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Safety

NMR systems are pretty safe if treated correctly but this short chapter outlines some of the things you may need to think about when using them. Note that we are not pretending to offer a full safety assessment but this should alert you to the major hazards associated with modern NMR systems. There are very good documents available from the major NMR manufacturers which cover this area in considerable detail.

NMR-associated risks fall into three categories: (1) magnetic fields, (2) cryogens and (3) sample-related risks. If you're picky, then you could also add things like risk from electrical shock, etc., but I'm sure that you're not!

13.1 Magnetic Fields

It might seem obvious but magnetic fields can attract magnetic materials towards them. It is something that we are all used to but most people haven't experienced the strength of field from an NMR magnet. Modern magnets are often shielded but they still have quite strong external fields, especially at the base of the magnet. Because the field is invisible it is easy to forget that it is there. We know of a case where a photographer forgot about the field and moved his tripod closer to the magnet to get a better shot. The next thing he knew, his tripod flew across the room and smashed into the magnet, damaging it in the process. It took nine months to get the magnet back to field and a lot longer to live down the embarrassment. Had someone been between the tripod and the magnet it could have been even more serious. There is also a story (maybe an urban myth?) about someone who had a metal ruler in their lab coat pocket whilst he did some work at the base of the magnet. The ruler flew out and sliced the end of his nose off.

As well as the obvious risks, there can be less obvious risks too. Heart pacemakers can be disrupted by strong magnetic fields so this needs to be pointed out to anyone who enters the area in case they are reliant on one. Another risk is for people who have certain metal prosthetics (e.g., hip joints) – you wouldn't want them stuck to the side of the magnet, would you? Another example that we have had is with metal breathing apparatus – someone was pulled back to the magnet when wearing it during a fire drill.

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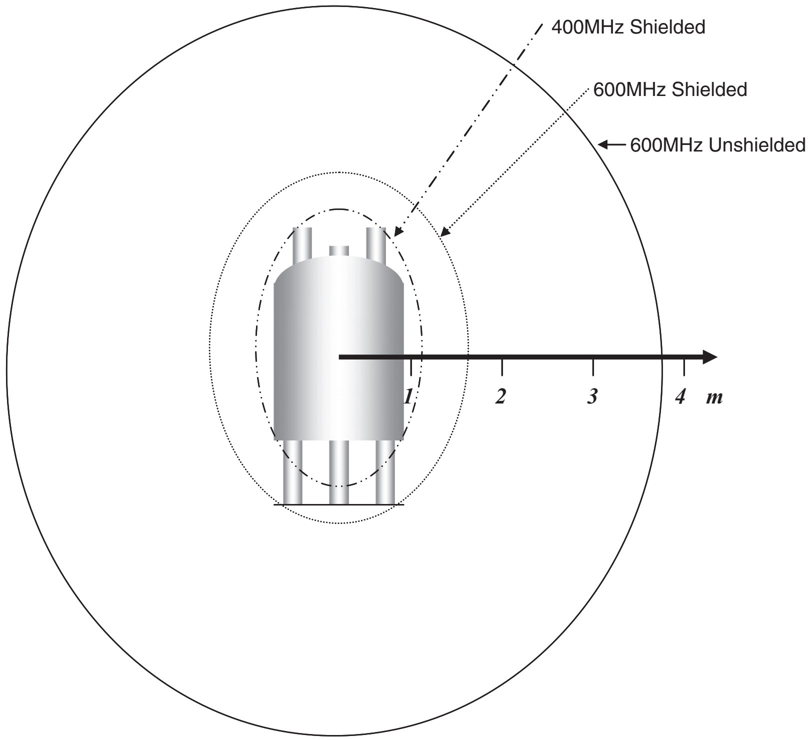

Figure 13.1 The 5 Gauss line for a range of magnets.

There can be other untoward effects which may not be exactly safety related but are inconvenient to say the least. Magnetic strips on credit cards can be erased, hard (and floppy) disks can become corrupted (watch your iPod near a magnet) and electrical equipment with relays can be affected. CRT monitors are particularly sensitive to stray magnetic fields and you end up with an artistic, if useless, monitor if it is too close to the magnet. Additionally, strong fields may saturate transformers so that they don't behave as expected – probably not a good thing if you are expecting a particular voltage out of them. Finally, analogue watches fare badly in strong magnetic fields. If you are lucky, the watch may just lose time whilst it is close to the magnet. If you are unlucky, it may stop and refuse to start again. As a rule of thumb, don't get close to the magnet when wearing a watch unless it doesn't have hands.

