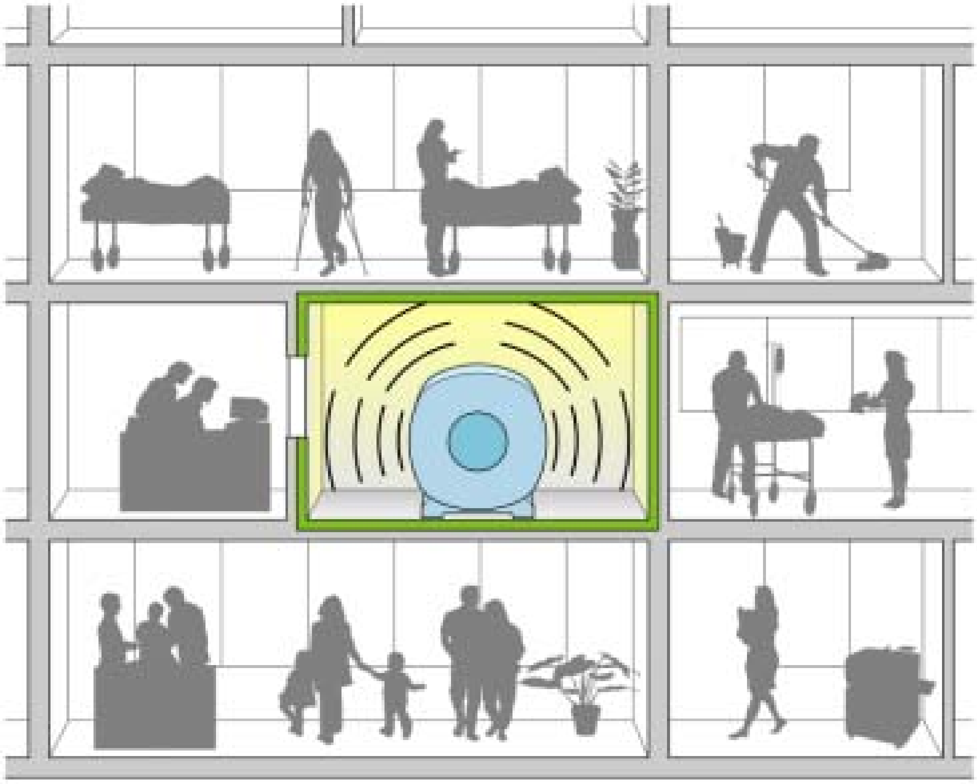
SilentSHIELD™

Acoustic and RF Shielding for Magnetic Resonance Imaging



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Medical RF & Magnetic Shielding Specialists – Worldwide

IMEDCO

Contents

1. Why IMEDCO ?

Because IMEDCO is one of the leading suppliers of combined acoustic and RF shielding enclosures worldwide. The IMEDCO advantages in brief:

- The conformity of all acoustic and RF shielding components has been measured by the independent company Akustik Projekt Reichmuth (member of the ”Swiss Acoustical Society” and the ”Deutsche Gesellschaft für Akustik”) according to ISO 140/717. The respective data sheets are available on request.

- The following US patents have been awarded:

A radio frequency shielded and acoustically insulated door	U.S. 6,519,899
Radio frequency shielded and acoustically insulated enclosure	U.S. 6,626,264

- Quality management system conforming to ISO 9001 since 1997.

- Monthly quality management meetings are held to ensure quality improvement.

- The company owners are also responsible for its day to day operations and success.

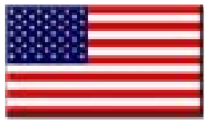
Robert Schweizer	CEO
Urs Schläpfer	Engineering and Development
Walter Christen	Sales and Project Management
Peter Hürzeler	Manufacturing and Installation

- More than 2’500 satisfied users worldwide (request our reference list).

All shielding products and services from a single source:

- Magnetic shielding
- Magnetically shielded rooms (MSR) for bio-magnetic research
- Magnetic field and vibration measurements
- Acoustic insulation planning and engineering, acoustic expertises
- Active compensation system for low frequency magnetic field fluctuations
- Shielding for special purposes

2. Foreword to our US customers



Soundproofing has been applied for a number of years in Germany and Switzerland. It is mandatory for dwellings and offices to be constructed such that they may be used for the purpose for which they are built without restriction. German DIN 4109 specifies permissible levels for residual noise in adjacent rooms. These levels are relatively low, but have been found to be correct in practice. Assuming that people around the world have roughly the same average perception of audible noise, we propose using the same permissible noise levels (see Page 6) for US projects as well. However, local regulations take precedence and only they count as binding.

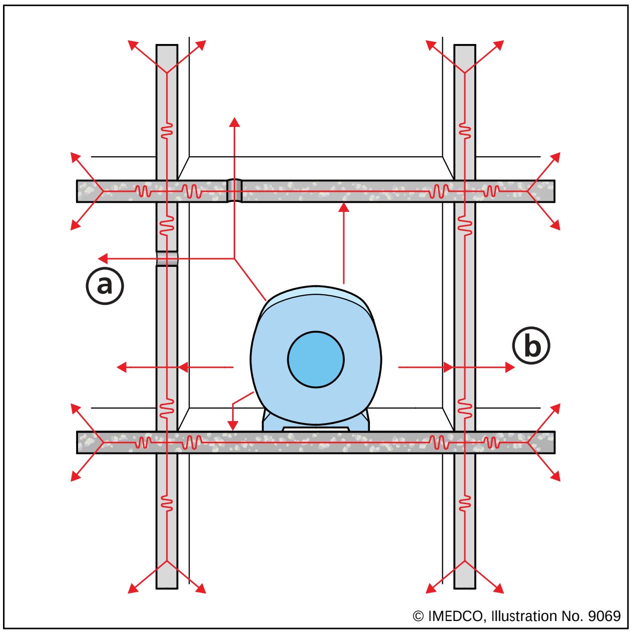
A list of units and symbols used in this brochure is given on pages 18 and 19. These units conform to DIN EN ISO. We are aware that these units are not binding in the US, nevertheless they are in common international use. Since in some cases other units are familiar in the USA, we have endeavored to indicate their international equivalents.

