Static and RF Magnetic Fields – Dealing with the Safety Issues

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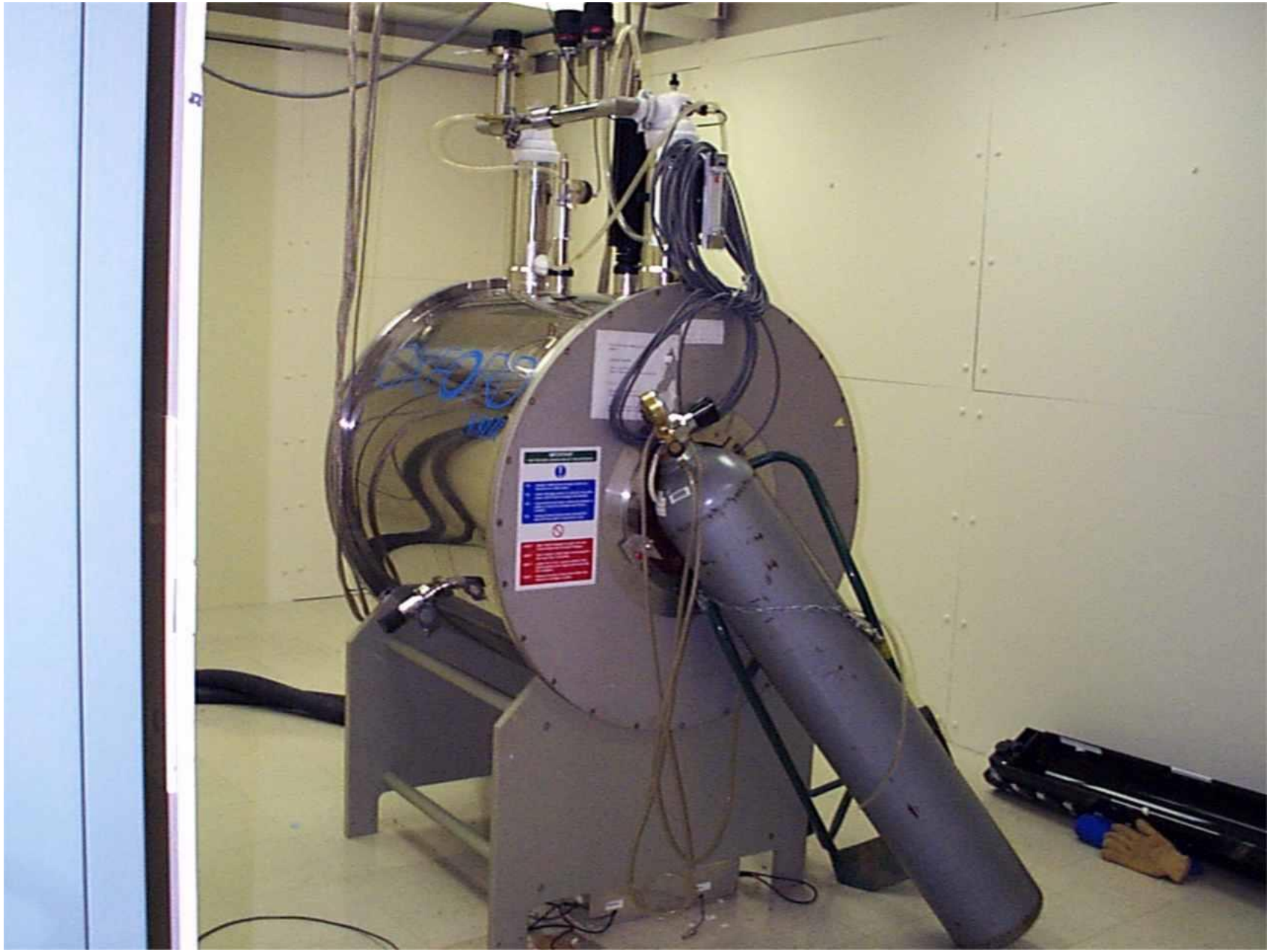


