METROLINK

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A14.1

Relevant guidance and standards

Contents

14. Guidance and Standards

This Appendix to Chapter 14 of the Environmental Impact Assessment Report (EIAR) discusses the guidance and standards relevant to groundborne noise and vibration that have been taken into account in the preparation of the Chapter.

14.1 Groundborne Noise from Construction

There is no published formal guidance on thresholds of effects due to groundborne noise during construction. The effects can be expected to be no greater than those due to operation (and may be less depending on duration) which is discussed below.

14.1.1 Vibration from Construction Blasting

14.1.1.1 Effects on Human Beings

The Environmental Protection Agency Guidance Note for Noise: in Relation to Scheduled Activities 2nd Edition states:

"At quarries or mines where blasting occurs once per week or less the vibration levels from blasting should not exceed a peak particle velocity (PPV) of 12mm/s, measured in any three mutually orthogonal directions at a receiving location. For more frequent blasting the peak particle velocity should not exceed 8mm/s. These levels are for low frequency vibration, i.e., less than 40Hz. However, when the frequency of vibration is less than 10Hz the peak particle velocity should not exceed 8mm/s."

In the EIAR this guidance has been taken to apply to blasting in the construction of station boxes.

The EPA notes that human beings are known to be very sensitive to vibration, the threshold of perception being typically in the PPV range of 0.15mm/s – 0.3mm/s, at frequencies between 8Hz and 80Hz for continuous vibrations, and 0.5mm/s – 1.5mm/s in the case of impulsive vibrations from blasting operations.

14.1.1.2 Effects on Buildings

There is no Irish Standard providing guidance on vibration from blasting and its effects on buildings.

There are two relevant British Standards: British Standard BS 7385-2: 1993: Evaluation and measurement for vibration in buildings Part 2: Guide to damage levels from ground borne vibration and British Standard BS 5228-2: 2009 + A1: 2014: Code of practice for noise and vibration control on construction and open sites – Vibration.

Standards BS7385-2:1993 and BS5228-2:2009+A1:2014 (which repeats the BS 7385-2 guidance) advise that, for soundly constructed residential property and similar structures that are generally in good repair, a threshold for minor or cosmetic (i.e. non-structural) damage should be taken as a peak component particle velocity (in frequency range of predominant pulse) of 15mm/s at 4Hz increasing to 20mm/s at 15Hz and 50mm/s at 40Hz and above for transient vibration. BS5228-2 notes that criteria may be reduced where there exist significant defects of a structural nature, the amount of reduction being judged on the severity of such defects.

Table 14.1: Transient Vibration Guide Values for Cosmetic Damage, BS 7385-2:1993 and BS 5228-2: 2009+A1:2019

Category of Building	Peak Component Particle Velocity in Frequency Range of Predominant Pulse	
	4Hz to 15Hz	15Hz and above
Reinforced or framed structures. Industrial and heavy commercial buildings	50mm/s transient vibration	
Unreinforced or light framed structures. Residential or light commercial-type buildings	15mm/s at 4Hz increasing to 20mm/s at 15Hz	20mm/s at 15Hz increasing to 50mm/s at 40Hz and above

NOTE 1: Values referred to are at the base of the building

NOTE 2: For line 2, at frequencies below 4Hz, a maximum displacement of 0.6mm (zero to peak) should not be exceeded.

BS5228-2:2009+A1:2014 goes on to say:

"Minor damage is possible at vibration magnitudes which are greater than twice those given in Table B.2, and major damage to a building structure can occur at values greater than four times the tabulated values. Definitions of the damage categories are presented in BS ISO 4866:2010, 12.6. The guide values in Table B.2 relate predominantly to transient vibration which does not give rise to resonant responses in structures, and to low-rise buildings. Where the dynamic loading caused by continuous vibration is such as to give rise to dynamic magnification due to resonance, especially at the lower frequencies where lower guide values apply, then the guide values in Table B.2 might need to be reduced by up to 50%."

BS 7385-2 notes that the probability of damage tends towards zero at 12.5mm/s peak component particle velocity.