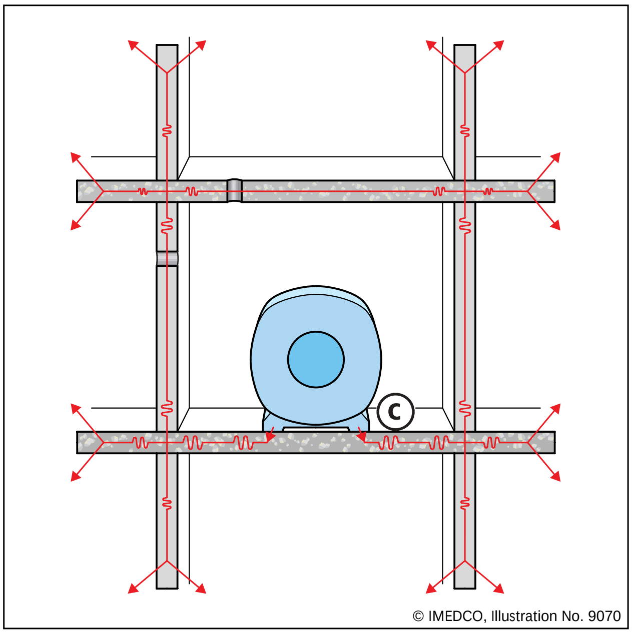
3. Why is soundproofing needed ?

Since their inception, magnetic resonance imaging (MRI) tomographs have become steadily more powerful. Whilst this improves image quality, it also means that the magnet assembly generates more audible noise. The propagation of this noise to neighbouring rooms has to be prevented. Examination of the noise situation on site is recommended for the following reasons:

- New buildings have to fulfil higher requirements with respect to noise reduction.
- Old buildings were not designed to accommodate magnet assemblies generating high levels of audible noise.
- Hospitals are now demanding lower levels of audible noise in neighbouring wards, operation theatres and consultation rooms.
- Where there are other tenants in the same building, their rights regarding audible noise and disturbance have to be respected.

4. Airborne and structurally borne noise





Airborne noise:

Airborne noise is the noise generated by the MRI equipment and transported via the air. It is conducted to neighbouring rooms either directly via ducts and penetrations in the building structure (a) or by impacting the building structure itself and causing it to vibrate (b).

Structurally borne noise:

Structurally borne noise is transmitted through the mounting of the MRI equipment to the floor (c). This energy causes the walls, floors and ceilings of neighbouring rooms to vibrate which then radiate airborne noise.

5. How much soundproofing does a building need ?

There are several German standards defining maximum noise levels in rooms where people work, so that neighbours are not disturbed and such that hospital patients can recover in a healthy environment. The unit of noise level in these standards, the time average sound pressure level ($L_{AF,r}$), is a mean value which takes into account the level when there is no noise disturbance and the level when there is (impulse and frequency content). Refer to DIN 45645 for the exact definition of assessment level.

The MRI workplaces

The maximum levels defined in the health and safety act (Arbeitsstättenverordnung) issued on May 20th, 1975 are:

- Operating, consultation and evaluation rooms — $L_{AF,r}$ = 55 dB(A)
- Normal office work mainly using machines — $L_{AF,r}$ = 70 dB(A)
- Other activities — $L_{AF,r}$ = 80 dB(A)

Areas belonging to other departments in the hospital

The health and safety act also applies to these areas, although its prime objective is to prevent damage to hearing and maintain working capacity and <u>not</u> to limit the subjectively disturbing transmission of acoustical noise. Thus the levels given in the health and safety act are inappropriate for satisfying today's workplace requirements. To ensure an undisturbed environment in other departmental areas they should be reduced by approximately 10 dB and therefore the following maximum levels are recommended:

- Wards (daytime 6 am to 10 pm) — $L_{AF,r}$ = 35 dB(A)
- Doctors' offices, consulting rooms, general offices — $L_{AF,r}$ = 35 dB(A)
- Quiet consulting rooms (e.g. psychiatric departments) — $L_{AF,r}$ = 35 dB(A)
- Noisy consulting rooms (e.g. with medical equipment) — $L_{AF,r}$ = 45 dB(A)
- Operating theatres — $L_{AF,r}$ = 45 dB(A)
- Intensive care — $L_{AF,r}$ = 45 dB(A)
- Waiting areas — $L_{AF,r}$ = 45 dB(A)

Areas used by third parties (e.g. apartments or offices)

Maximum levels according to DIN 4109 or the instructions concerning for noise suppression.

- Living rooms and bedrooms (night time 10 pm to 6 am) — $L_{AF,r}$ = 25 dB(A)
- Living rooms and bedrooms (daytime 6 am to 10 pm) — $L_{AF,r}$ = 35 dB(A)
- Training and working rooms — $L_{AF,r}$ = 35 dB(A)

DIN 4109 specifies that these maximum levels may be exceeded only briefly by a maximum of 10 dB.

6. Designing soundproofing

Since they mutually influence each other, soundproofing and RF shielding should be designed together and wherever possible come from the same supplier. This is necessary, for example, to prevent penetrations through the RF shielding for air-conditioning, quench lines or filters from diminishing the efficiency of the soundproofing. All penetrations should be in the wall to the technical room and in cases where this is impossible, silencers or extra insulation layers have to be included.

6.1 Is an acoustic engineer necessary ?

Where a building structure has special characteristics or several rooms adjacent to the MRI room have to be protected, we can arrange for an expertise by an acoustic engineer. He then specifies how the RF shielding of the walls, floor and ceiling has to be executed to ensure that the maximum permissible audible noise level is not exceeded.

New buildings:

An acoustic engineer can calculate the transmission of noise to adjacent rooms to be expected on the basis of the plans and the material specifications for the new building. The sound reduction indices of the various kinds of materials are obtained from the respective data sheets or standards.

Old buildings:

Since the sound reduction indices of the building materials are seldom available, the best procedure is for an acoustic engineer to simulate the noise emitted by the MRI equipment to be installed and to measure the noise levels in the adjacent rooms.

Where the sound reduction indices of the building materials are already known, we can offer a wide range of soundproofing solutions with values of D for floors, walls and ceilings from 35 dB to 80 dB.

- We guarantee the tested sound reduction indices of the RF enclosure components.
- The assessment of the overall sound transmission depends on the availability and accuracy of the data on which it was based.

