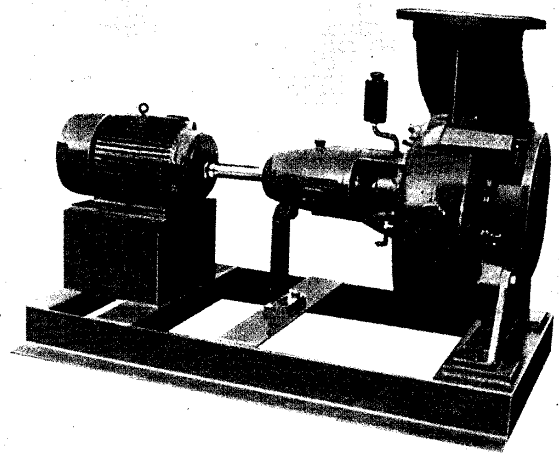
GOOD PRACTICES
ON
PUMPING SYSTEM NOISE CONTROL



香港環境保護署
Environmental Protection Department

GOOD PRACTICES

ON

PUMPING SYSTEM NOISE CONTROL

Environmental Protection Department

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1. INTRODUCTION

Under the Noise Control Ordinance, noise generated from industrial or commercial activities should comply with the noise standards as stipulated in the relevant Technical Memorandum. It is generally recognized that operation of pumping systems is one of these noisy activities. This booklet highlights the importance of planning against noise problems. It gives a brief description of potential noise problems associated with pumping systems and provides guidelines on practical noise control measures that are applicable for new designs and for retrofitting existing designs.

The reader is reminded that compliance with the recommendations of this booklet does not necessarily mean compliance with the legislative requirements. Besides, the recommendations made in this booklet are not exhaustive. Alternative solutions to achieve the same results may exist. The reader is therefore recommended to consult independent experts throughout the process for ensuring the use of proper and cost effective noise control measures.

This booklet is designed mainly for reference by restaurant operators, building operators and those pumping contractors who do not have sufficient noise control knowledge. Architects, building services engineers or other relevant professional parties may also use it as a checklist to ensure that proper measures will be taken to avoid noise problem in designing pumping systems and locating pumping equipment. The main contents are written in plain language illustrated by schematic diagrams for easy understanding by a layman. The focus is on practicable measures. More technical information can be found in appendices.

The reader is also advised that there is another booklet "Good Practices on Ventilation System Noise Control" available which describes ventilation system noise problems and possible solutions.

2. QUICK REFERENCE GUIDE

The following quick reference guide allows the reader to go directly to the relevant section or appendix concerning a particular problem.

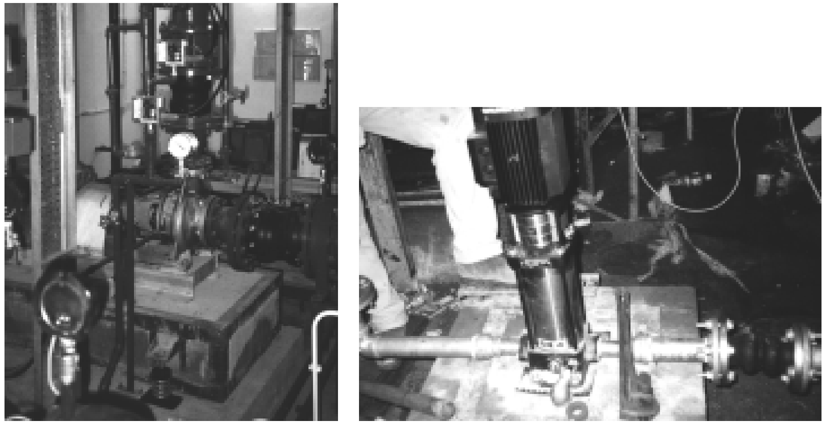
Table 1 : Quick Reference Guide

Source of Noise Problem	Remedies	Relevant Section	Relevant Appendix
Pumpsets	- Barrier	4.3	VI
	- