium temperature before inserting it into the right helium neck tube. You should see liquid helium leaving of the short end transfer lines for a few moments, before inserting it into the right helium neck tube.

6.5 Rapid Helium transfer

Do not remove the nitrogen security flow system during any transfer liquid helium!

During a rapid transfer of liquid helium, super cooling of the liquid nitrogen occurs. This can lead to the following:

- Decrease of static boil off to zero, and producing a negative pressure in the nitrogen vessel
- Transfer of air or moisture that can be sucked into the necks of the vessel, and which would solidify and create ice blockages.

7. Ventilation

7.1 General safety rules concerning ventilation

General safety rules concerning ventilation include, but are no limited to:

- Cryogenic liquids, even when kept in insulated storage dewars, remain at a constant temperature by their respective boiling points and will gradually evaporate. These dewars must always be allowed to vent or dangerous pressure buildup will occur.
- Cryogenic liquids must be handled and stored in well ventilated areas.
- The very large increase in volume accompanying the vaporization of the liquid into gas and the subsequent process of warming up is approximately 740:1 for helium and 680:1 for nitrogen.

7.2 Ventilation during normal operation

Superconducting magnets use liquid nitrogen and liquid helium as cooling agents, and a boil-off of liquid cryogens is expected during the normal operation of the magnet system, as follows:

- Normal boil-off of liquids contained in the magnet based on the given boil-off specifications
- Boil-off of cryogens during the regular refills with liquid nitrogen and liquid helium.

The gases are nontoxic and completely harmless as long as adequate ventilation is provided to avoid suffocation. Rules for ventilation during normal operation include but are not limited to:

- The NMR magnet system should never be in an airtight room. The magnet location should be selected such that the door and the ventilation can be easily reached from all places in the room.
- Room layout, ceiling clearance and magnet height should be such that an easy transfer of liquid nitrogen and helium is possible. This will considerably reduce the risk of accidents.

7.3 Emergency Ventilation during a quench and during magnet installation

A separate emergency ventilation system should be provided to prevent oxygen depletion in case of a quench or during the magnet installation.

During a quench, an extremely large quantity of helium gas (i.e. 1,500 to 21,000 ft^3 depending on the magnet type) are produced within a short time

During the installation and cooling of superconducting magnets, under certain conditions, large volumes of nitrogen or helium gases may be generated.

Continued on next page

7.3 Emergency Ventilation during a quench and during magnet installation (continued)

Although these gases are inert, if generated in large enough quantities, they can create dangerous circumstances if they displace the oxygen in the room. The table below illustrates this with examples.

Notes:

- The values below are approximate may not reflect actual conditions. They are to be used for example only.
- Pre-cool times vary.
- Quench times are generally longer.
- Please consult with Bruker BioSpin for values associated to your NMR magnet system

Magnet type	N2 gas liberated during pre-cool	Time to liberate N2 gas during pre-cool	He gas liberated during Cooling and filling	Time to evolve He gas during cooling and filling	He gas liberated during a "quench"	Time to liberate He gas during a "quench"
UltraShield 300/54	3,600 ft^3	4 hours	5,300 ft^3	3 hours	1,400 ft^3	0.5 minute
UltraShield 700/54	31,500 ft^3	24 hours	30,000 ft^3	6 hours	11,800 ft^3	1 minute

7.4 Emergency exhaust

There are various types of emergency exhaust that can be implemented to avoid oxygen depletion during a quench or during the installation of the magnet system. These include, but are not limited to:

- **Active exhaust**: This solution is based on a motorized fan, vents, and exhaust duct pipe that is not connected to the magnet itself. The exhaust should be activated both automatically by an O2 sensor, as well as manually by a switch in the room. The latter is needed during magnet installation and regular refills to prevent cryogen build-up in the room by evacuating them faster than the regular HVAC system.
- **Passive exhaust**: This solution is based on louvers in the ceiling that open by the gas due to the overpressure of helium gas during a quench.

Continued on next page

7.4 Emergency exhaust (continued)

- **Quench pipe**: This solution is based on a pipe connected directly to the magnet, which is then routed to the outside of the building. It is important to note the following:
  - Ideally, the helium exhaust from the magnet should be vented directly to the outside of the building in case a quench occurs.
  - The ducting to the outside of the building should be of large enough diameter to avoid excessive pressure build up due to the flow impedance of the duct.
  - The location of the exit end of the exhaust duct must not allow unrestricted access to anyone other than service personnel; in addition the exit opening should be protected from the ingress of rain, snow or any debris which could block the system.
  - It is also essential to ensure that any gas which vents from the exhaust duct cannot be drawn in to any air conditioning or ventilation system intakes. The location of duct's exit should be carefully sited to prevent this from happening in all atmospheric conditions and winds.
  - Insulation of accessible exhaust piping should also be provided to prevent cold burns during a quench.
- **Exhaust for magnet pits**: Special attention to ventilation and emergency exhaust must be given when magnets are placed inside pits. Magnet pits are confined spaces with a possibility of increased risk of oxygen depletion if appropriate exhaust measures are not taken.
  - Nitrogen is heavier than the air and starts filling the pit from the bottom during the magnet pre-cool or regular nitrogen fills
  - It is essential to provide a low exhaust system down inside the pit to efficiently evacuate the nitrogen gas and prevent oxygen depletion