6.2 MRI equipment data

The sound pressure level (L_p) of the MRI equipment during operation is generally given in the supplier’s engineering manuals. In order to determine the effective operating noise on site as accurately as possible, the following information is required:

- Make and Model of MRI equipment to be installed
- The operating sound pressure level L_p measured at a distance of 1 m or the sound power level L_w of the MRI equipment
- Level of the structural sound energy transmitted by the MRI equipment to the floor
- The proportion of operating noise peaks in relation to total operating time
- Any increase in sound level planned for the future

6.3 Utilisation of adjacent rooms

The purposes for which the adjacent rooms are used bears a decisive influence on whether the operating noise of the MRI equipment actually disturbs or is barely audible in relation to the existing background noise.

- For what purpose is each of the adjacent rooms used?
- Which rooms require special soundproofing?
- Are there any rooms occupied by third parties close by and if so for what purpose are they used?
- Is a change in the utilisation of any of the adjacent rooms planned for the future?

6.4 Construction of existing walls, ceiling and floor

The propagation of MRI operating noise depends on the construction of the building and different methods of insulation have to be adopted to confine noise and prevent it from being transmitted through the structure.

The following data are required to calculate the overall characteristics necessary:

- How good is the existing soundproofing for airborne noise (D) between the MRI room and the adjacent rooms?
- How is the floor constructed, how thick are the various layers and what is the mass per unit area?
- Is the floor construction isolated from the rest of the building?
- Is the floor slab on grade?
- What are the longitudinal and lateral (R_F) sound transmission indices of the entire floor?
- Are there any unnecessary openings in the partition walls (ventilation)?
- Can noise be conducted via services ducts or pipes?
- Does the room below the MRI have a suspended ceiling?
- Does the soundproofing against airborne and structurally borne noise conform to building regulations?

"As is" drawings are absolutely essential to clarify the conditions prevailing on site. However, should some of the data needed not be available, measurements by an acoustic engineer can provide them.

6.5 What soundproofing is actually necessary ?

The soundproofing to be integrated in the RF shielding is given approximately by the following:

	Noise emitted by the MRI equipment	
–	Tolerable noise in the adjacent room concerned	
=	Required soundproofing step	
Example:		
	MRI equipment	105 dB
–	Third-party conference/doctor's consulting room	-35 dB
=	Required soundproofing step	70 dB

7. Reduction of airborne noise

Noise either passes as air vibrations through openings (see Type a on Page 5) or causes walls, ceiling or floor to vibrate (Type b). Sound transmission can be limited by installing partition walls to create an inner shell. The IMEDCO RF shielding can be integrated in the overall design for this purpose. The aim is a "room-in-room" configuration with optimised spacing with respect to the building structure. To this end, the following criteria must be observed:

- The minimum gap specified between the RF enclosure and the structure of the building must be maintained.
- The inner shell must have a certain mass per unit area.
- The inner shell must be uninterrupted at all transitions.
- Ridgid connections to the building structure must be avoided.
- Cavities should be filled to $^{2}/_{3}$ with mineral wool.

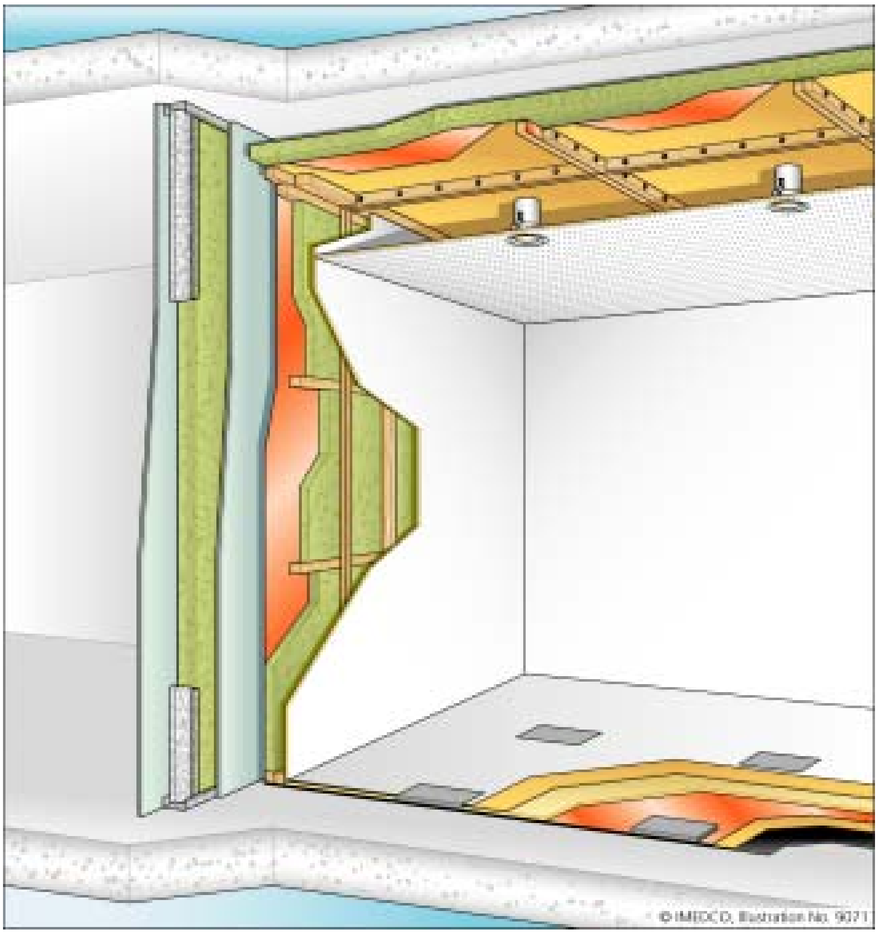
To simplify project design, IMEDCO has grouped the many possibilities into a three-step soundproofing system.

SilentSHIELD™ 1	**65 dB**
SilentSHIELD™ 2	**70 dB**
SilentSHIELD™ 3	**80 dB**

The noise suppression characteristic of the "ideal" uniform wall can be impaired by penetrations for windows, ventilation, wave-guides, filters, quench lines etc. Air-conditioning ducts and quench lines between NOISY and QUIET rooms are conductors of noise and must be correspondingly encapsulated.