Current experience suggests that these values may be reduced where the preliminary survey reveals existing significant defects (such as defects which are a result of settlement) of a structural nature, the amount of reduction being judged on the severity of such defects (see for example BS ISO 4866:2010, 5.5). Important buildings which are difficult to repair might require special consideration on a case-by-case basis. A building of historical value should not (unless it is structurally unsound) be assumed to be more sensitive. Internationally, guidance is provided for a wider range of building types, including buildings particularly sensitive to vibration.

The German standard DIN4150-3:2016-12 Vibrations in buildings – Part 3: Effects on structures, provides the following guidance in its Table 1.

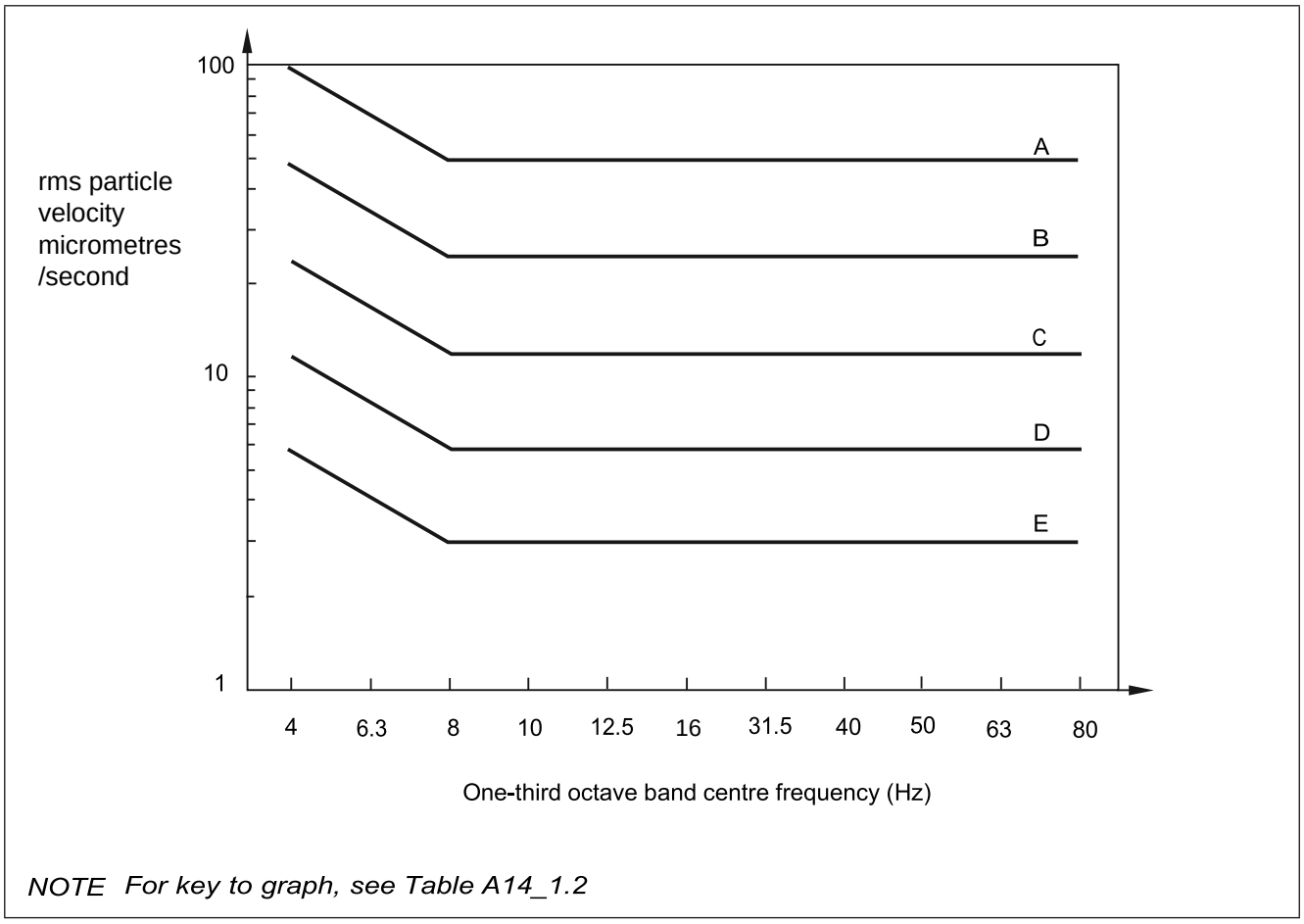
14.1.1.3 Effects on Contents of Buildings

