Safety in the NMR laboratory

There are two main safety hazards in the NMR laboratory of CAF. The first relates to the (sometimes) sizeable stray magnetic fields which are associated with the NMR magnets. The second relates to the cryogens which are contained within these magnets.

Magnetic Field

The (sometimes) intense stray magnetic fields in the vicinity of the four NMR instruments in the CAF laboratory may specifically affect or interfere with any or all of the following:

- Heart pacemakers. Anyone with a heart pacemaker should not go beyond the warning signs which are posted on the doors at the entrance to the NMR laboratory in CAF.
- Medical implants (such as the metal pegs which tie bones together). Anyone with a medical implant should consult the NMR staff before entering the CAF lab.
- Bank cards – there is a risk that the magnetic strip on the reverse side of a credit or debit card will be erased if taken too close to the magnet. Therefore bank cards should not be taken within the 5G line of a magnet (see below).
- Mechanical watches – the moving parts of a mechanical watch may become magnetized if taken too close to the magnet, resulting in the watch malfunctioning. Mechanical watches should not be taken within the 5G line of a magnet (see below).

In addition, the stray magnetic fields from the NMR magnets can exert strong attractive forces on any nearby metallic objects. Since the force experienced by a ferromagnetic object will increase as it gets closer to the magnet, once such an object has started to move, it will inevitably accelerate towards the magnet. Small pieces of equipment and other lose metallic objects which have been left in the vicinity of an NMR magnet can therefore be transformed into projectiles - NMR folklore has it that, once an operator has become aware that an object is starting to move towards the magnet, it is generally already too late to do anything about it! Because of the risks associated with the stray magnetic fields around the NMR magnets, ferromagnetic objects should NOT be taken into the NMR laboratory. For this reason, laboratory coats, which often contain spatulae or other miscellaneous metallic objects in pockets, are not generally worn in the NMR laboratory. Note also that metallic fire extinguishers should not be used near the NMR magnets (fire extinguishers which are clearly labelled as being non-ferromagnetic are available in the G40 CAF laboratory for use in emergencies).

The intense magnetic field which is present at the centre of an NMR magnet can be several hundred thousand times as strong as the Earth's magnetic field. The intensity of this field decays away exponentially as a function of distance from the magnet centre. The extent of this invisible "stray" magnetic field which surrounds an NMR magnet is generally quantified using the concept of the "5 Gauss line", which connects all point in 3-dimensional space at which the field from the NMR magnet has decayed away to around 50 times the Earth's magnetic field. Outside the 5G line, the stray field is less than 50 times the natural magnetic field which we experience in daily life, and this is generally considered to be safe for most normal operations. Red circles have been painted on the floor* of the NMR laboratory around each of the four magnets in order to indicate the radial

position of the 5G line. As illustrated by the table below, the DPX400 presents the most serious safety issues with regard to stray magnetic field, whilst the Nano400 has an almost negligible stray field:

Magnet	Radial 5G line from magnet centre
Nano400	0.5 M
DPX400	*ca* 2.5M
AV500	1.3 M
AV700	1.0 M

All the large equipment in the NMR laboratory (and all lose metallic objects) should normally be located outside the 5G line of each of the four magnets.

*Note that there is also an axial component to the magnetic field that actually extends further from the magnet centre vertically than the horizontal radial field, which is indicated by the red lines on the floor. Warning signs have been posted in the common room below the NMR laboratory in order to indicate the hazard from the vertical stray field which is associated with the DPX400.

Cryogens

All four NMR systems in CAF (Nano400, DPX400, AV500 and AV700) incorporate superconducting magnets which require both liquid nitrogen and liquid helium in order to maintain their strong magnetic fields. Each magnet contains between approximately 50-300 L of both of these cryogens and, under normal operation, both liquids will be boiling off very slowly over a period of weeks/months. This continuous but gentle escape of gas is not considered to be a hazard because both the nitrogen and helium gas boil-off products are non-toxic and their slow release into the CAF lab leads to negligible concentrations in the atmosphere, given the size of the lab and its ventilation. However, under exceptional circumstances, it is possible for a NMR magnet to suddenly lose its associated magnetic field in a catastrophic event, which is referred to as a “quench”. During a quench there is a rapid conversion of cryogens from the liquid to the gaseous state, as the large amount energy which is contained in the magnet is suddenly released. Under these circumstances, there is a risk of asphyxiation, and for this reason oxygen-depletion meters have been located above and below each of the 4 magnets in the NMR laboratory. A drop in atmospheric oxygen level from 21% to 19% will register a warning on the gas control system for the CAF lab, while a drop to 18% will cause the evacuation alarm to sound. If the evacuation alarm sounds you should vacate the CAF lab IMMEDIATELY.

All aspects of safety in the NMR laboratory are covered during the course for Training in Use of the Open Access NMR Instruments which must be taken by all users of the Open Access NMR service.