7.1 IMEDCO **SilentSHIELD™ 1**

Building wall and ceiling	IMEDCO	Total audible noise suppression
KNAUF™ W112, w = 150 mm, and concrete ceiling w ≥ 200 mm R_w = 54 dB	RF attenuation/soundproofing: Mineral fibre panels in ceiling and walls	**65 dB**



(The supports for the MRI equipment feet depend on the make and may vary from the drawing.)

Advantages:

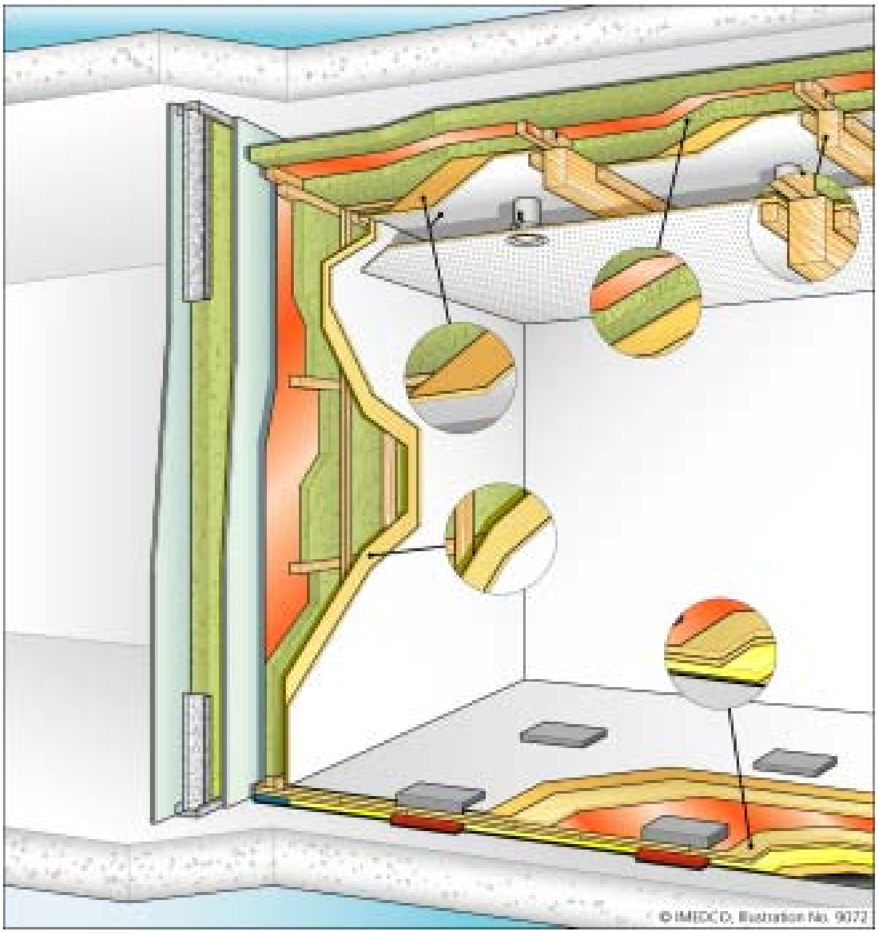
- Optimum arrangement of layers to minimise thickness
- Soundproofing can be largely integrated during production and therefore extremely cost effective
- Low static load

Alternative:

KNAUF™ W143, w = 175 mm and concrete ceiling w ≥ 300 mm R_w = 60 dB	RF attenuation/soundproofing: Mineral fibre panels in ceiling and walls	Total audible noise suppression **70 dB**

7.2 IMEDCO **SilentSHIELD™ 2**

Building wall and ceiling	IMEDCO	Total audible noise suppression
KNAUF™ W112, w = 150 mm, and concrete ceiling w ≥ 200 mm R_w = 54 dB	RF attenuation/soundproofing: Heavier ceiling and walls, elastic floor foundation	**70 dB**



Increased performance in relation to the 65 dB step:

Self-supporting ceiling attached to joists.

Additional mineral fibre sound-proofing in RF ceiling.

Extra layer makes soundproof ceiling heavier.

Double inner shell forms heavy cavity wall.

Elastically supported enclosure floor with chipboard reinforcement.

Elastically supported floor with different densities.

(The supports for the MRI equipment feet depend on make and may vary from the drawing.)

Advantages:

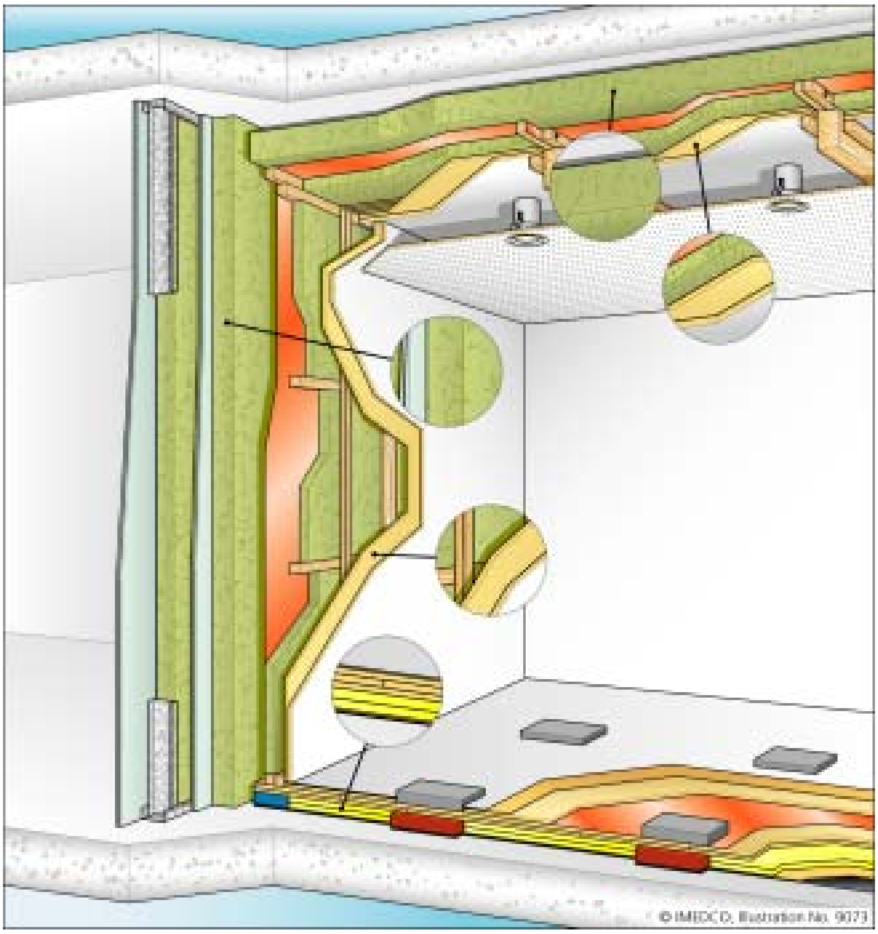
- Highly cost effective
- Minimum width
- Elastically supported RF floor

