Fourier Systems

General Safety Considerations

User Manual

Version 001

Innovation with Integrity

NMR

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Table of Contents

1 About

1.1 This Manual

The purpose of this manual is to summarize the safety considerations which apply to the Fourier system. It does not replace the individual manuals but is meant as a quick and easy access to the relevant information concerning safety issues. As such, one copy should always be available at the operator's desk. Please, take care that each operator of the system is aware of the importance of this manual. In addition, each operator is advised to read the manual in order to be aware of any safety risks which may be related to the use of the Fourier system.

The figures shown in this manual are designed to be general and informative and may not represent the specific Bruker model, component or software/firmware version you are working with. Options and accessories may or may not be illustrated in each figure.

Carefully read all relevant chapters before working on the device!

1.2 Policy Statement

It is the policy of Bruker to improve products as new techniques and components become available. Bruker reserves the right to change specifications at any time.

Every effort has been made to avoid errors in text and figure presentation in this publication. In order to produce useful and appropriate documentation, we welcome your comments on this publication. Support engineers are advised to regularly check with Bruker for updated information.

Bruker is committed to providing customers with inventive, high quality products and services that are environmentally sound.

1.3 Symbols and Conventions

Safety instructions in this manual are marked with symbols. The safety instructions are introduced using indicative words which express the extent of the hazard.

In order to avoid accidents, personal injury or damage to property, always observe safety instructions and proceed with care.

⚠ DANGER
This combination of symbol and signal word indicates an immediately hazardous situation which could result in death or serious injury unless avoided.

WARNING

This combination of symbol and signal word indicates a potentially hazardous situation which could result in death or serious injury unless avoided.

CAUTION

This combination of symbol and signal word indicates a possibly hazardous situation which could result in minor or slight injury unless avoided.

NOTICE

This combination of symbol and signal word indicates a possibly hazardous situation which could result in damage to property or the environment unless avoided.

This symbol highlights useful tips and recommendations as well as information designed to ensure efficient and smooth operation.

2 Introduction

2.1 Fourier NMR Spectrometer Intended Use

The Bruker Fourier systems should only be used for their intended purpose as described in their respective manuals and outlined in this section.

Use of the unit for any purpose other than that for which it is intended is taken only at the users own risk and invalidates any and all manufacturer warranties. Service or maintenance work on the consoles must be carried out by qualified personnel. Only those persons schooled in the operation of Bruker spectrometers should operate the unit.

The Bruker Fourier systems are ultra high precision spectrometers for the analysis of chemical structures and molecular properties. Small liquid or solid samples are placed into an extremely strong magnetic field. They are irradiated with short radio frequency pulses and the resulting weak transient radio frequencies emitted thereafter by the magnetically active nuclei (of selected chemical elements) of the samples are then observed. The instrumental technique is called Nuclear Magnetic Resonance spectroscopy (NMR).

Fourier spectrometers are available with vertical bore magnets of field strength between 4.7T to 7T with a room temperature bore size of 54 mm. Typical sample amounts range from nanogram to less than gram level.

The method allows to identify and/or confirm the structure of chemical and biochemical compounds and mixtures including information concerning molecular mobility and interactions.

The method is also used to obtain information about the distribution of magnetically active nuclei within a sample (NMR Imaging, NMR Microscopy).

Typical applications of NMR spectrometers are in all areas of academic and industrial research and quality control in the fields of materials science, organic chemistry, inorganic chemistry, and in the analysis of biological samples.

The Fourier spectrometer line can be equipped/connected with a large variety of optional accessories such as:

- Variable temperature control
- Variable magnetic field gradients
- Automatic sample changers
- Automatic sample preparation

Fourier spectrometers are not designed primarily for:

- Investigations of ferromagnetic materials.

Fourier Spectrometers are not approved for diagnostic purposes in the medical field such as IVD according to legal requirements.

2.2 Purpose of this Manual

The purpose of this manual is to summarize the safety considerations which apply to the Fourier system. It does not replace the individual manuals but is meant as a quick and easy access to the relevant information concerning safety issues. As such, one copy should always be available at the operator's desk. Please, take care that each operator of the system is aware of the importance of this manual. In addition, each operator is advised to read the manual in order to be aware of any safety risks which may be related to the use of the Fourier system.