BS 5228-2:2009+A1:2014 gives guidance on the effects of vibration on the contents of buildings:

"Many types of equipment, activities and processes are sensitive to vibration, often at levels of vibration below those that are directly perceptible to people. These include hospital operating theatres (especially those where microsurgery is undertaken), scientific laboratories and a range of industrial processes, such as optical typesetting, microelectronics manufacturing and automatic letter sorting. In electrical power generation, turbine shafts are not able to accommodate large oscillatory displacements."

Where there is uncertainty concerning the level of transmitted vibration and its acceptability to the particular environment, it is advisable to investigate the actual conditions and requirements in detail. Preliminary trials and monitoring can then be designed to establish a suitable procedure for the work. Alternatively, vibration criteria can be established through discussion with the manufacturer, supplier or operator. Where case-specific information is not available, or if otherwise appropriate, reference may be made to information from other sources, such as previous experience or published information. Diagram 14.1 illustrates a suite of curves showing the sensitivity to vibration of a variety of equipment, taken from reference [56]. Although modern electrical installations incorporate

solid state electronics, any disc drive units can be vulnerable to excessive vibration or shock. Major manufacturers have set acceptable external vibration criteria for their equipment, in both operating and transit modes. Criteria are often expressed in terms of limits on vibratory displacement up to a certain frequency and limits on vibratory acceleration at higher frequencies. A sinusoidal relationship is given between these parameters which can therefore be used to calculate the corresponding particle velocities. For continuous vibrations, the allowable thresholds are typically set at about 40% of the permitted levels of intermittent vibrations. Guidance in relation to telephone exchanges is given in ETS 300 019.



NOTE For key to graph, see Table A14_1.2

Diagram 14.1: Example of Vibration Criteria (BS5228-2:2009+A1:2014)

Table 14.2: Key to Vibration Criteria Illustrated in Figure A14_1.1

Curve (From Figure A14.1)	Facility, Equipment or Use	Rms Vibration Velocity µm/s
A	Bench microscopes at up to 400× magnification; optical and other precision balances; coordinate measuring machines; metrology laboratories; optical comparators. Microelectronics manufacturing equipment – Class A: Inspection, probe test, and other manufacturing support equipment.	50

Curve (From Figure A14.1)	Facility, Equipment or Use	Rms Vibration Velocity µm/s
B	Microsurgery, eye surgery, neurosurgery; bench microscopes at magnification greater than 400×; optical equipment on isolation tables. Microelectronics manufacturing equipment – Class B: aligners, steppers, and other critical equipment for photolithography with line widths of 3 µm or more.	25
C	Electron microscopes at up to 30 000× magnification; microtomes; magnetic resonance imagers. Microelectronics manufacturing equipment – Class C: aligners, steppers, and other critical equipment for photolithography with line widths of 1 µm.	12
D	Electron microscopes at greater than 30 000× magnification; mass spectrometers; cell implant equipment. Microelectronics manufacturing equipment – Class D: aligners, steppers, and other critical equipment for photolithography with line widths of 0.5 µm; includes electron-beam systems.	6
E	Microelectronics manufacturing equipment – Class E: aligners, steppers, and other critical equipment for photolithography with line widths of 0.25 µm; includes electron-beam systems; un-isolated laser and optical research systems.	3

Internationally, guidance is provided for a wider range of building types, including buildings particularly sensitive to vibration. The German standard DIN4150-3:2016-12 Vibrations in buildings – Part 3: Effects on structures, provides the following guidance in its Table 14.3.

