

7 Vibration Management

7.1 Vibration Criteria

Ensuring human comfort against vibration emissions is paramount. Vibration caused by plant, medical equipment and activities within the building should not affect the use of the building.

Health facilities, may include medical equipment which are sensitive to vibration. The same applies to people. Excessive vibration can lead to adverse comment from the building occupants and can impair the operation of sensitive equipment.

The following table has been shown to be adequate for medical equipment in certain common areas of health facilities.

| Area | Multiplying factors |
|--|---------------------|
| Operating theatre, precision laboratory, audiometric testing booth | 1 |
| Inpatient Units | 2 |
| General laboratories, Treatment areas | 4 |
| Offices, Consulting rooms | 8 |

Table 9 – Multiplying factors for rooms corresponding to a low probability adverse comment

Plant vibration is to meet the structure–borne noise criteria shown in Table 12.

7.2 Continuous vibration

Assess continuous vibration in terms of the root mean square (RMS) value (averaged over one second) of the frequency – weighted acceleration on the floors of occupied areas.

The frequency weighting should be W_g as specified in BS 6841. The frequency – weighted acceleration base value is 0.005m/sec^2 .

Multiplying factors that relate to the referenced base values are derived from dividing the weighted RMS acceleration by the base value.

7.3 Intermittent vibration

Intermittent vibration is when there are interrupted periods of continuous emissions or repeated periods of impulsive vibration or continuous vibration that varies significantly in magnitude i.e. rapid rise or drop of magnitude. Conservatively can be assumed to be continuous. Alternatively, if the duration and frequency of event occurrence is known, the vibration dose value (VDV) can be used. Refer to low values of probability adverse comment for different types of spaces:

| Area | VDV ($\text{m/s}^{1.75}$) |
|---------------------------------------|-----------------------------|
| Wards | 0.2 |
| General laboratories, treatment areas | 0.4 |
| Offices, consulting rooms | 0.8 |

Table 10 – VDV criteria for different spaces

For operating theatres and precision laboratories, there is no allowance made for intermittent events. Thus, the criteria relate to the maximum frequency–weighted acceleration of continuous vibration.

7.4 Critical areas and building structure vibration

The following figure recommends the appropriate vibration curves for different room types. Relevant curves are extracted below:

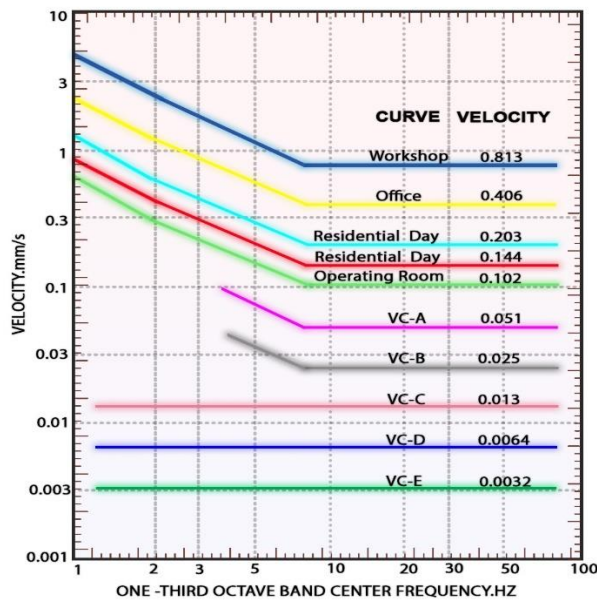


Figure 1 – Building vibration criteria for vibration measured on building structured

Note:

- When the vibration source is constant (as generated by plant), the rms (average) level is to be used.
- When the vibration source is intermittent (as generated by footfall during normal walking), the rms (max 1 second) level is to be used.

7.5 Vibration isolation and material selections

It is recommended that system components containing rotating machinery be isolated for vibration both in physical mounting and in all duct and pipe connections. This includes, but is not necessarily limited to, the following equipment:

- AHUs, FAHUs & Ecology Units
- Boilers
- FCUs and VAVs
- Fan Systems
- Generators
- Motors and Pumps
- Transformers
- Vertical Transportation Systems

Specifics on isolator types (spring, neoprene, etc.), mounting (floor, hanger, etc.), and required deflection can be determined on a case-by-case basis if required. General vibration isolator requirements are shown in Tables below:

| Equipment Type | Base Type | Isolator Type | Deflection (mm) |
|---|-------------------|---------------|-----------------|
| Reciprocating Air Compressors and Vacuum Pumps | Concrete Inertia | Spring Type | 19 mm |
| Tank-Mounted horizontal Air Compressor up to 7.5 kW | None | Spring Type | 19 mm |
| Axial Fan Over 500 RPM, up to 500 Pa | Steel or Concrete | Spring Type | 19 mm |
| Centrifugal Fan 37 kW & Over 500 RPM | Steel or Concrete | Spring Type | 25 mm |
| Packaged Air Handler Over 115 kW & Over 300 RPM | Steel or Concrete | Spring Type | 19 mm |
| Packed Pump System | None | Spring Type | 19 mm |