2.3 Magnetic Safety

In terms of safety the presence of a relatively strong magnet is what differentiates NMR spectrometers from most other laboratory equipment. When designing an NMR laboratory, or training personnel who will work in or around the laboratory, no other feature is of greater significance. As long as correct procedures are adhered to, working in the vicinity of superconducting magnets is completely safe and has no known harmful medical side effects. Negligence however can result in serious accidents. It is important that people working in the vicinity of the magnet fully understand the potential hazards.

Of critical importance is that people fitted with cardiac pacemakers or metallic implants should never be allowed near the magnet.

A magnetic field surrounds the magnet in all directions. This field (known as the stray field) is invisible and hence the need to post warning signs at appropriate locations. Objects made of ferromagnetic materials, e.g. iron, steel etc. will be attracted to the magnet. If a ferromagnetic object is brought too close, it may suddenly be drawn into the magnet with surprising force. This may damage the magnet, or cause personal injury to anybody in the way!

Because the strength of the stray field drops significantly as one moves away from the magnet, it is useful to discuss safety in terms of two broadly defined regions, the inner and outer zone. In terms of organizing a laboratory as well as defining good work practices, the concept of an inner and outer zone is particularly useful.

The physical extent of these two zones will depend on the size of the magnet. The bigger the magnet, the stronger the stray magnetic fields and hence the larger the extent of the two zones. Details of stray fields for various magnets can be found in the Site Planning Guides delivered with the BASH CD.

2.3.1 Safety Precautions within the Inner Zone

The inner zone extends from the magnet center to the 1mT (10 Gauss) line. Within this region objects may suddenly be drawn towards the magnet center. The attractive force of the magnet can change from barely noticeable to uncontrollable within a very short distance. **Under no circumstances should heavy ferromagnetic objects be located or moved within this zone**.

Any ladders used when working on the magnet should be made of non-magnetic material such as aluminum. Helium and nitrogen dewars which are used to top up the liquid levels inside the magnet must be made of non-magnetic material.

Do not allow small steel objects (screwdrivers, bolts etc.) to lie on the floor near the magnet. These could cause serious damage if drawn into the magnet bore, especially when no probe is inserted in the magnet.

Mechanical watches may be damaged if worn within the inner zone. Digital watches can be worn safely. Of course, the precautions for the outer zone which will now be discussed must also be adhered to within the inner zone.

2.3.2 Safety precautions within the outer zone

The outer zone extends from the 1mT line to the 0.3mT line. The magnet's stray field does not get blocked by walls, floors or ceilings and the outer zone may well encompass adjoining rooms. The stray field may erase information stored on magnetic tapes or discs. Bank cards, security passes or any devices containing a magnetic strip may be damaged. CD's will not be damaged, although CD drives may contain magnetic parts. When using pressurized gas cylinders made of steel, they should be located well beyond the outer zone (preferably outside the magnet room) and must always be properly fixed to the wall. The color display of computer monitors may suffer some distortion when located too close to the magnet, although permanent damage is unlikely. Once beyond the outer zone any special precautions on account of the magnet stray field are no longer necessary.

2.4 Cryogenic Safety

The magnet contains relatively large quantities of liquid helium and nitrogen. These liquids, referred to as cryogens, serve to keep the magnet core at a very low temperature.

Because of the very low temperatures involved, **gloves**, a **long sleeved shirt or lab coat** and **safety goggles** should always be worn when handling cryogens. Direct contact with these liquids can cause frostbite. The system manager should regularly check and make sure that evaporating gases are free to escape from the magnet, i.e. the release valves must not be blocked. Do not attempt to refill the magnet with helium or nitrogen unless you have been trained in the correct procedure.

Helium and nitrogen are non-toxic gases. However, because of a possible **magnet quench**, whereupon the room may suddenly fill with evaporated gases, adequate ventilation must always be provided.