---

7.5 Oxygen monitor and level sensors

An oxygen monitor is required inside the magnet room. The following sensors should be provided:

- **Above the magnet**: One oxygen level sensor above the magnet, to detect low oxygen levels due mainly to He gas
- **Close to floor**: One oxygen level sensor 1' off the floor of the magnet room
- **Down in the pit**: One additional oxygen level sensor 1' off the bottom of the pit, in case the magnet is located inside a pit.

AVANCE™ UltraStabilized™

PRE-INSTALLATION SITING REVIEW, *Rev. 3.0, January 2006*

CUSTOMER INFORMATION

Institution:

Users Name/Title:

E-mail
Phone

Name of person
filling out this form:

Date:

Magnet Type	**Accessories**
☐ 750 MHz WB	☐ MAS
☐ 800 MHz	☐ Solids
☐ 800 US^2 MHz	☐ BCU-05 Cooling Unit
☐ 900 MHz	☐ BACS Sample Changer, NMR Case
☐ Other ______	☐ CryoProbe
	☐ u Imaging
	☐ Other _______________

Expected Date of Delivery and Start of Installation:

NMR SYSTEM AND LARGE PACKAGES DELIVERY ADDRESS:

End Users Name:
Phone:
E-mail:

Facility manager:
Phone:
E-mail:

Receiving hours of operation:

FEDEX , UPS, MAIL – REGULAR PACKAGES DELIVERY ADDRESS

Receiving hours of operation:

1. ACCESS AND RIGGING

Delivery Area and Off-loading

- Is there sufficient space in the driveway or parking for the overhead crane and for the delivery flat-bed truck?
  - ❑
- Is there sufficient leveled area for uncrating the magnet crate?
  - ❑
- Distance of reach for the crane, estimated crane size needed
  - ❑
- Is access to the NMR room being done with a crane through hatch in the roof?
  - ❑
- Is the NMR room at a different elevation relative to the delivery area? If yes, explain how is the access to the NMR room being done
  - ❑
- Is access to the NMR room requiring air-skates?
  - ❑

Continued on next page

ACCESS AND RIGGING, Continued

Access to the NMR Room

- Is there a suitable leveled slab (pad) in front of the access doors for positioning the magnet on air-skates? Is the slab capable to handle the size and weight of the magnet?
  - ❑
- Are masonite sheets needed to correct imperfections and protect flooring?
  - ❑
- Clearances along the access path from the delivery area to the NMR room
  - ❑
- Load bearing capacity along the access path
  - ❑
- Access of fork-truck or palette-jack
  - ❑

Rigging inside the lab for magnet lifting

- Fixed lifting hook in the ceiling/beam:
  - ❑ Hook height (floor to bottom of ceiling hook)
  - ❑ Max. lifting load
  - ❑ Height clearance from floor to hook of hoist system
- Hydraulic lift system with I-beam
  - ❑ Height clearance for setting-up the hydraulic lift system:
- Bruker special hydraulic lift system:

2. CEILING HEIGHT REQUIREMENTS

Height for lifting magnet	• Ceiling height from the floor to underside of ceiling: • Ceiling hook height if applicable: • Footprint of ceiling above magnet with max. height clearance:
Height for magnet energization	• Final ceiling height above magnet measured from the floor: • Type of energizing rods (standard or bendable):
Height above He dewars	• Ceiling height above He transport dewar measured from the floor:
Obstructions above and below magnet	•

3. FLOOR PLAN

Stray Fields

- Is the 5G line completely enclosed within the NMR room?
  ❑
- Is the magnet He cooling pump unit as well as the He compressor for the CryoProbe going to be located outside the 5G line?
  ❑

Magnet Pit

- Footprint of the magnet pit:
- Depth of the pit:
- Reinforcement in the slab and walls of the pit:

Magnet Slab

- Is the magnet going to be placed on its own slab, isolated from the rest of the floor of the NMR room?
  ❑
- Is the isolation preventing the transmission of both vertical and horizontal vibrations? How is the isolation being done?
  ❑
- Size of the magnet slab:
- Type of reinforcement used for the magnet slab:
- Type of reinforcement is used for the main floor of the NMR room:

Magnet Platform

- Material:
- Overall footprint of the magnet platform:
- Is the magnet platform going to be supported from the outside the magnet slab?
  ❑
- Are the support posts going to interfere with the magnet, with the access to the magnet, or with the installation of the CryoProbe?