Table:11 Vibration isolation criteria for slab on grade

| Equipment Type | Base Type | Isolator Type | Deflection (mm) |
|---|------------------|---------------|-----------------|
| Reciprocating Air Compressors and Vacuum Pumps | Concrete Inertia | Spring Type | 38 mm |
| Tank-Mounted horizontal Air Compressor up to 7.5 kW | None | Spring Type | 38 mm |
| Axial Fan Over 500 RPM, up to 500 Pa | Concrete Inertia | Spring Type | 38 mm |
| Centrifugal Fan 37 kW & Over 500 RPM | Concrete Inertia | Spring Type | 38 mm |
| Packaged Air Handler Over 115 kW & Over 300 RPM | Concrete Inertia | Spring Type | 64 mm |
| Packed Pump System | None | Spring Type | 38 mm |

Table 12 - Vibration isolation criteria for slab above grade, floor span 6-9m

Vibration isolators should be sized and selected with knowledge of the loads exerted by the item being isolated to meet the specified deflection requirements.

The information regarding the equipment should be verified including:

- Equipment identification
- Isolator type
- Weight of the item
- Static deflection of each mount under the load of the item

The vibration isolation system should have levelling screws and locking nuts to allow the deflection of each mounting to be adjusted to the design value at the operating condition of the supported equipment.

Housed spring isolators are not preferred as they are prone to misalignment and short-circuiting. It is recommended that un-housed spring isolators should be specified.

7.6 Air handling units (AHU's)

All AHU's should be installed on double deflection neoprene type mounts that provide a minimum static deflection of 10 mm. The internal spring mounts for the fans must be bolted down before installation.

The plenum manufacturer should provide all factory fabricated panels, joiners, access doors, structural supports, channels, fasteners, sealing accessories, assembly drawings and all other items necessary for erection.

Coils and filters in built-up AHU's should be supported from the housekeeping pad on neoprene pads. Any remaining gap beneath the coil/filter frame must be sealed airtight with a suitable non-hardening sealant.

7.7 Conduit isolation

Where isolated containment is ganged on a trapeze, it should rest on the trapeze and the trapeze should be isolated from the structure with the appropriate isolators. Neoprene pipe riser guides should be used where lateral restraint is required.

The first three containment support vibration isolators should provide the same static deflection as the equipment vibration isolators.

Wiring conduit to panel boards, ballast panels and any electrical equipment enclosures containing relays, small transformers or choke coils do not require special isolation.

7.8 Duct and pipe isolation

Pipes, ducts, and their contents, or other services connected, should be supported to avoid load on equipment items.

Flexible duct connectors at connections to fans or AHU's should be coated fabric 200 mm across a clear gap of 100 mm.

The first five supports for ductwork on either side of the vibration source shall also be provided with vibration isolators equal in static deflection to that of the Fan/ AHU.

Electrical connections to equipment mounted on vibration isolation bases should be made through flexible conduit which changes direction by at least 90° in a minimum length of 25 conduit diameters.

Mineral insulated cables should be looped through at least 360° at 75 mm radius or double the permissible minimum radius, whichever is larger.

7.9 Fan coil units and VAVs

All FCU's and VAV's serving occupied areas should be hung from 10 mm thick neoprene isolation hangers with the internal isolators and to avoid rigid connections to the walls, soffits and ceilings. If there are no internal springs, then spring isolators as recommended shall be provided.

7.10 Fan systems

To reduce the degree of vibration transmitted into the base structures, it is recommended that all fans serving occupied areas and located in plant rooms adjacent to occupied areas are installed on steel bases with spring type vibration isolation mounts having a static deflections of 50 mm.

Suspended fans from overhead structures should be hung on steel spring hangers. The static deflection of the isolators should be 50 mm. If the fan does not contain a frame with mounting brackets of suitable rigidity and strength, or if there is an extreme overhang condition, then a structural steel base should be used.

Fans should be suspended from above only if expressly noted as such on the design drawings and schedules. Any required thrust restraint should only be by pre-compressed isolators.