2.5 Electrical Safety

The spectrometer hardware is no more or less hazardous than any typical electronic or pneumatic hardware and should be treated accordingly. Do not remove any of the protective panels or grounding measures from the various units. They are fitted to protect you and should be opened by qualified service personnel only. The main panel at the rear of the console is designed to be removed using two quick release screws, but again, this should only be done by trained personnel. Please note that, unless disconnected, cooling fans on the rear panel will continue to run even with the panel removed.

Before maintenance, repair or shipment, the Fourier System and/or its components must be completely switched off and unplugged or disconnected and dismounted from the rack. Refer to the individual component manuals for specific

information.

2.6 Chemical Safety

Users should be fully aware of any hazards associated with the samples they are working with. Organic compounds may be highly flammable, corrosive, carcinogenic etc.

2.7 CE Certification

All major hardware units housed in the Fourier with SGU consoles as well as peripheral units such as the magnet, HPPR, shim systems, probe and BSMS keypad comply with the CE Declaration of Conformity. This includes the level of any stray electromagnetic radiation that might be emitted as well as standard electrical hazards. Note that to minimize electromagnetic radiation leakage, the doors of the console should be closed and the rear paneling mounted.

2.8 Operating Environment

Permissible Ambient Temperature:	5 to 40 °C.
Permissible Altitude:	Up to 2000 meters above sea level.
Relative Humidity:	A maximum of 80% up to 31 °C and linear decreasing to 50% at 40 °C.
Permissible Storage Temperature:	5 to 40 °C
Ingress Protection Class:	IP 20

The power requirements for the various Fourier systems vary according to the configuration. Additional information on power requirements can be found in the corresponding Site Planning Manual.

2.9 Signs and Labels

Signs and labels always relate to their immediate vicinity. The following signs and labels are found on or around the Fourier system:

Prohibition sign: No person with pacemakers!

- People with pacemakers are endangered in the marked area and are not allowed to enter these areas!

Prohibition sign: No person with implants!

People with metallic implants are endangered in the marked area and are not allowed to enter these areas!

Prohibition sign: No watches or electronic devices!

Watches and electronic devices may be damaged in the marked area!

Prohibition sign: No credit cards or other magnetic memory!

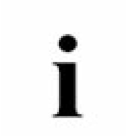
Credit cards and magnetic memory may be damaged in the marked area!.

Prohibition sign: Do not touch!

Do not touch the marked area!

Hazard warning sign: Warning!

Disregard of this may lead to personal injury!



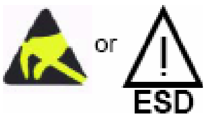
Notes: Hint for good operating practice.

Hazard warning sign: Strong magnetic field!

- No magnetic memory.
- No jewelry.
- No metallic items.

Hazard warning sign: Risk of damage to life and limb due to electricity and high voltage!

Risk of damage to life and limb due to contact with electrical lines and damaged isolation!



Electrostatic Sensitive Device

Observe precautions for handling.

Protective Ground (Earth) Terminal

Used to identify any terminal which is connected to the external protective conductor or protection against electrical shock in case of fault.

2.10 SI to US Conversion Factors

The following conversion factors can be/were used to convert the units used within this manual:

Measure	SI Units	U.S. 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.
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 (standard)
Temperature	°C	°F	F = C × 1.8 + 32
	°F	°C	C = (F - 32) / 1.8
Magnet Field Strength	Tesla (T)	Gauss (G)	1 T = 10^4G

Table 2.1 SI to U.S. Conversion Factors

3 Cabinet Safety

3.1 General Safety Instructions

The Fourier system user should check the equipment at regular intervals for any damage or wear and inform service immediately of any abnormality.

Do no use the equipment and inform the service staff, if you are in doubt about the correct state of any component!

In the unlikely case of one of the following, stop using the equipment, interrupt the current supply, disclose this circumstance to the service staff and ask for instructions:

- The power cord, power plug or power supply are cracked, brittle or damaged.
- Signs of excessive heat appear.
- There is evidence or suspicion that a liquid has intruded into any enclosure.
- The power cord or the power supply have been in contact with any liquid.
- The unit/components has been dropped or damaged in any way.

3.2 Console Safety

WARNING: To minimize shock hazard the Fourier console must be connected to an electrical ground as noted in the section above.