Table 14.3: Guideline Values for Vibration Velocity, $v_{i,max}$, for Evaluating the Effects of Short-Term Vibration on Structures

-	Type of Structure	Guideline				
		Foundation, all directions, i = x, y, z, at a frequency of			Topmost floor, horizontal direction, i – x, y	Floor slabs, vertical direction, i = z
		1Hz to 10Hz	10Hz to 50Hz	50Hz to 100Hz[a]	All frequencies	All frequencies
	1	2	3	4	5	6
1	Buildings used for commercial purposes, industrial buildings, and buildings of a similar design	20	20 to 40	40 to 50	40	20
2	Residential buildings and buildings of similar design and/or occupancy	5	5 to 15	40 to 50	15	20
3	Structures that, because of their particular sensitivity to vibration, cannot be classified under lines 1 and 2 **and** are of great intrinsic value (e.g. listed buildings)	3	3 to 8	8 to 10	8	20[b]
NOTE Even if guideline values as in line 1, columns 2 to 5, are compiled with, minor damage cannot be excluded.						
[a] At frequencies above 100Hz, the guideline values for 100Hz can be applied as minimum values [b] Paragraph 2 of 5.1.2 in DIN 4150 says "In the case of building types as in Table 1, line 3, it may be necessary to lower the relevant guideline value markedly to prevent minor damage"						

In other countries a range of recommendations appear in guidance and standards, as summarized below.

Table 14.4: DGMS Prescribed Permissible Limit of Ground Vibration (INDIA)

Type of Structures	Dominant Excitation Frequency, Hz		
	< 8Hz	8-25Hz	>25Hz
(A) Buildings/structures do not belong to the owner			
Domestic houses/structures (Kuchcha, bricks & Cement)	5	10	15
Industrial building	10	20	25
Objects of historical importance & sensitive Structures	2	5	10
(B) Buildings belonging to the owner with limited span of life			
Domestic houses/structures Industrial buildings	10 15	15 25	20 50

Table 14.5: CMRI Standard (Dhar et al, 1993)

Type of Structures	PPV (mm/s)	
	<24Hz	>24Hz
Domestic houses, dry well interior, construction Structures with plasters, bridge	5.0	10.0
Industrial buildings, steel or reinforced concrete structures	12.5	25.5
Object of historical importance, very sensitive Structures, more than 50 years old construction and Structures in poor state condition	2.0	5.0

Table 14.6: After Australian Standard (As A-2183) (Just and Chitombo,1987)

Type of Structures	Ground ppv (mm/s)
Historical building and monuments and buildings of special value	2
Houses and low-rise residential buildings, commercial buildings not included below	10
Commercial buildings and industrial buildings or structures of reinforced concrete or steel construction	25

Table 14.7: After Australian Standard (Ca-23-2183) (Just and Chitombo,1987)

Types of Structures	Ground ppv (mm/s)
Historical buildings and monuments and buildings of Special value	0.2mm displacement for frequencies less than 15Hz
Houses and low-rise residential buildings, commercial Buildings not included below	19mm/s resultant PPV for frequencies greater than 15Hz
Commercial buildings and industrial buildings or Structures of reinforced concrete or steel construction	0.2mm maximum displacement corresponds to 12.5mm/s PPV at 10Hz and 6.25mm/s at 5Hz

Table 14.8: After Hungarian Standard

Type of Structures	Permissible Limit (mm/s)
Construction demanding special protection, military, telephones, Airport, dams, bridges which have length of more than 20m	Extra opinion from expert
Statistically not solid damaged construction, temples, monuments, oil and gas wells and up to 0.17Mpa and below 0.7Mpa pressure in pipes (oil and gas)	2
Panel houses and statistically not fully determined structures	5
Statistically good condition structures, towers, electrical apparatus, water plant	10
RCC and structures concrete, tunnels, canals and other pipelines Beneath the soil surface greater than 0.7m, opening the sublevel	20
Public road, railway and electrical lines, telephone lines ropeway	50

Table 14.9: USSR Standard

Type of Structures	Allowable PPV (mm/s)	
	Repeated	One-fold
Hospitals	8	30
Large panel residential buildings and children's institution	15	30
Residential and public buildings of all type except large panels, Office and industrial buildings having deformations, boiler rooms and high brick chimneys	30	60
Office and industrial buildings, high reinforced concrete pipes, Railway and water tunnels, traffic flyovers, saturated sandy slopes	60	120
Single storage skeleton type industrial buildings, metal and block Reinforced concrete structures, soil slopes which are part primary Structures, primary mine openings (service life up to 10 years) pit bottom, main entries, drifts	120	240
Secondary mine openings (service life up to 3 years) haulages and drifts	240	480