7.11 Flexible pipe connectors

Reinforced flexible pipe connectors should be used where pipes are to be located adjacent to acoustically sensitive spaces needing to achieve NC 35 or below and as recommended in the Table below:

| Equipment | Isolator type |
|---|---|
| Pump connections (< 16 bar(g)) | Flexible connectors (FC) |
| Pump connections (> 16 bar(g)) | Multiple grooved couplings (MGC) to provide adequate vibration isolation |
| AHU connections (< 80 mm) | Direct connection |
| AHU connections (> 80 mm) | Flexible connector (FC) or multiple grooved couplings to provide adequate vibration isolation |
| FCU connections (< 25 mm) | Direct connection |
| FCU connections (> 25 mm) | Flexible hose (FH) |
| Connections to expansion tanks, desecrators, heat exchangers etc. | Multiple grooved couplings (MGC) to provide adequate vibration isolation |
| Connections to chillers, cooling towers and similar plant | Multiple grooved couplings (MGC) to provide adequate vibration isolation |

Table 13 - Flexible pipe connections

Flexible pipe connectors of corrugated metal, or rubber, neoprene or other flexible liner with braided metal or other similar internal or external reinforcing, and intended for use without tie rods, shall have the minimum live lengths given in the table below when used for anti-vibration purposes.

| Nominal Pipe Bore Diameter | Live Length |
|----------------------------|-------------|
| 0 – 65 mm | 300 mm |
| 80 – 100 mm | 450 mm |
| 125 – 250 mm | 600 mm |
| 300 mm or greater | 900 mm |

Table 14 - Flexible pipe connector live lengths

Note that the live length applies to the end-to-end length for flanged flexible rubber hose. For other types of hose, the live length applies to the overall end-to-end length less the fitting length. Where hose connectors are used to connect equipment with high pressures > 16 bar(g) multiple grooved couplings are recommended

All flexible connectors require end restraint to counteract pressure thrust, as. Over-extension caused by pressure thrust on isolated equipment will cause failure which must be avoided. It is recommended that the manufacturer's recommendations on restraint, pressure and temperature limits are followed.

Where tie rod systems are used for vibration isolation on expansion joints or arched-type connectors, these should be designed to achieve the vibration isolation required across the entire joint. The tie rod fixings should use rubber/neoprene bushed washers to prevent metal to metal contact throughout the normal range of movement of the joint.

7.12 Generators

For vibration control, each engine-generator should be bolted to a separate sub-frame with resilient mountings which is then in turn attached to a main frame, to provide complete vibration isolation of the control gear, radiator and other components. Skid vibration isolators with a minimum 50 mm static deflection and restrained spring isolators, mounted on a 100 mm thick housekeeping pad, should be considered

7.13 Boilers

Install boilers on waffle pad mounts with minimum static deflection of 6 mm.

7.14 Motors and electrical equipment

All wiring connections to motors and electrical equipment supported on vibration isolators should be made with a minimum of 1 m long flexible conduit in a 360° loop.

The vibration severity quality of the motor in any direction, due to all sources are recommended as follows:

- Motors with shaft centre height greater than 400 mm and speeds of 10 Hz or more, as Table 2, Column 1 of BS 4999.
- Motors with shaft centre heights less than 400 mm and speeds of 10 Hz or more, Grade R.
- Motors operating at speeds below 10 Hz, as severity grades (or tabulated values of Table 2 of BS 4999) for 10 Hz motors.
- Motors in occupied spaces, or on fan convectors, canned rotor pumps etc., vibration velocity limits as for Grade R for motors with shaft heights between 80 and 132 mm.
- Variable or multi-speed motors shall satisfy the balance quality grade required for their highest operating speed.

The resonant frequency of vibration isolation systems for electric motors with stepped speed starting arrangements (star delta, tapped resistor and transformer etc.) should not correspond to any of the speeds at the step changes and shall allow for long “run-up” and “run-down” times.

7.15 Piped services

Provide vibration isolation to all distributed piped services following the guidelines provided in Table below which refer to the use of Resilient Inserts (RI) within the pipe clamps, Neoprene Hangers (NH), Spring Hangers, Neoprene Mounts (NM) and Spring Mounts (SM).

| Service | Pipe Diameter | Isolator Types | Static Deflection |
|-------------------|------------------|----------------|-------------------|
| Heating | Less than 50 mm | NH, NM | 8 mm |
| | 50 – 150 mm | SH, SM | 25 mm |
| | More than 150 mm | SH, SM | 50 mm |
| Chilled Water | Less than 50 mm | NH, NM | 8 mm |
| | 50 – 150 mm | SH, SM | 25 mm |
| | More than 150 mm | SH, SM | 50 mm |
| Domestic Water | Less than 50 mm | NH, NM | 8 mm |
| | More than 150 mm | SH, SM | 25 mm |
| Heat Recovery | Less than 50 mm | NH, NM | 8 mm |
| | More than 150 mm | SH, SM | 25 mm |
| Condenser Cooling | Less than 50 mm | NH, NM | 8 mm |
| | More than 150 mm | SH, SM | 25 mm |
| Rainwater | Less than 50 mm | RI | Not required |
| | More than 150 mm | RI | Not required |
| Sprinkler | All | RI | Not required |
| Dry Riser / Vent | All | RI | Not required |
| Hose Reel | All | RI | Not required |

| Service | Pipe Diameter | Isolator Types | Static Deflection |
|----------------|---------------|----------------|-------------------|
| Compressed Air | All Steel | RI | Not required |
| Sanitary Sewer | All | RI | Not required |

