FRINGE FIELD

The Zone IV/Controlled Access Area/MR Environment (we will simply call it "Zone IV") is usually defined by the extent of the 0.5 mT contour (previously called "the 5 Gauss line") or a suitable physical barrier, e.g. the walls of the MR room. The word "contour" better describes this region than "line" because it forms a three-dimensional volume, with rotational symmetry about the magnet axis (Figure 12.3).

The purpose of Zone IV is threefold:

- To restrict access of unauthorized persons not trained in MR safety
- To prevent the introduction of MR unsafe items which may become dangerous projectiles
- To prevent the inadvertent exposure of magnet-sensitive devices or equipment. In particular the value of 0.5 mT was selected to ensure that MR-unsafe cardiac pacemakers remain unaffected by the field.

Where the 0.5 mT contour extends beyond the physical barriers of the building, an exclusion zone must be established with suitable barriers and signage.

The extent of the fringe field is one of the principal design considerations. Magnetic shielding may be required if the field extends beyond the magnet room into adjacent areas. Magnetic shielding uses sheets of iron and is both heavy and expensive. It also affects the shim of the magnet. Consideration must be given to floors immediately above or below the scanner. Magnet-sensitive equipment should be suitably excluded (Table 12.1). The influence of nearby ferromagnetic items on the scanner's B_0 uniformity or homogeneity should be considered (Table 12.2).

After installation the fringe field should be confirmed using a suitable magnetometer, as the presence of steel structures in the building can distort the field contours. This may be carried out by the MR manufacturer or by a medical physicist/ MRSE (Figure 12.4).

HELIUM EXHAUST AND QUENCH PIPE

A key aspect of the installation is the provision made for the exhaust of helium gas: the "quench pipe." A "quench" occurs when the magnet's windings lose their superconductivity, resulting in a catastrophic and rapid loss of the field, heating of the windings, and the vaporizing or "boil off" of the helium liquid as gas (see Chapter 1).

Quench

A magnet quench may occur in a controlled manner as a safety feature used, for example, in the event of a serious or life-threatening projectile incident or a major fire in the magnet room. It may also occasionally happen spontaneously as an accident (see https://youtu.be/1R7KsfosV-o, accessed 25 May 19). In a quench the magnetic field collapses over 20–30 seconds. The helium boils off with one liter of liquid typically expanding as 800 liters of gas. The exhaust system has to be capable of handling this volume of high-pressure gas. As the helium encounters the atmosphere it condenses into a fog. It is lighter than air, so will rise – like steam – but very cold. In the event of a leakage into the magnet room, the helium fog will accumulate from the ceiling downwards. If this happens, evacuate the room, keeping low to avoid inhaling the helium gas.