Table 14.10: After Swiss Standard

Type of Structures	Frequency Band Width [Hz]	Blast Induced PPV [mm/s]	Traffic/Machine Induced PPV [mm/s]
Steel or reinforced structures such as factories, retaining walls, bridges, steel towers, open channels, underground tunnels and chambers	10-60	30	-
	60-90	30-40	-
	10-30	-	12
	30-60	-	12-18

Type of Structures	Frequency Band Width [Hz]	Blast Induced PPV [mm/s]	Traffic/Machine Induced PPV [mm/s]
Buildings with foundation walls and floor in concrete, well in concrete or masonry, underground chambers and tunnels with masonry linings	10-60	18	-
	60-90	18-25	-
	10-30	-	8
	30-60	-	8-12
Building with masonry walls and wooden ceilings	10-60	12	-
	60-90	12-18	-
	10-30	-	5
	30-60	-	5-8
Objects of historic interest or other sensitive structures	10-60	8	-
	60-90	8-12	-
	10-30	-	3

Table 14.11: After Sweden Standard (after Pesson et al., 1980)

Type of Structures	Limiting Vibration Parameters		
	Amplitude (mm)	Velocity (mm/s)	Acceleration (mm/s^2)
Concrete bunker steel-reinforced	-	200	-
High rise apartment block-modern concrete of steel frame design	0.4	100	-
Underground rock cavern roof hard rock, span 15-18 m	-	70-100	-
Normal block of flat-brick or equivalent walls	-	70	-
Light concrete buildings	-	35	-
Swedish National Museums-Building structures	-	25	-
Swedish National Museums-Sensitive exhibits	-	-	5
Computer centre	0.1	-	2.5
Circuit breaker control room	-	-	0.5-2.0

14.1.2 Vibration from Construction – Other Than Blasting

14.1.2.1 Effects on Human Beings

There is no Irish Standard or guidance for vibration from sources other than blasting.

With regard to non-blasting vibration effects on people, guidance is contained in BS 6472-1:2008 and BS 5228-2:2009+A1:2014 which is set out above in terms of ppv. Since BS5228-2:2009+A1:2014 post-dates BS 6472:2008 and recommends the use of ppv (for construction vibration) rather than the vibration dose value (VDV) of BS 6472.

The following table is provided in BS 5228-2:2009:+A1:2014

Table 14.12: Guidance on Effects of Vibration Levels

Vibration level A), B), C)	Effect
0.14mm·s^{-1}	Vibration might be just perceptible in the most sensitive situations for most vibration frequencies associated with construction. At lower frequencies, people are less sensitive to vibration.
0.3mm·s^{-1}	Vibration might be just perceptible in residential environments.
1.0mm·s^{-1}	It is likely that vibration of this level in residential environments will cause complaint but can be tolerated if prior warning and explanation has been given to residents.
10mm·s^{-1}	Vibration is likely to be intolerable for any more than a very brief exposure to this level in most building environments.

A) The magnitudes of the values presented apply to a measurement position that is representative of the point of entry into the recipient.

B) A transfer function (which relates an external level to an internal level) needs to be applied if only external measurements are available.

C) Single or infrequent occurrences of these levels do not necessarily correspond to the stated effect in every case. The values are provided to give an initial indication of potential effects, and where these values are routinely measured or expected then an assessment in accordance with BS 6472^{-1} or $^{-2}$, and/or other available guidance, might be appropriate to determine whether the time varying exposure is likely to give rise to any degree of adverse comment.

Effects on Buildings

There is no Irish Standard or guidance for vibration from sources other than blasting. International guidance and standards on vibration effects on buildings is included in the summary give above with regard to vibration due to blasting. That guidance focuses on transient effects. Where vibration sources produce continuous vibration, other standards apply. However, the only sources capable of causing continuous vibration in the MetroLink project are mechanical plant and services, for example in stations. With regard to continuous vibration BS 7385-2:1993 advises "*Where the dynamic loading caused by continuous vibration is such as to give rise to dynamic magnification due to resonance, especially at the lower frequencies where lower guide values apply, then the guide values in Table 1 may need to be reduced by up to 50%. NOTE There are insufficient cases where continuous vibration has caused damage to buildings to substantiate these guide values, but they are based on common practice".*