Alternative:

KNAUF™ W143, w = 175 mm and concrete ceiling w ≥ 300 mm R_w = 60 dB	RF attenuation/soundproofing: Heavier ceiling and walls, elastic floor foundation	Total audible noise suppression **75 dB**

7.3 IMEDCO **SilentSHIELD™ 3**

Building wall and ceiling	IMEDCO	Total audible noise suppression
KNAUF™ W143, w = 175 mm, and concrete ceiling w ≥ 300 mm R_w = 60 dB	RF attenuation/soundproofing: Much heavier ceiling and walls, thick elastic floor foundation	**80 dB**



Increased performance in relation to the 70 dB step:

Ceiling cavity filled with 100 to 150 mm of mineral fibre panels.

Soundproof ceiling with different degrees of weight increase.

Wall cavity filled with mineral fibre panels

Two inner shell panels of different thicknesses form heavy cavity wall.

Two layers of Elastomer provide a super soft sprung floor.

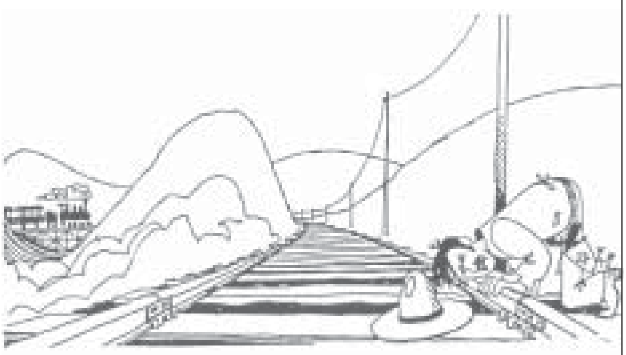
(The supports for the MRI equipment feet depend on make and may vary from the drawing.)

Advantages:

- Extremely high sound level difference D
- Optimised construction makes best use of available space
- Elastically supported RF floor with 2 instead of 1 layer of Elastomer

8. Structural soundproofing

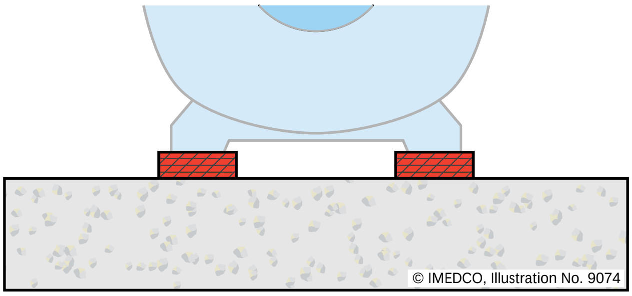
The current in the gradient windings generates an oscillating magnetic field in the core of the MRI equipment which gives rise to audible vibrations. If the magnet is standing directly on the floor the vibrations are transferred to it (see Type c on Page 5). Depending on the material of the floor, they will be conducted over a greater or smaller distance.

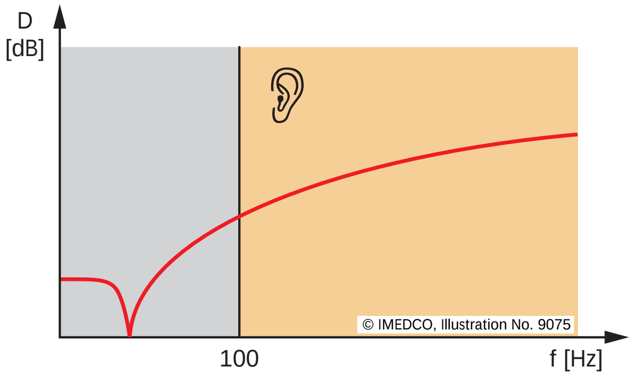


José can hear the train when it is still miles away.

8.1 Single elastic supports

The mass per square metre m' of a solid concrete floor for w ≥ 200 mm is approximately 460 kg. On this basis, the weighted apparent sound reduction index R'_W is already about 54 dB (DIN 4109, Table 1). In this case, a single elastic support under each foot is generally sufficient to prevent the MRI vibrations from being transferred to the floor. They are usually supplied together with the MRI equipment, otherwise IMEDCO can supply them.



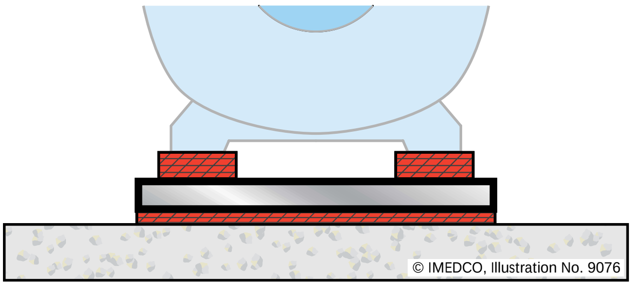


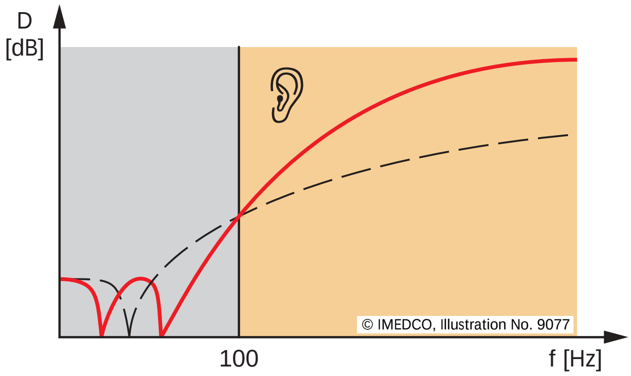
Where the mass of the floor is particularly high, it can only be excited to a small degree by MRI vibration. Single elastic supports are usually all that are needed to optimally decouple the MRI equipment from the building structure and provide adequate soundproofing in the audible range (100 Hz to 20,000 Hz).