Caveats

- I’m not an expert at this, my experience only
- Brought up by our Safety Office
- Local Interpretations may differ

Outline

- Static Fields
  - Obvious hazard in NMR (and MS) labs
  - MRI has similar (worse?) issues
- RF Fields
  - Less obvious
  - Safety Offices starting to be interested

Static Magnetic Fields

- Obvious hazard in NMR (and some MS) labs
- Serious hazard due to stray field:
  - Pacemakers
  - Medical implants
    - E.g. stents, plates, screws, staples etc
  - Artificial limbs
- Other hazards
  - Hearing aids
  - Credit cards / access cards etc
  - Building services e.g. water pipes, electrical services

Who has access?

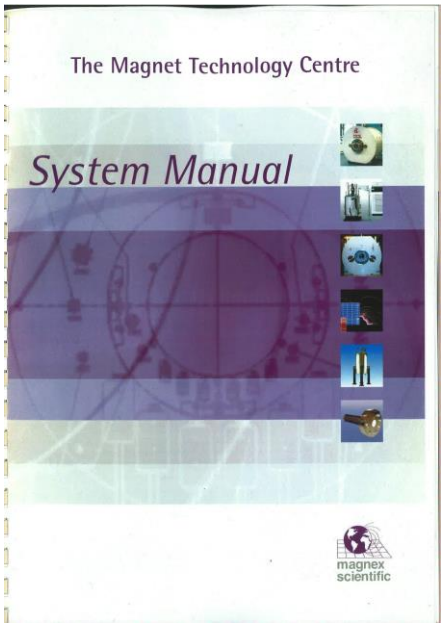
- Facility staff
- Trained users
- Undergraduate students?
- Building services?
- Cleaners?
- Service engineers?
- Workmen?