Table 15 - Pipe services and resilient isolators

7.16 Plant without pumps and motors

Expansion tanks, desecrators, heat exchangers, water heaters, etc., without pumps or motors which are floor mounted should be supported on neoprene pads. Where pipes on isolators are connected to the units the connection should be made with a neoprene flexible connector.

7.17 Pumps and inertia bases

Base mounted pumps ≥ 1.1 kW should be bolted and grouted to prefabricated, reinforced concrete inertia bases, which weigh not less than 1.5 times the combined weight of the fluid filled pump(s) and motor(s).

Any rigid pipe elbows at the pump suction and discharge connections should be supported from the inertia base. Each inertia base should be supported on spring isolators.

Base-mounted pumps < 1.1 kW and installed on floors above grade should be installed on concrete inertia bases on at least four neoprene mounts. Base-mounted pumps under 1.1 kW and located on grade should be mounted directly on a concrete housekeeping pad on at least four neoprene mounts.

In-line pumps ≥ 1.1 kW should be supported by the piping which is isolated on spring isolators. If support is required below the pump, the pump should be supported on spring hangers or mounts as appropriate. In-line pumps < 1.1 kW and adjacent pipework should be supported on neoprene isolating hangers unless other provisions call for greater static deflections.

If an associated circulation pump or chemical feed pump is to be mounted on the unit and if the pump is < 0.4 kW then the pump should be mounted to the unit through restrained neoprene isolators. Such pumps ≥ 0.4 kW should be supported from the building structure on neoprene mounts or neoprene hangers. Pumps ≥ 1.2 kW should be supported on concrete inertia bases supported on un-housed steel spring isolators. All connections to these circulation pumps should be with flexible connections.

Inertia bases should be designed to the thicknesses stated in Table below.

| Motor Size in kW (Approximate HP) | Inertia Base Thickness (mm) |
|-----------------------------------|-----------------------------|
| < 15 kW (< 20 HP) | 150 mm |
| 15 – 45 kW (20 – 60 HP) | 200 mm |
| 50 – 75 kW (65 – 100 HP) | 250 mm |
| 80 – 150 kW (105 – 200 HP) | 300 mm |
| 155 – 195 kW (205 – 260 HP) | 350 mm |
| 200 – 225 kW (265 – 300 HP) | 400 mm |
| > 225 kW (> 300 HP) | 450 mm |

Table 16 - Inertia base thicknesses

Concrete inertia bases for pumps should be sized to support the suction elbow of end suction pumps and both the suction and discharge elbows of horizontal split-case pumps. The bases should be T - shaped where necessary to conserve space and sized to extend a minimum of 100 mm beyond the base of the equipment, and in the case of belt-driven equipment, 100 mm beyond the end of the drive shaft.

7.18 Vertical transportation systems (Lifts)

Lift vibration should be controlled, so far as is reasonably practicable, to the limits specified in Table below:

| Measurement Performance Parameter | Passenger Lifts | MRL Goods Passenger Lifts | Freight Lifts |
|--|-----------------|---------------------------|---------------|
| Maximum Horizontal Vibration (milli g) | < 15 | < 15 | < 20 |
| Maximum Vertical Vibration (milli g) | < 12 | < 12 | < 15 |
| Minimum Acceleration (m/s ²) | > 0.6 | > 0.8 | > 0.6 |
| Maximum Jerk (m/s ³) | < 1.5 | < 1.5 | < 1.5 |

Table 17 - Elevator vibration transmission criteria

Lifts to be located away from sensitive areas in consideration of vibration and acoustics, and with respect to magnetic distortion for MRIs.

7.19 Vibration for sensitive medical equipment

Medical equipment such as scanners and microscopes are sensitive to vibration. The aforementioned criteria do not necessarily cover the negative effects of vibration on sensitive medical equipment. It is recommended that designers seek specialist advice on this subject. Reference should be made to their position within the building, their equipment vibration performance criteria and consideration of other generated vibration emissions within the building.

Laboratory furniture may amplify ambient vibration. This depends on their design e.g. benches for sensitive microphones. This should be taken into consideration in design.