There are different kinds of elastic supports. If they are necessary at all and if so which type depends on the make and model of MRI equipment.

8.2 Double elastic support

Where the mass of the floor is low, the oscillations generated by the MRI equipment can be transferred to the building structure. By adding an additional elastically supported mass to create a double elastic foundation, the total elastically supported mass can be increased. This improves the soundproofing of the MRI equipment with respect to structurally conducted noise thus reducing its transmission to the building structure.

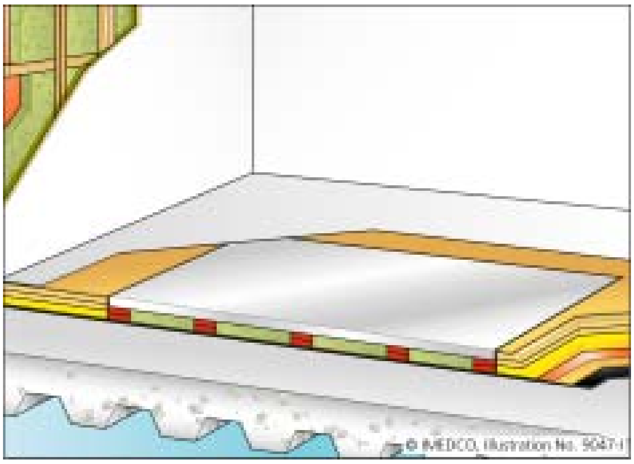




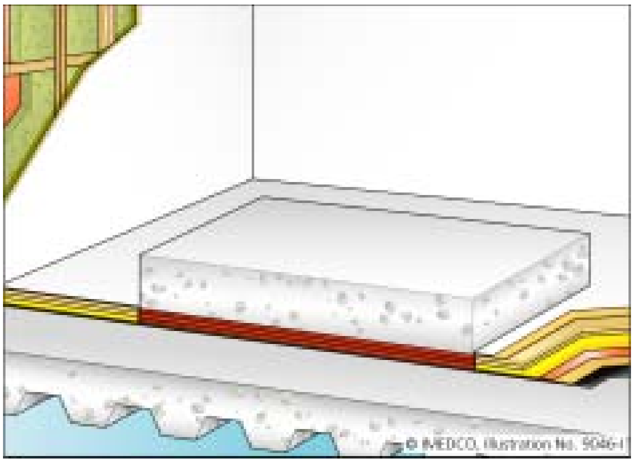
What is used for the additional mass, its dimensions and the type of support depend on the building structure and the make and model of MRI equipment.

An elastic system having two degrees of freedom achieves better noise reduction.

IMEDCO offers either a stainless steel plate or a concrete slab. The additional heavy mass can either be integrated in the shielding floor to form a level surface or placed on the floor as a pedestal.



- Elastically supported stainless steel plate (height 30 to 50 mm)
- Slight additional thickness has to be accommodated
- Good load distribution
- Wherever possible, the heavy plate is transported into the building together with the MRI equipment
- U.S. Patent No.: 6,626,264



- Elastically supported concrete pedestal (height 180 to 250 mm)
- An ideal solution for maintaining the minimum spacing when a magnetic shield is installed between the MRI equipment and the floor
- Cheaper than a stainless steel plate

9. Soundproofing components

9.1 IMEDCO **SilentSHIELD™** RF doors

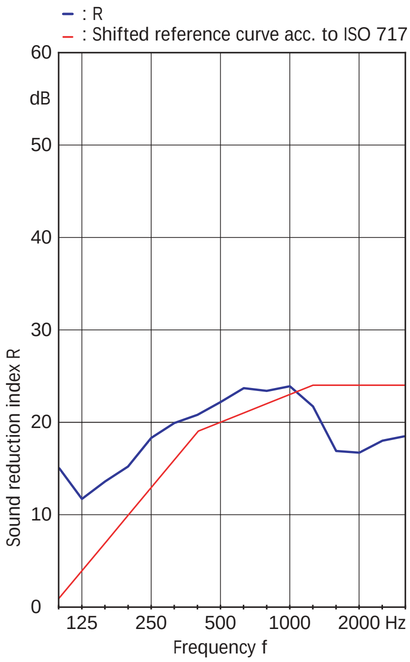
US type door with handle/roller latch and dead bolt cylinder lock

- Standard size: 1200 mm x 2100 mm, other sizes on request
- U.S. Patent No.: 6,519,899

European type door with safety lock

Standard RF door

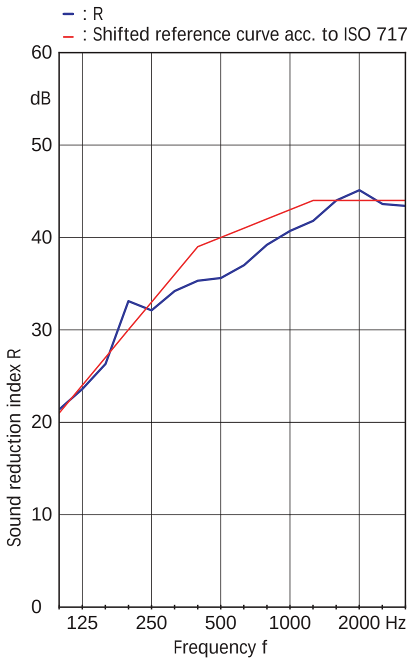
Double shell construction with contact fingers



R_w = 20 dB
Measurement Report No. 990604-B1

Extra soundproofed RF door
R_w = 40 dB

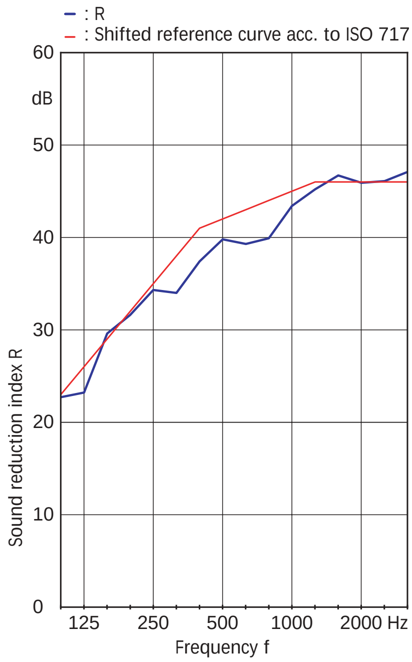
Double shell door with weighted and decoupled shells and integrated seal



