SPECTROSPIN
NMR Magnet System

SPECTROSPIN NMR Magnet System
Safety Notes

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BRUKER

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1 Safety Notes

1.1 Introduction

Read this first!

Within this manual the Users Manual for NMR Magnet Systems is found in chapters 8 and 9.
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.

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, 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 Spectrospin and 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.

1.2 The Magnetic Field

Hazards

Certain 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. Typical of such effects are the following:

Magnet field forces

Large attractive forces may be exerted on equipment in proximity to 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 to the NMR magnet system, the larger the force. The larger the equipment mass, the larger the force.

Medical electronic implants

The operation of medical electronic implants, such as cardiac pacemakers, may be affected either by static or changing magnetic fields. Pacemakers do not all respond in the same way or at the same field strength if exposed to fields above 5 gauss.

Medical implants

Other medical 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 resulting in heat generation.

Operation of equipment

The operation of equipment may be directly affected by the presence of large magnetic fields. Items such as watches, tape recorders and cameras may be magnetised 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.

Reading attentively

To prevent situations as described above to occur, the following general precautions are provided as guidelines. They should be regarded as minimum requirements. Every magnet site location should be reviewed individually to determine precautions to be taken against these hazards. Also, 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 the surrounding space at the same level.

Before ramping the magnet to field

Ensure all loose ferromagnetic objects are removed from within 5 meters of the NMR magnet system.

- Especially remove the pumping unit.
- Display illuminated warning signs that the NMR magnet system is operating 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.
- The safe working field level of other equipment must be individually assessed by the system manufacturer.

After ramping the magnet to field

Do not bring ferromagnetic objects into the magnet room.
Use only nonmagnetic cylinders and dewars for storage and transfer of compressed gas or cryogenic liquids. Equipment for transportation of cylinders and dewars must also be nonmagnetic.

1.3 The safe handling of Cryogenic Substances

Cryogens

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.

The 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. The substances referred to in these recommendations are nitrogen, helium and air.

General safety rules

Cryogenic liquids, even when kept in insulated storage vessels (dewars), remain at a constant temperature by their respective boiling points and will gradually evaporate.

The very large increase in volume accompanying the vaporization of the liquid into gas and the subsequent process of warming up is approximately 700:1 for helium and nitrogen and therefore:

Warning:

Containers for 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 leads to large product losses!.

In the event of a large spillage, immediately evacuate the area.

Health hazards

An oxygen shortage of varying severity may occur if the magnet room is not properly ventilated. Helium can displace air in the upper parts of a room and cold nitrogen can displace air in the lower parts.

Cryogenic substances in liquid or vapour form (or as low temperature gases) produce effects on the skin similar to burns (cold burns).

Exposed or insufficiently protected parts of the body coming into contact with uninsulated venting pipes or vessels (see ventilation section) will immediately stick and the flesh will be torn if the affected body part is removed.

First aid

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.

Protective clothing

Protective clothing must be worn mainly to avoid cold burns. Therefore dry leather or P.V.C 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.

Eyes must be protected by goggles.

Do not wear any metallic objects (e.g. jewellery) on those parts of the body which may come into contact with the liquid.

Handling

Cryogenic liquids must be handled and stored in well ventilated areas.

Do not allow cryogenic liquids to come into contact with the body.

Always handle the liquids carefully. Boiling and splashing will always occur when filling a warm container.

Beware of liquid splashing and rapid flush off of helium when lowering equipment at ambient temperature into the liquid. This operation must be carried out very slowly.

When inserting open ended pipes into the liquid, block off the warm end until the cold end has cooled down, otherwise cold liquid may spurt out of the open end under self generated pressure. Never allow such 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.

Equipment

Use only containers constructed of non magnetic materials and specifically designed for use with particular cryogens.

Liquid nitrogen

Good ventilation is essential. Store and use in a well ventilated place. If sufficient gas evaporates from the liquid in an unventilated place (e.g. overnight in a closed room) the oxygen concentration in the air may become dangerously low. Unconsciousness may result suddenly without prior warning symptoms and may be fatal. For example, the evaporation of 40 litres of liquid nitrogen produces 27’000 litres (1’070 cubic feet) of nitrogen gas. If this vaporisation takes place in an unventilated room of $27m^3$ (3m x 3m x 3m) (1’070 cubic feet = 10,2 ft x 10,2 ft x 10,2 ft) it can produce a very dangerous situation. Appropriate multiplication of these parameters will indicate actual site conditions.

Condensing oxygen

Minimise contact with air. Since liquid nitrogen is colder than liquid oxygen, the oxygen in the air will condense out. If this happens for some time, the oxygen concentration in the liquid nitrogen may become so high that it becomes as dangerous to be handled as 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.