So how close is too close? Well it depends on the magnetic field, whether it is shielded or unshielded and whether it is a wide bore or normal magnet. The magnet manufacturer will be able to give you the figures. We measure the safe distance by the stray field at that point. Normally we take the 5 Gauss field line as a safe distance and this is normally marked in some way (tape on the floor or a physical barrier). For a 400 MHz shielded spectrometer, this distance is about 1.0–1.5 m from the centre of the magnet. The larger the magnet, the further the stray field (generally), although modern shielded magnets may have the 5 Gauss line at the edge of the magnet can. Figure 13.1 shows the 5 Gauss line for a set of magnets.

There are no known biological effects of static magnetic fields and it has been deemed that they do not cause problems to people working with them. This is always under review and there may be moves to limit time spent in strong magnetic fields at some time in the future.

13.2 Cryogens

Because the magnet is essentially a Dewar containing liquid nitrogen and liquid helium, the biggest risk is from those cryogens. The first risk is from the low temperatures of these liquids (liquid helium boils at about –270°C) which can cause serious burns. The second risk is of asphyxiation as the cryogens boil off.

The risk of burns is normally only experienced when filling a magnet with nitrogen or helium. You need to be protected in case the liquid spills or the transfer line breaks. Protection just means covering up any exposed skin (lab coat, visor and thick gloves are normally sufficient). At all other times, the cryogens are safely in their cans and should stay there unless something catastrophic happens.

Asphyxiation is another invisible hazard. If the oxygen level in a room decreases below a certain level you may become unconscious and die. In general, big laboratories are better than small labs because the natural volume of the room will help to dilute these effects. Likewise, an efficiently air conditioned room will change the air in the room fairly rapidly and this will also help keep oxygen levels up. If your NMR magnet is in a small room, it may be necessary to install oxygen depletion sensors. These will alert you should the oxygen level fall below a safe value.

When a magnet is not being filled, it will give off a steady stream of nitrogen and helium. The helium will normally sit near the ceiling whereas the nitrogen will tend to permeate the whole volume of the room. When your instrument is installed, a survey should have been carried out to evaluate the risks.

Lastly (on the subject of asphyxiation), when transporting Dewars of cryogens it is important that you and the Dewar are not in a small space together. This includes lifts (elevators). If you need to transport a Dewar up or down floors in a building, you should send the Dewar on its own and prevent people from joining it!

There is a special condition that can arise in an NMR magnet, called a ‘quench.’ This occurs if the magnet coils suddenly cease to be superconducting and all the energy stored within them is released as heat. This causes the helium in the can to boil off very rapidly. There are two major risks from this. The first is obviously asphyxiation; the second is the pressure that is generated by the increased gas volume. To minimise problems from the latter, the room should be constructed so that the gas can escape quickly. The other precaution is to ensure that the doors to the laboratory open outwards, otherwise the gas pressure may make it difficult to open them, trapping the occupants. The asphyxiation risk from a quench is quite low because the helium has a tendency to sit at the ceiling of the room and it also escapes very rapidly from wherever it can. Nonetheless, it is advisable to leave the room if a quench happens. You will know when a system is quenching – it makes a lot of noise and you get clouds forming in the ceiling!

The event that would cause the largest release of cryogens would be a catastrophic failure of the can. This would release the helium and the nitrogen very quickly. Fortunately, this is an unusual event and previously mentioned precautions should still work.

One last hazard with cryogens is that they may lead to local build-up of oxygen through liquefaction of air. When filling a magnet, it is possible to see liquid air condensing at the fill port. If this happens, there is a risk of causing combustion of oil or other materials that are close to the liquefied air. This risk can be eliminated by keeping sources of combustion away from the magnet and Dewar.

13.3 Sample-Related Injuries

Whilst the potential hazards associated with powerful magnetic fields and cryogens are spectacular, it's the everyday hazards associated with the handling of NMR samples that are most likely to catch out the unwary! Standard 5 mm NMR tubes are very fragile (3 mm even more so!) and the thin-walled glass tube they are made from can cause nasty cuts. Pushing on the plastic tube tops is the most dangerous part of the process as considerable force is sometimes needed. We have found that it is safest to hold the tube in one hand and lay the knuckles of that same hand into the palm of the other which is used to push on the top. Locking your hands together in this way, minimises the chance of injury should the tube shatter, as there will be no danger of sudden violent movement of flesh towards broken glass!

Another source of danger relates to the samples themselves. In a research environment, many of the compounds made are of totally unknown toxicity and so should be handled with extreme caution. NMR solvents are obviously toxic in their own right but when they contain unknown organic compounds in solution, the hazards are far worse. Be warned that all organic solvents commonly used for NMR, can pass through skin and into the bloodstream but DMSO is particularly good at it. If this happens, it will take anything dissolved in it through as well so avoid spilling any solutions on your hands whilst making up or filtering samples. Don't be lulled into a false sense of security by wearing thin rubber gloves – they offer little protection because solvents can penetrate them too!