- Diameter of the circular opening:
- Height of the platform deck:
- Border around the opening:
- Removable section to allow for magnet access:

Continued on next page

3. FLOOR PLAN, Continued

Magnet Orientation	• Stairs of the platform: • Magnet Manifold: • He fill port, He supply dewars • Front of magnet stand, CryoProbe, Shims:
Trenches	• Are there any trenches? If yes, please describe the scope and provide dimensions. ❑
Magnet Pump Line – Route to the Pump Unit	• Route of magnet pump line:
NMR Equipment	• UPS, Pump unit, BMPC, Avance cabinet, workstation: • BCU-05:
CryoProbe Siting	• CryoCooling unit: • Transfer lines from CryoProbe to the CryoCooling unit: • Buck-booster transformer: • He compressor: • Water chiller, and water quality: • He gas cylinder (high purity): • Back-up gas cylinder:

Continued on next page

3. FLOOR PLAN, Continued

Floor plan drawing

4. ENVIRONMENT AND SITE SURVEY MEASUREMENTS

Vibrations

- Measurements on the magnet slab and outside the slab
- Sources of vibrations:
- Expected vertical accelerations on the magnet with the standard vibration isolation units (inflatable Firestone tires) activated:

Magnetic Environment

- Is there any iron mass including reinforcement in the walls and floor that is present within an area of 12’ (4 m) radius from the magnet center (MC)?
  ❑
- Are there any steel beams, columns radiators, plumbing pipes, metal tables, metal doors, filing cabinets, or other massive static steel objects within an area of 14’ (4.3 m) radius from MC?
  ❑
- Is there any moving iron mass present within an area of 20’ (6 m) from MC?
  ❑
- Are there any moving steel objects as large metal doors, hand trolley, or any large steel parts of rotatory machines and other mechanical equipment present within an area of 30’ (10 m) radius from MC?
  ❑
- Are there any elevators, trucks, cars, fork-lifts and alike being operated within 45’ (14 m) distance from MC?
  ❑
- Are there any trains passing within 120’ (37 m) distance from MC?
  ❑

Continued on next page

4. ENVIRONMENT AND SITE SURVEY MEASUREMENTS, Continued

EMF Interference

- DC: a) Are there any trains, subways, trams or associated DC power lines present within 600’ (~ 190 m) distance from MC? b) Are there any mass spectrometers located into the room or adjacent spaces?
  - ❑
  - ❑ DC EMF measurements
- AC: Are there any large transformers, AC power lines, or powerful lighting in close proximity to the magnet location?
  - ❑
  - ❑ AC 60Hz EMF measurements
- RF: a) Are there any known TV / Radio Stations, Cellular Phone Towers and Antennas, or other possible sources of RF in the building or within a radius of 5 miles (~8 km)? b) Are there any other NMR or MRI systems operating at the same resonance frequency?
  - ❑
  - ❑ Details on possible RF sources
  - ❑ RF analysis

5. UTILITY REQUIREMENTS

Electrical Power, phone line commun.

- Main Power Disconnect Box: 208V/60A single phase
  ❑
- Additional 208V single phase NEMA L6-30R (1), L6-20R (2)
  ❑
- 110V outlets:
  ❑
- Power for the CryoCooling. Would a UPS cover it?
  ❑
- Power for the He compressor. Is it on emergency power?
  ❑
- Power for BCU-05:
  ❑
- Power for the workstation. Would a UPS cover it?
  ❑
- Back-up emergency generator:
  ❑
- Fax / modem dedicated line:
  ❑

(Refer to the Site Planning Manual for non-North American requirements)

Compressed gas

- Air:
  ❑
- Nitrogen:
  ❑
- Pressure
- Flow:
- N2 separator:

Water

- Chiller and quality specs for water (CryoProbe with indoor water-cooled He compressor
  ❑

Continued on next page

5. UTILITY REQUIREMENTS, Continued

Lighting

- Types of lights:
  - ❑
- Are all lights at least 10’ (3 m) away from the magnet center?
  - ❑
- Are there any spot lights on the magnet?
  - ❑

HVAC

- Is there an HVAC system dedicated to the NMR room?
  - ❑
- Is the air flow into the NMR room continuous:
  - ❑
- How is the air temperature control being done? Are there any control switches operating the HVAC that may cause oscillations in flow/temperature:
  - ❑
- Is the HVAC exchanging a large air-volume and are there any air drafts inside the NMR room associated to it?
  - ❑
- Is there noticeable noise (acoustical vibrations) produced by the HVAC system?
  - ❑
- Is there ductwork present in the room or adjacent space, what is the material that is made out of, and does it show signs of vibrations?