14.1.2.2 Ground-borne Noise from Construction – Tunnel Boring Machine

There is no Irish guidance or Standard relating to groundborne noise from tunnel boring machines. There is no international standard on the subject. However, the previous Metro North scheme completed examination in the Oral Hearing process and a Railway Order was granted for its construction. The approach taken regarding standards for groundborne noise from the tunnel boring machine are therefore material to the Metro Link assessment process. The Metro North EIS stated "Because of the finite duration of this effect, the night-time impact thresholds have been set 5dB higher than those for the operation of the proposed scheme. Separate day-time thresholds (not relevant to operation as there is no difference between LAmax, for a passing tram by day or night) have been used which are 5dB above the night-time thresholds (i.e. 10dB above the thresholds for operation)."

14.1.2.3 Vibration from Construction – Tunnel Boring Machine

There is no Irish guidance or Standard relating to vibration from tunnel boring machines. General guidance and standards relating to vibration effects on humans, buildings and building contents are discussed above.

14.1.2.4 Vibration from Operation – Effects on Human Beings

There is no Irish guidance or Standard relating to thresholds of effects due to vibration from the operation of an underground railway, nor any international standard on the subject. In the UK. Railway schemes in the UK involving trains operating in tunnels have adopted their own standards, the most recent being High Speed 2 (HS2). The following table is table from HS2 Information Paper E21, based on the VDV method of BS 6472-1:2008.

Table 14.13: HS2 Information Paper E21

Vibration	Lowest Observed Adverse Effect Level	VDVday[m/s$^{1.75}$]	0.2
		VDVnight[m/s$^{1.75}$]	0.1
	Significant Observed Adverse Effect Level	VDVday[m/s$^{1.75}$]	0.8
		VDVnight[m/s$^{1.75}$]	0.4

With regard to effects on human beings in non-residential buildings the following table appears in HS2 IP21.

Table 14.14: HS2 Information Paper IP21

Examples	VDVday [m/s$^{1.75}$]	VDVnight [m/s$^{1.75}$]
Hotels; hospital wards; and education dormitories	0.2	0.1
Offices; Schools; and Places of Worship	0.4	n/a
Workshops	0.8	n/a
Vibration sensitive research and manufacturing (e.g. computer chip manufacture); hospitals with vibration sensitive equipment / operations; universities with vibration sensitive research equipment / operations	Risk assessment will be undertaken based on the information currently available for the relevant equipment / process, or where information provided by the building owner or equipment manufacturer.	

14.1.2.5 Ground-borne Noise from Operation – Effects on Human Beings

There is no Irish guidance or Standard relating to thresholds of effects due to vibration from the operation of an underground railway, nor any international standard on the subject. In the UK. Railway schemes in the UK involving trains operating in tunnels have adopted their own standards, the most recent being High Speed 2 (HS2). The following table is table from HS2 Information Paper E21 and relates to groundborne noise measured near but not at the centre of a residential room.

Table 14.15: HS2 Information Paper E21

Groundborne Noise	Lowest Observed Adverse Effect Level	LpASMax [dB]	35
	Significant Observed Adverse Effect Level	LpASMax [dB]	45

With regard to non-residential premises, the following table appears in HS2 IP21.

Table 14.16: HS2 Information Paper IP21

Examples	LpASMax [dB]
Large auditoria; and concert halls	25
Sound recording & broadcast studios; theatres, and small auditoria	30
Places of meeting for religious worship; courts; cinemas; lecture theatres; museums; and small auditoria or halls	35
Offices; schools; colleges, hospitals; hotels; and libraries	40

14.1.2.6 Vibration from Operation – Effects on Buildings

There is no Irish guidance or Standard relating to thresholds of effects due to vibration from the operation of an underground railway, nor any international standard on the subject. General guidance and standards relating to vibration effects on buildings and building contents are discussed above.

14.1.2.7 Vibration from Maintenance – Operational Phase

There is no Irish guidance or Standard relating to thresholds of effects due to vibration from the operation of an underground railway, nor any international standard on the subject.

14.1.2.8 Especially Sensitive Receptors – Construction and Operation

Receptors with particular sensitivity to vibration include laboratories containing sensitive equipment such as electron microscopes, and buildings containing fragile artefacts.