The electronics cabinet is equipped with a three-conductor AC power cable. Only use power cables approved by BRUKER or compliant with IEC safety standards.

3.3 Emergency Shutoff

The mains switch on the back of the Fourier console serves as an EMERGENCY OFF.

The on/off switch on top of the console switches the unit off, but the unit remains in standby mode. The mains switch on the back of the consoles powers down the console completely.

Location of the Emergency Shutoff

Figure 3.1 Location of the Console Emergency Shutoff

3.4 Personnel Safety

Technically Qualified Personnel Only

WARNING: Installation and servicing should only be done by BRUKER qualified personnel. Always disconnect power cable before servicing. Under certain conditions dangerous voltages may exist even with the power cable removed. To avoid injuries, always disconnect power and discharge circuits before touching them.

NOTE: Operating personnel must not remove chassis covers except as described in this manual. User interface, system messages, and manuals require a good understanding of the English language.

Electrical Safety

The Fourier systems's degree of protection against electrical hazard complies with IEC IP20, i.e. all electrical parts are protected against touching.

WARNING: All electrical connectors must be used as supplied by BRUKER. Do not substitute them by other types.

Cleaning

WARNING: Always switch power off and disconnect the power cable before cleaning. Never power on until all surfaces are completely dry.

Clean the outside of the cabinet with a soft, lint-free cloth dampened in water. Do not use any detergent or other cleaning solvents.

4 Magnet Safety

An UltraShield™ or Ascend™ 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 an UltraShield™ 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.

Warning: To minimize shock hazards the magnet and its stand must be connected to the electrical ground of the cabinet!

Warning Areas

The installation and operation of an UltraShield 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, and the process of the installation generally, **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. It is the intention of Bruker's customers to communicate effectively the information in this manual regarding safety procedures and hazards associated with NMR magnet systems to their own customers and to users of the equipment.

4.1 Magnetic Field

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.

4.1.1 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!

4.1.2 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.

4.1.3 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.

4.1.4 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.

4.1.5 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.

4.1.6 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.

4.1.7 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.

4.2 Controlled Access Area

For equipment that generates a stray field exceeding 0.5 mT outside its permanently attached cover, and/or an electromagnetic interference level that does not comply with IEC 60601-1-2, a *Controlled Access Area* must be defined and permanently installed around the equipment such that outside this area:

- The magnetic fringe field strength shall not exceed 0.5 mT, and
- The electromagnetic interference level complies with IEC 60601-1-2:2001.

The stray field plots for the various magnets can be found in the corresponding magnet manual. These plots indicate the position of the 0.5 mT line.

The Controlled Access Area shall be delimited, e.g. by markings on the floor, barriers and/or other means to allow the responsible staff to adequately control access to this area by un-authorised persons.

The Controlled Access Area should be labelled at all entries by appropriate warning signs, including an indication of the presence of magnetic fields and their attractive force or the torque on ferromagnetic materials.

The following figure shows the recommended layout of the warning sign:

4.3 Safe Handling of Cryogenic Substances

A superconducting magnet uses two types of cryogens, 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.

4.3.1 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 4 K. 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. It 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.

4.3.2 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.

4.3.3 Cryogen Transport Dewars

The rules concerning the cryogen dewars used to transport cryogenic liquids transport 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.

4.3.4 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 since the body parts will immediately stick to them. This will cause the flesh be torn if the affected body part is removed.

4.3.5 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!

4.3.6 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.

4.3.7 Other Safety Rules

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.

4.3.8 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.
- 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!

4.4 Liquid Nitrogen Refill

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.

4.4.1 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.
- Ensure that contact with air is kept to a minimum.

4.4.2 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 should be mounted at all times even when the vessel is being refilled!

4.4.3 Other General Rules

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.

4.5 Liquid Helium Refill

Please read this section 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.

Be aware of the following 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.

4.5.1 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

4.5.2 Helium Refill Instructions

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.
    - The transfer pressure does not exceed 2 psi (0.14 bar).
- 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.

4.5.3 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.

4.6 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.

4.6.1 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.