R_w = 40 dB, R_{f1600}= 44 dB,
Measurement Report No. 020401-B2
U.S. Patent Appl. Publication
No. US 2003/0167697 A1

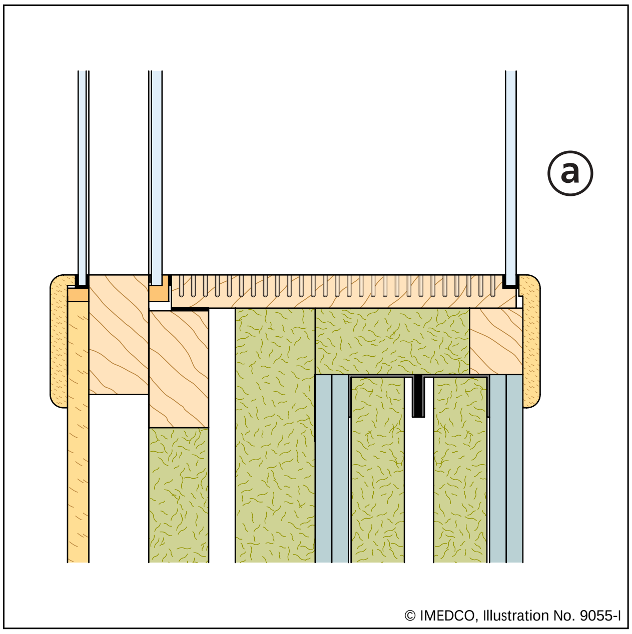
Super soundproofed RF door
R_w = 42 dB

As 40 dB door but with perforated door frame



R_w = 42 dB, R_{f1600}= 46 dB,
Measurement Report No. 991101-B2
U.S. Patent No. 6,519,899

9.2 IMEDCO **SilentSHIELD™** RF window

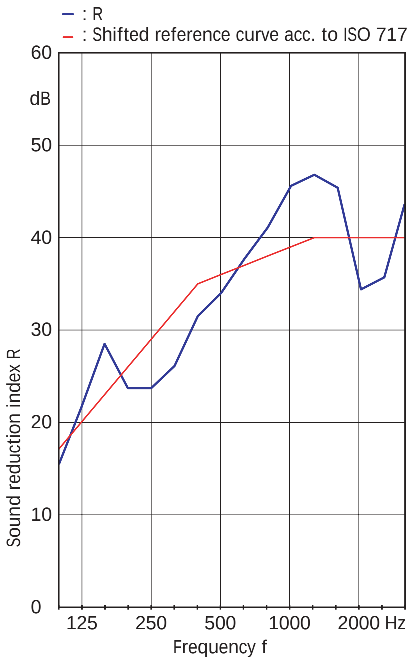


Thin panes of glass suppress high frequency sound waves very well and thick ones suppress low frequencies. An effective soundproof window therefore includes thin and thick panes of glass.

Further appreciable improvement is obtained by a third pane in the plain (a) (not normally part of our scope of supply). Connections to the building wall must be decoupled by elastic junctions.

Soundproofed RF window
R_w = 36 dB

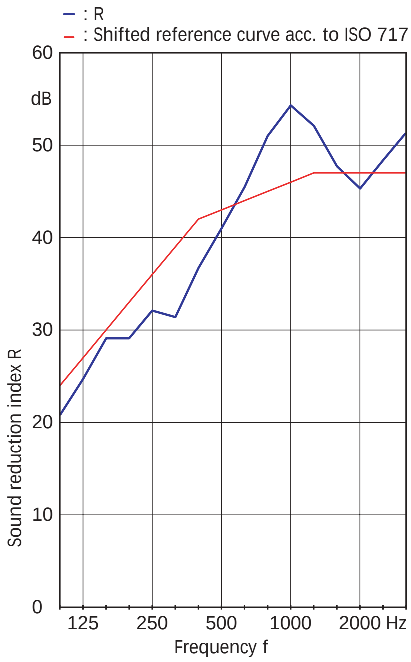
Two safety glass panes



R_w = 36 dB, R_{f1600}= 46 dB
Measurement Report
No. 990604-B3

Highly soundproofed RF window
R_w = 43 dB

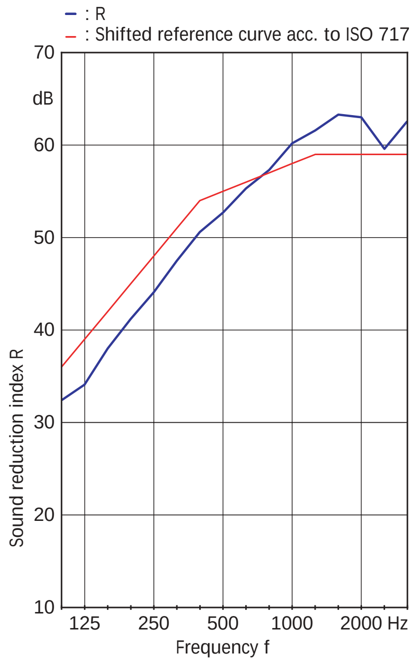
Two safety glass panes in different thicknesses



R_w = 43 dB, R_{f1600}= 48 dB
Measurement Report
No. 991101-B10

Super soundproofed RF window combination
R_w = 55 dB

Three glass panes of different thicknesses, laminated glass and perforated intermediate frame