Smoking

Do not smoke. Rooms in which cryogenic liquids are being handled should be designated "No Smoking" areas. While nitrogen and helium do not support combustion, their extreme cold can cause oxygen from the air to condense on cold surfaces and 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!**

Liquid helium

Liquid helium is the coldest of all cryogenic liquids. It will therefore condense and solidify any other gas (air) coming into contact with it. The consequent danger is, that pipes and vents may become blocked with frozen gas!

Liquid helium must be kept in specially designed storage or transport dewars. Dewars should have a one way valve fitted in the helium neck at all times, in order to avoid air entering the neck and plugging it with ice. Vacuum insulated pipes should be used for liquid transfer. Breakdown of the insulation may give rise to the condensation of oxygen.

Helium is inert.

1.4 The safe operation of a superconducting NMR Magnet System Refill of liquid nitrogen and liquid helium

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The nitrogen vessel

The nitrogen vessel should be checked daily for boil off and nitrogen level. These values should be recorded. If the boil off falls to zero, the necks should immediately be checked for the presence of ice as described below.

Nitrogen security flow system

A pressure relief valve is provided for the nitrogen vessel to ensure that one neck tubes 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.**
In addition the nitrogen necks should be checked for blockages after every refill of either nitrogen or helium. This can be done simply by inserting a brass or copper rod of 0,635 cm diameter into each neck in turn.

Rapid transfer

During a rapid transfer of liquid helium, supercooling of the liquid nitrogen occurs. This can reduce the static boil off to zero and create a negative pressure in the nitrogen vessel. Thereby air or moisture could be sucked into the necks of the vessel, where it would solidify. Do not remove the nitrogen security flow system during any transfer liquid helium!

Refill of liquid nitrogen

When the vessel is being refilled, liquid nitrogen should not be allowed to spill onto the room temperature bore closure flange. Put gum rubber tubes 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 NMR magnet system.

Important Note: **Transfer of liquid nitrogen can be done easily and safely, provided the transfer pressure does not exceed 350 mbar (5 psi). Never apply a transfer pressure of more than 350 mbar (5 psi) to the nitrogen vessel and always make sure, that all nitrogen neck tubes are fully open!**

Protective clothing must be worn when handling liquid nitrogen. This includes dry leather or P.V.C. gloves to avoid cold burns and goggles for eye protection.

The helium vessel

The helium vessel should be checked weekly for boil off and helium level. Use a helium flowmeter or a helium gas counter!

These values should be recorded. If the boil off falls to zero for a period greater than 24 hours, the neck tubes should be checked for the presence of ice. The procedure for checking the neck tubes and removing any blockage should be attempted only by a trained technician with considerable experience on cryogenic systems.

Important: **Note that every measuring of the helium level incorporates some helium loss due to the heating of the level sensor. The specified hold time is guaranteed only when the helium level is measured once a week or less!**

A one way valve is supplied to be mounted on the helium manifold to ensure that the helium neck tubes cannot be blocked by the ingress of air or moisture. This valve should be mounted at all times except during a helium transfer.

Important: **Do not leave the helium manifold open to the atmosphere longer than 5 seconds unless a large gas flow is present!**

Refill of liquid helium

We recommend to refill the helium vessel within the specified hold time period and certainly before the level falls below the allowed minimum level (see chapter 3.x).

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 350 mbar (5 psi).
Never insert a warm helium transfer line into the cryostat, 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.
Do not use extensions on the helium transfer line that will reach the syphon for refilling.
Normally there is no extension needed for refilling. Only special transfer lines used at very low ceiling heights need an extension also during the refill process.
Never apply a transfer pressure of more than 350 mbar (5 psi) to the helium vessel and always make sure, that the outlet of the helium manifold is fully open either to the atmosphere or to a helium recovery system.

Controls after refill of helium

The O ring sealing the syphon entry port should be checked after every transfer. The helium vessel should never be left open to atmosphere for more than 5 seconds.

Check that there is a gas flow through the flow meter after the refill of helium.

Check that the nitrogen neck tubes are free of ice.

Check that after some time the nitrogen neck tubes become cool again. Ice or condensing moisture should be visible.

Protective clothing must be worn when handling liquid helium. This should include dry leather or P.V.C gloves to avoid cold burns and goggles for eye protection.

1.5 Properties of Cryogenic Substances

Properties		Nitrogen	Helium
Molecular weight		28	4
Normal boiling point	[˚C] [˚K]	-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
Odour (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		yes	yes

Cryogenic liquids

Superconducting magnets use liquid nitrogen and liquid helium as cooling agents. These liquids expand their volume by a factor of 700 when they are evaporated and then allowed to warm up to room temperature. The gases are nontoxic and completely harmless as long as an adequate ventilation is provided to avoid suffocation. During normal operation only 3-5 m^3/day (100-180 cubic feet/day) of nitrogen are evaporated, but during a quench 50-100 m^3 (1800-3600 cubic feet) of helium are produced within a short time. Windows and doors are sufficient for ventilation even after a quench, but 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.