- Location of air supply diffusers and return (exhaust) grills
  - ❑
- Is there any air draft towards magnet or console?
  - ❑
- Are there any windows in the NMR room and any direct sunlight in the space?
  - ❑
- What is expected temperature stability inside the NMR room, in the area of the magnet and console?

Continued on next page

5. UTILITY REQUIREMENTS, Continued

Emergency Gas Exhaust, and misc. utilities

- Space volume available in the NMR room (approx.):
- Volume of He gas after a quench:
- Calculated height of He gas cloud (measured from the floor) after a quench:
- Type of emergency exhaust:
  - ❑ Passive (louver):
  - ❑ Active (fan) and activation:
  - ❑ Quench pipe:
- Ventilation required during the installation (cooling of magnet) and follow-up cryogen fills:
- Make-up air for emergencies:
- Location of smoke detectors:
- Location and type of sprinkler heads”
- O2 sensors - in the upper part as well as lower part of the room?
  - ❑ Location
  - ❑ Automatic switch-on of the emergency exhaust
  - ❑ Heat sensors wired-in to the O2 sensors
- Manual override button for emergency exhaust / conditions:
  - ❑

Cryogens

- Cryogen storage room:
- Cryogens needed for the installation:
  - ❑ Liquid cryogens: LN2 and LHe
  - ❑ Gases
- What is the access path for cryogen supply dewars, and are all openings large enough for these dewars. Is the access path for the cryogen dewars intrude into the 5G areas of adjacent magnets?
- High purity He gas for the CryoProbe:
- Back-up N2 or air for the CryoProbe (assumes the sample protection is included with the order):

6. DECLARATION BY THE INSTALLATION CONTACT

Declaration by the Installation Contact

I acknowledge receipt of the Bruker BioSpin document entitled "General Safety Considerations for the Operation and Installation of Superconducting Magnets".

I confirm that, to the best of my knowledge and belief, the information that I have given in sections 1 – 5 of this Site Planning Checklist is accurate.

For safety reasons I agree that the Bruker BioSpin installation engineer will not be allowed to work alone at any time, and his work will be suspended if left unaccompanied.

I understand that after the magnet has been installed, for safety reasons, routine maintenance tasks involving transfer of cryogenic liquids must be performed by personnel formally trained to do so.

Signature of Installation Contact: ……………………………..

Name of Installation Contact: ……………………………..

Date: ……………………………..

7. DECLARATION BY THE SAFETY OFFICER

Safety Officer

Your Site Safety Officer must complete this section.

Magnet Lab Safety Officer's name …………………………
Magnet Lab Safety Officer's telephone number …………………………
Magnet Lab Safety Officer's e-mail address …………………………

Safety Hazards: Please describe any existing hazards present on your site that our Installation Engineer should be aware of e.g. chemicals/acids, laser equipment, radioactive sources, other magnetic devices, etc.

....
...........………………………………*please continue on separate sheets if necessary*

Induction Training: If you feel that our Installation Engineer will require Induction Training to prepare him for the hazards on your site, please indicate the type and duration of such training:

....

Cryogen Storage: Is there a facility for the safe storage of cryogens and gas cylinders on your site?

☐ Yes If no, briefly explain………………………………………
☐ No ………………………………………………………………….

Cryogen Transportation: What arrangements do you have to safely transport cryogen dewars from the delivery point to their final point of use?

…………………………………………………………………………………
…………………………………………………………………………………

Note: Users are reminded that personnel must never accompany cryogen dewars in elevators.

O2 Monitor: Will an oxygen level monitoring device be available at the magnet's location?

☐ Yes If no, briefly explain………………………………………
☐ No ………………………………………………………………….

Lifting Equipment: Are records/certificates available to confirm that the lifting equipment to be used to move and assemble the magnet is in sound condition and subject to regular examinations?

☐ Yes If no, briefly explain………………………………………
☐ No ………………………………………………………………….

Continued on next page

7. DECLARATION BY THE SAFETY OFFICER, Continued

Declaration by the Safety Officer

I acknowledge receipt of the Bruker BioSpin document entitled "General Safety Considerations for the Operation and Installation of Superconducting Magnets".

I confirm that, to the best of my knowledge and belief, the safety information that I have given in this section 7 of the Site Planning Checklist is accurate.

For safety reasons I agree that the Bruker BioSpin installation engineer will not be allowed to work alone at any time, and his work will be suspended if left unaccompanied.

I understand that after the magnet has been installed, for safety reasons, routine maintenance tasks involving transfer of cryogenic liquids must be performed by personnel formally trained to do so.

Signature of Site Safety Officer:	…………………………..
Date:	……………....................
Name of Site Safety Officer:	…………………………..
Telephone:	…………………………..
Fax:	…………………………..
E-mail:	…………………………..