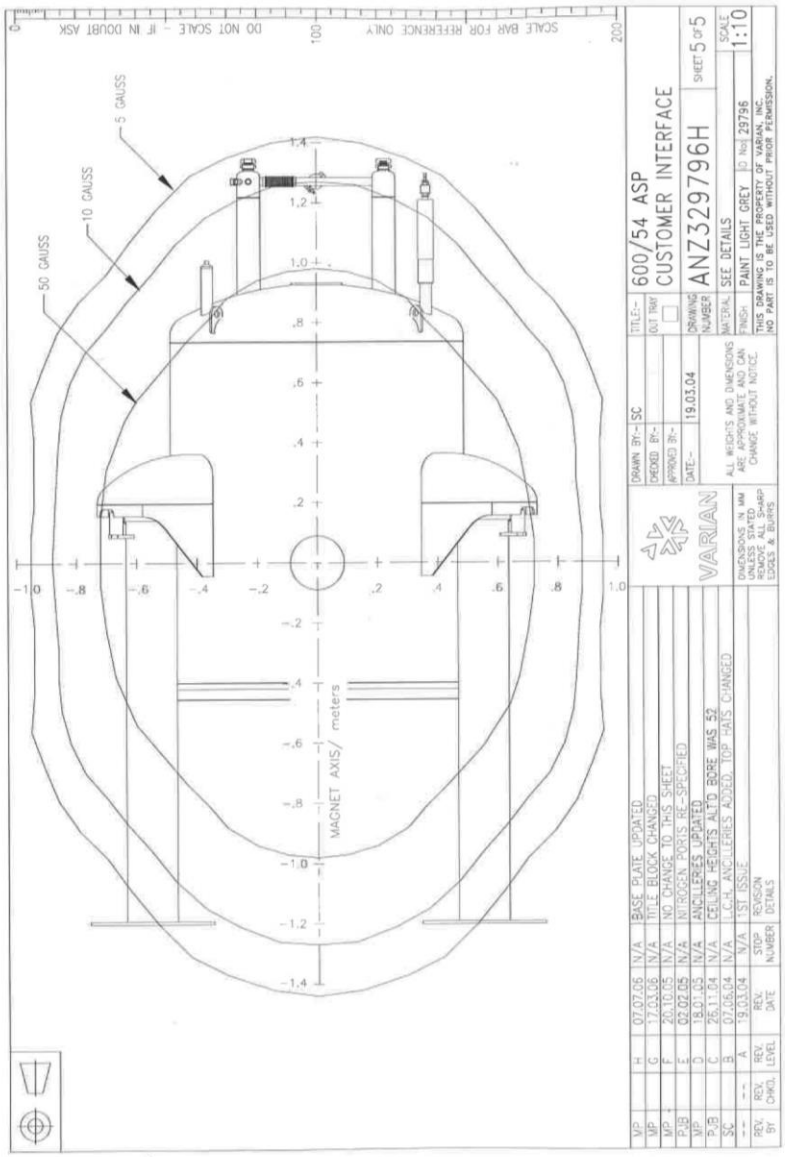
Risks

- Facility staff
  - Overfamiliarity with instruments???
  - Dewars (should be non-magnetic!)
  - Tools
- Chemists
  - E.g. spatula in pocket
- Cleaners
  - E.g. floor polisher!

Information

- Stray field plots
  - Magnet manuals
  - Vendor





Information

- Signage
  - Lab doors

  - 5G line marked within the lab

Mitigation of Risk

- Training of users
  - Medical questions “do you have a pacemaker or any medical implants?
  - Record of training / standardised questions
- Issue reduced by shielded magnets
  - Though dB/d$\boldsymbol{r}$ increases rapidly!
    - Mainly issue for facility staff and service engineers
- Use of autosamplers
  - No need to enter 5G line for most users

RF Fields

- Recently brought up by our safety office
- Not really thought about before
- “Everything is connected up correctly, should be fine”
- Some information in vendor manuals
  - Varian “Installation and Planning Guide”
  - Presumably Bruker / Jeol similar?

Table 15. Results of RF Emissions Tests on Varian NMR Equipment

Spectrometer System and NMR Experiment	*Frequency (MHz)*	*RF at Probe (mW/cm^2)*	*RF at Amplifier (mW/cm^2)*	*IEEE/ANSI C95.1-1991*
600-MHz				
Carbon observe `tpwr`=58 pulse	150	0 E-field 0 H-field	0 E-field 0 H-field	1.0 E-field 1.0 H-field
Carbon observe `tpwr`=63 pulse, 50-ohm load	150	0 E-field 0 H-field	0 E-field 0 H-field	1.0 E-field 1.0 H-field
Proton observe `tpwr`=63 pulse	600	0 E-field 0 H-field	0 E-field 0 H-field	2.0 E-field 2.0 H-field
Proton observe `tpwr`=63 pulse, 50-ohm load	600	0 E-field 0 H-field	0.05 E-field 0.05 H-field	2.0 E-field 2.0 H-field
500-MHz				
Carbon observe `tpwr`=63, `dpwr`=63 pulse terminated	125	0 E-field 0.05 H-field	0 E-field 0.01 H-field	1.0 E-field 1.0 H-field
Carbon observe `tpwr`=63 pulse, 50-ohm load	125	0.01 E-field 0.2 H-field	0.05 E-field 0.02 H-field	1.0 E-field 1.0 H-field
Proton observe `tpwr`=63 pulse	500	0.25 E-field 0.25 H-field	0.05 E-field 0.05 H-field	1.7 E-field 1.7 H-field
Proton observe `tpwr`=63 pulse, 50-ohm load	500	0.25 E-field 0.25 H-field	0.05 E-field 0.05 H-field	1.7 E-field 1.7 H-field
400-MHz				
Cross-polarization 300 W, 2 ms pulse	75	0.005 E-field 0.05 H-field	0 E-field 0.005 H-field	1.0 E-field 1.8 H-field
Cross-polarization 100 W, 20 ms pulse	300	0.1 E-field 0.1 H-field	0 E-field 0 H-field	1.0 E-field 1.0 H-field
CMA amplifier				
Cross-polarization 300 W, 2 ms pulse	75	0.005 E-field 0.05 H-field	0 E-field 0.005 H-field	1.0 E-field 1.8 H-field
Cross-polarization 100 W, 20 ms pulse	300	0.1 E-field 0.1 H-field	0 E-field 0 H-field	1.0 E-field 1.0 H-field