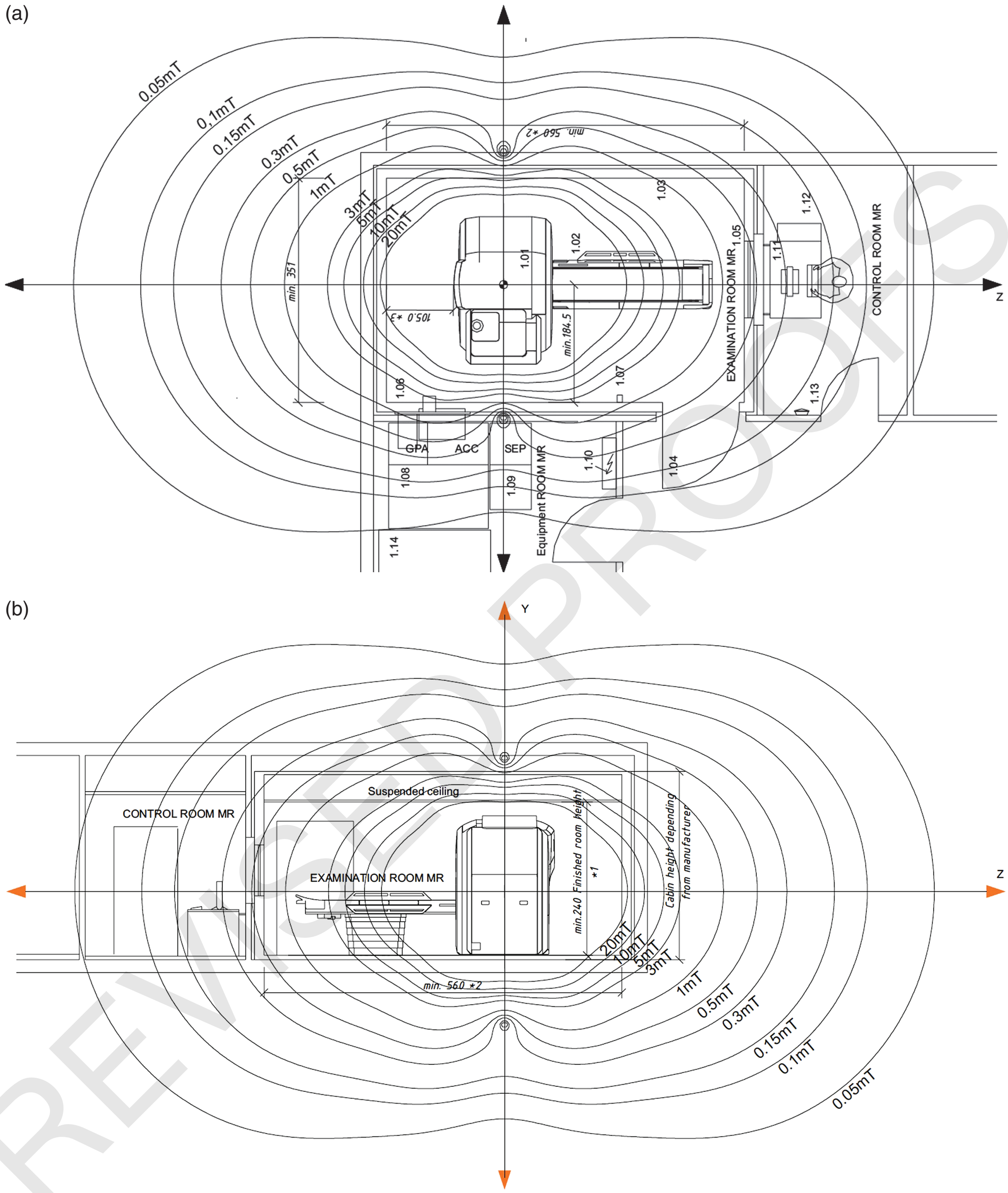

Figure 12.3 Fringe field contours for a 1.5T MRI installation: (a) top view; (b) side view. Reproduced with permission of Siemens Healthineers.

Table 12.1 Typical safe operating distances for the avoidance of interference with various items of equipment.

Fringe field (mT)	Item	Typical Minimum distance (m) 1.5 T		Typical Minimum distance (m) 3 T	
		On axis	Radially	On axis	Radially
10	Oxygen monitors, Laser imager	2.2	1.6	2.6	1.8
3	Magnetic media, LCD displays	2.8	2.0	3.3	2.2
1	Computer hard disks, X-ray tubes	3.4	2.2	4.3	2.4
0.5	Conventional pacemakers	4.0	2.5	4.6	2.6
0.2	CT Scanners	4.9	3.0	5.6	3.2
0.1	Gamma cameras, Image intensifiers, PET scanners	5.6	3.3	6.8	3.9
0.05	Linear accelerators	6.8	3.9	8.2	4.6

Table 12.2 Typical distances for the avoidance of interference with B_0 homogeneity.

Item	Distance (m)	
	Radial	Axial
Wheelchair /trolley	5	6
Car	6	8
Truck	7	10
Train	40	40

Example 12.1 Quench

Looking at the MR room in Figure 12.1 compare the volume of helium gas released in a quench with the volume of the room. Assume that the magnet cryostat contains 1000 L of liquid helium and the the ceiling height is 3.5 m.

The dimensions of the room are 5.5 x 3.5 m. The volume of the room is

$$V_{room} = 5.5 \times 3.5 \times 3.5 = 67.4\, m^3$$

The volume of the gas is

$$V_{gas} = 1000 \times 800 = 800\,000 \text{L}$$

One liter equals 0.001 m³ so the volume of helium gas is 800 m³, enough to fill 12 MR rooms!

(a)

(b)

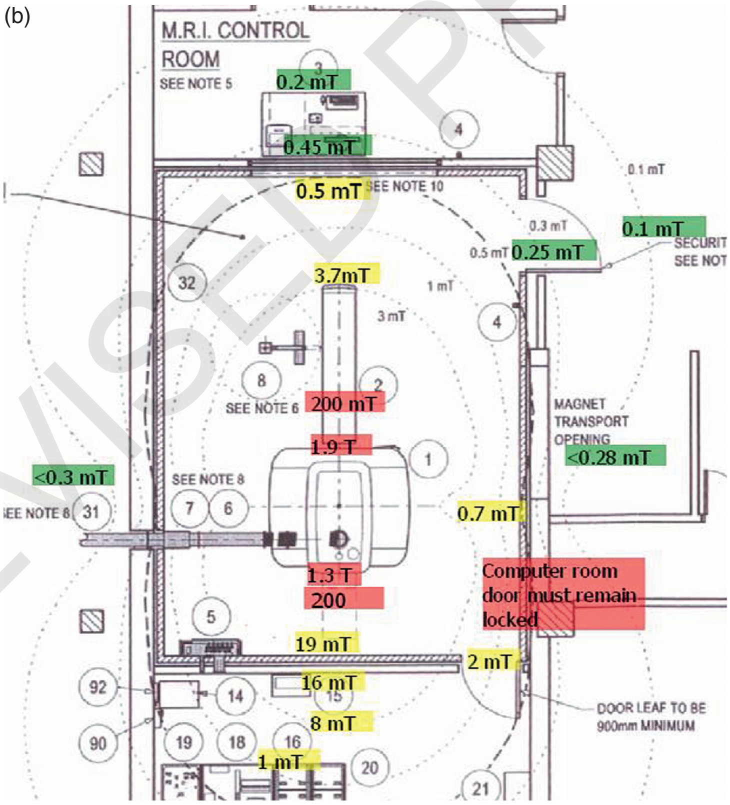

Figure 12.4 Confirming the fringe field: (a) Handheld 3-axis magnetometer TMH117-6, image courtesy of Metrolab (technology@metrolab.com); (b) spot check measurements of the fringe field.