In addition to the guidance given in BS5228:2009+A1:2014 set out in A14_1.12 above, a frequently used set of criteria for the effects of vibration on sensitive equipment is the ASHRAE guidelines[1], which are reproduced in Diagram 14.2.

[1] Sound and Vibration Control, The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE): HVAC Applications (SI Edition), 2007

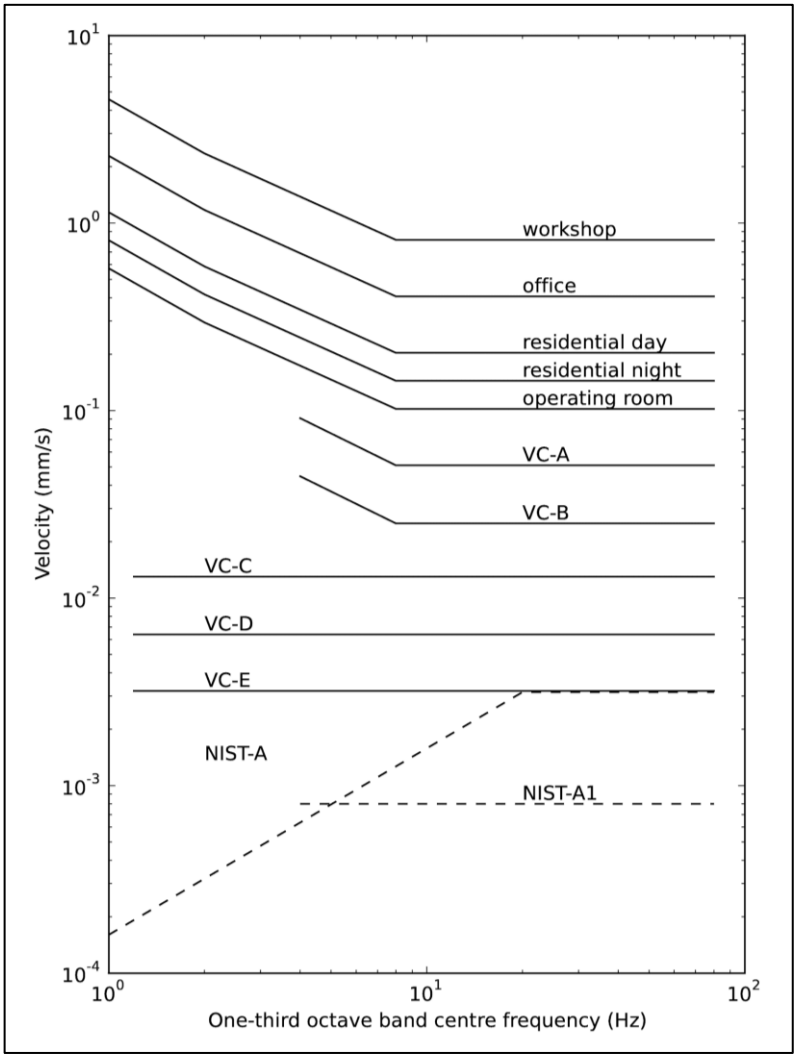


Diagram 14.2: ASHRAE and NIST Criteria

For highly sensitive spaces in which submicron processes are carried out, criterion VC-D or VC-E are used. (Both are routinely used worldwide for semiconductor facilities). An alternative is NIST-A which was originally used for 'metrology' laboratory space at the Advanced Measurement Laboratory (AML) of the USA's National Institute of Standards and Technology (NIST) in Gaithersburg, Maryland. NIST-A is more stringent than VC-E at frequencies below 20Hz. Spaces requiring a better environment than can be provided even by a quiet site may have a 'better than NIST-A' environment defined by NIST-A1.

The British Museum adopted VC-D as the most stringent criterion during the construction of The World Conservation and Exhibition Centre built between 2008 and 2014. As shown in Diagram A14.1 the VC-D curve has a flat frequency response in terms of velocity, and its value is 0.003125mm/s at all frequencies.

With regard to sensitive laboratory spaces, the Francis Crick Institute in St Pancras, London, was designed with a general criterion requirement of VC-E, which is 70dB re 1nm/s.