RF Fields

- “Control of Electromagnetic Fields at Work Regulations 2016”
- A statutory instrument
  - i.e. a piece of secondary legislation
  - Refers to the Health and Safety at Work Act 1974
- Defines:
  - Action Levels (AL)
  - Exposure Limit Values (ELV)
- Exemptions for MRI (!)

http://www.legislation.gov.uk/uksi/2016/588/pdfs/uksi_20160588_en.pdf

MRI Exemption

- **4.**—(1) Subject to paragraphs (2) and (3), an employer must ensure that employees are not exposed to electromagnetic field levels in excess of the ELVs.
- …
- (3) Paragraph (1) does not apply in relation to
  - the development, testing, installation, use and maintenance of, or research related to, magnetic resonance imaging equipment for patients in the health sector, where
    - (i) the exposure of employees to electromagnetic fields is as low as is reasonably practicable; and
    - (ii) employees are protected against any health effects and safety risks related to that exposure.

http://www.legislation.gov.uk/uksi/2016/588/pdfs/uksi_20160588_en.pdf

So what does the SI say?

- Employers must ensure that employees are not exposed above ELVs
- Employer must make a suitable assessment of the levels of magnetic fields
- Employer must make a suitable action plan to ensure compliance
- Employer must make a suitable and sufficient risk assessment

http://www.legislation.gov.uk/uksi/2016/588/pdfs/uksi_20160588_en.pdf

Action Levels

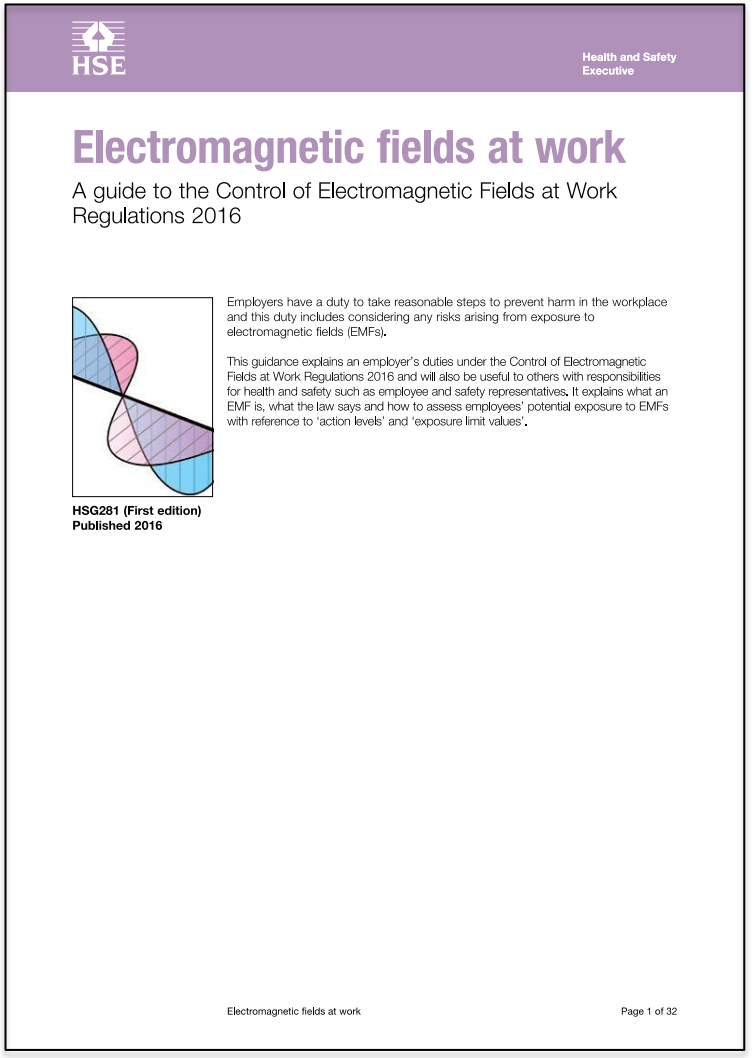
Table AL1 – ALs for exposure to electromagnetic fields from 1 Hz to 10 MHz