R_w = 55 dB, R_{f1600}= 63 dB
Measurement Report
No. 031003-B4

10. Notes

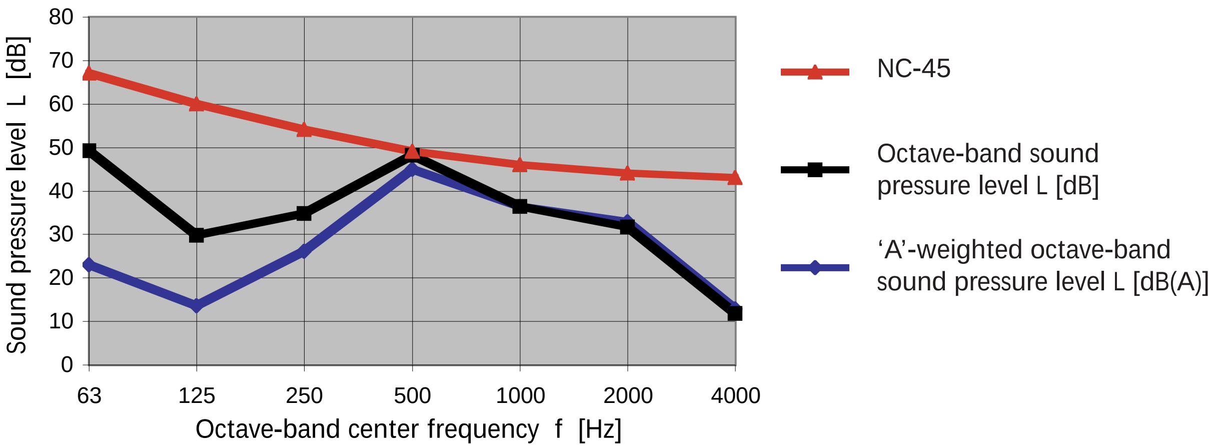
11. Glossary of technical terms

The following terms are frequently used in acoustics

dB		Symbol for decibel; unit for logarithmic physical quantities including sound pressure level
dB(A) A-weighted sound pressure level (SPL)		Sound pressure level adjusted to take account of the variation in human perception of different frequencies. A tone of 100 Hz is subjectively perceived as being quieter than a tone of 1,000 Hz at the same sound level. (see graph on the next page).
Frequency f	(Hz)	Cycles per second
Resonance frequency f_0	(Hz)	The natural frequency of an oscillatory system
Airborne sound	(dB)	Sound propagated through the air
Structure borne sound	(dB)	Sound propagated through solid material
One-third sound pressure level octave band	(dB)	Sound pressure level measured in each third of an octave
Sound reduction index (SRI) R *(Sound transmission loss)*	(dB)	Airborne noise suppression of components measured in the laboratory (excluding parallel paths) according to ISO 140/III. R is derived from the difference of noise levels D, the equivalent absorption area A in the receiving room and the test area S.
Apparent sound reduction index R'	(dB)	As for sound reduction index R, but measured on site (including parallel paths) according to ISO 140/IV
Weighted sound reduction index R_w *(almost identical to STC)*	(dB)	As for sound reduction index R, but reduced to a single number rating determined according to ISO 717/1 for classification of the frequency dependence
Weighted apparent sound reduction index R'_w *(Apparent sound transmission loss)*	(dB)	As for apparent sound reduction index R', but reduced to a single number rating determined according to ISO 717/1 for classification of the frequency dependence
Sound level difference D	(dB)	Difference between the sound pressure level in the source room L_1 and the sound pressure level in the receiving room L_2. $D = L_1 – L_2$
Weighted normalized sound level difference $D_{n,w}$	(dB)	As for sound level difference but reduced to a single number rating according to ISO 717/1 for the classification of the frequency dependant normalized sound level difference
Sound power level L_w (PWL)	(dB)	Sound emitted by the MRI equipment as airborne sound excluding the influence of the MRI room. Assuming the acoustic properties of the future MRI room are known, the prospective sound pressure level L_p can be calculated from the sound power level L_w.
Sound pressure level L_p (SPL)	(dB)	The operating noise level e.g. of the MRI equipment in the MRI room

Maximum sound pressure level $L_{AF,max}$	(dB)	'A' weighted maximum sound pressure level determined with time weighting "fast"
Time-average sound pressure level $L_{AF,r}$	(dB)	'A' weighted mean sound level determined during an assessment period (e.g. operating time of the MRI equipment) (DIN 45645). The purpose of this unit is similar to the day/night-sound level although the definition is slightly different
Day-night sound level (DNL)		Day/night sound level is a descriptor that takes account of the added impact of night time noise. It is a 24 hour L_{eq} based on 'A' weighting with 10 dB(A) added between the hours of 10:00 p.m. to 7:00 a.m. DNL is an accepted descriptor of environmental noise where sleep disturbance is an issue. Community noise impact is commonly described by DNL contours
Absorption coefficient α		Sound absorption coefficient
RF shielding		Metal screening preventing the propagation of radio frequency electromagnetic waves, i.e. Faraday cage

11.1 How to convert the MRI sound into NC limitation



The **octave band sound pressure level** is the true NON-WEIGHTED energy sound pressure level of a typical MRI system measured in the control room (incl. RF door and RF window).

The **noise criteria** (**NC**) are single numerical indices used primarily for air conditioning systems to define design goals for the maximum permissible noise in a given space. The NC criterion consists of a family of curves that define the maximum permissible octave band sound pressure level corresponding to a chosen NC design goal. To achieve the NC design goal the sound pressure level shall not exceed the given limit in each frequency band. Sound pressure level at 1000 Hz provides the single number value.

The **'A' weighted sound pressure level** is adjusted to take account of the variation in human perception of different frequencies. A tone of 100 Hz is subjectively perceived as being quieter than a tone of 1000 Hz at the same sound level. The curve is given for comparison only.

12. RF Attenuation

IMEDCO RF components and structures are available with the RF attenuations given on the right. These figures can, however, be adjusted according to the MRI equipment in use.

Magnetic field:	15 MHz	100 dB
Electric field:	10 kHz	100 dB
	30 MHz	100 dB
Plane waves:	30 MHz	100 dB
	100 MHz	100 dB
	130 MHz	100 dB

13. IMEDCO, Switzerland

Headquarters and manufacturing facility in Hägendorf, Switzerland (located 50 km south of Basle and 70 km west of Zurich at the motorway junction of the A1 and A2, motorway exit Egerkingen, Olten).

Administration and Production

- 90 Employees
- Company owned premises
- Fully equipped with laboratory and test instruments for RF and magnetic shielding applications
- Own manufacturing facility

Storage and Logistic

- 11 agents in Europe, Asia and America
- Quality management system according to ISO 9001 since 1997
- More than 2'500 reference installations

Medical RF & Magnetic Shielding Specialists – Worldwide

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