4.6.2 Emergency Ventilation During Magnet Installation or a Quench

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, and under certain conditions, large volumes of nitrogen or helium gases may be generated.

Although these gases are inert, if generated in large enough quantities, they can create dangerous circumstances if they displace the oxygen in the room.

4.6.3 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 (Heating Ventilation Air Conditioning) system.

Passive Exhaust

This solution is based on lovers in the ceiling that open by the gas due to the overpressure of helium gas during a quench.

Quench Pipe

This solution is based on a pipe connected directly to the magnet, which is then routed to the outside of he 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 ducts 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.

4.6.4 Oxygen Monitor and Level Sensors

An oxygen monitor is required inside the magnet room.The following monitor and 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.

5 Probe Safety Considerations

BRUKER probes are designed to hold the sample, transmit radio frequency signals which excite the sample and receive the emitted response. The transmission and reception is achieved by using specially designed RF coils.

The probe is inserted into the bottom of the magnet and sits inside the room temperature shims. Coaxial cables carry the excitation signals from the console amplifiers to the probe and the NMR signal back from the sample to the receiver. The cables are routed through a set of preamplifiers (the HPPR) which are situated next to the base of the magnet. The **preamplifiers** are needed to boost the NMR signals which are typically very weak.

5.1 Safety Issues

All persons who work with or in the close vicinity of an NMR system must be informed about its safety issues and emergency procedures.

If in doubt: Wear goggles and protective gloves, particularly when handling samples!

Inherent Safety

An NMR system, including the probe, is designed for inherent safety. Pressure relief valves, sensors, and error handling in hardware and software have been included to protect the operator, equipment, and environment.

Technically Qualified Personnel Only

Only persons with a basic technical understanding of electricity, pressurized gas systems, and cryogens should operate and maintain an NMR system. User interface, system messages, and manuals require a good understanding of the English language.

No User-serviceable Parts Inside

There are no user-serviceable parts inside a probe. Do not open these devices.

Magnetic Stray Field

When working within the 0.5 mT (5 Gauss) stray field of the magnet, all magnetic parts and tools must be avoided or handled with great care.

CAUTION: Deposit mechanical watches and cards with a magnetic strip (e.g. credit cards) outside the 0.5 mT (5 Gauss) range of the magnet.

General Safety Issues

- NMR laboratories should not be accessible to the public. Make sure access is restricted to authorized and qualified persons only.
- Strong magnetic fields involve various hazards. The danger zone should be labelled as precise as possible by the use of barriers, floor-taping or visual warning devices. Consult your safety manual for specific information concerning the danger zone (0.5 mT line).
- Strictly enforce the smoking ban during refill procedures.

5.2 First Aid

If cold helium or nitrogen gas comes in contact with eyes or skin, immediately flood the affected area with cold or tepid water.

6 Transmitter Safety

Signals of relatively large amplitude are often required to excite the NMR sample and hence the need for transmitters (also known as amplifiers). Cables running directly from the console to the probe carry the RF signal to the sample.

The RF signal leaving the amplifier can be of the order of 150 volts and is not recommended to be viewed on the scope without attenuation.

6.1 Transmitter Safety

Bruker amplifiers are built in accordance with the standard 61010-1 Safety Requirements for Electrical Equipment.

6.1.1 Safety Labels

Labels are provided on amplifiers to alert operating and service personnel to conditions that may cause personal injury or damage to the equipment from misuse or abuse. Users should read the labels and understand their meaning.

Operating personnel should not remove RF output cables without checking whether an experiment is running. To be sure that no RF signal is generated, type „stop“ on the TopSpin command line, or click on the STOP icon in the TopSpin menu bar. When in doubt turn off the RF transmitter.

Disconnect the mains power cable before opening the unit to prevent risk of electrical shock.

7 Contact

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NMR Hotlines

Contact our NMR service centers.

Bruker BioSpin NMR provide dedicated hotlines and service centers, so that our specialists can respond as quickly as possible to all your service requests, applications questions, software or technical needs.

Please select the NMR service center or hotline you wish to contact from our list available at:

http://www.bruker-biospin.com/hotlines_nmr.html

Appendix A

A.1 Figures

A.2 Tables

A.3 Index

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