Frequency range	External electric field strength Low ALs (E) [Vm^{-1}]	External electric field strength High ALs (E) [Vm^{-1}]
$1 \leq f < 25$ Hz	2.0×10^4	2.0×10^4
$25 \leq f < 50$ Hz	$5.0 \times 10^5/f$	2.0×10^4
50 Hz $\leq f <$ 1.64 kHz	$5.0 \times 10^5/f$	$1.0 \times 10^6/f$
1.64 $\leq f <$ 3 kHz	$5.0 \times 10^5/f$	6.1×10^2
3 kHz $\leq f \leq$ 10 MHz	1.7×10^2	6.1×10^2
Exposure levels not exceeding the ALs will be compliant with:	Tables ELV2 and ELV3	

http://www.legislation.gov.uk/uksi/2016/588/pdfs/uksi_20160588_en.pdf

More Information

- SI is hard going and written in “legalese”
- So, HSE published “Electromagnetic Fields at Work” a guide to the regulations
- Much more information and readible



HSE

Health and Safety Executive

Electromagnetic fields at work

A guide to the Control of Electromagnetic Fields at Work Regulations 2016

Employers have a duty to take reasonable steps to prevent harm in the workplace and this duty includes considering any risks arising from exposure to electromagnetic fields (EMFs).

This guidance explains an employer's duties under the Control of Electromagnetic Fields at Work Regulations 2016 and will also be useful to others with responsibilities for health and safety such as employee and safety representatives. It explains what an EMF is, what the law says and how to assess employees' potential exposure to EMFs with reference to 'action levels' and 'exposure limit values'.

HSG281 (First edition)
Published 2016

Electromagnetic fields at work

Page 1 of 32

http://www.hse.gov.uk/pubns/priced/hsg281.pdf

HSE Guide

- Information on:
  - Health effects at various frequencies
  - Typical sources (not just NMR!)
  - Exposure limits
  - Record keeping requirements
  - Risk assessments requirements
  - Flow charts for risk assessment

More recently

Radiation Protection Dosimetry (2017), pp. 1–10 doi:10.1093/rpd/ncx058

OCCUPATIONAL EXPOSURE OF NMR SPECTROMETRISTS TO STATIC AND RADIOFREQUENCY FIELDS

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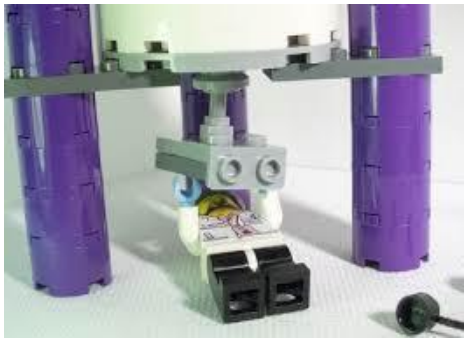
- Study of 19 spectrometer installations
- Mix of shielded and unshielded
- Static and RF fields measured

https://doi.org/10.1093/rpd/ncx058

More recently



- Exposure to static field depends on proximity and action
  - E.g. greater exposure tuning probe (called shimming in paper!) than sample insertion
- Measurement of RF fields below LOD for instrumentation used
  - Makes sense if RF path is correctly terminated
  - Don’t really want to pulse on an open circuit cable
- MRI may have have greater exposure due to greater access to bore / coil region

https://doi.org/10.1093/rpd/ncx058

So what now?

- From our safety office:
  - Exposure to electromagnetic fields will come under non-ionising radiation policy
  - Maintain record of trained users
  - Standardise medical questions for all users
  - Record assessment of static and RF fields in risk assessment for facility
    - Reference to Berlana and Ubeda sufficient for present assessment requirements

Related links

http://www.legislation.gov.uk/uksi/2016/588/pdfs/uksi_20160588_en.pdf

http://www.hse.gov.uk/pubns/priced/hsg281.pdf

https://doi.org/10.1093/rpd/ncx058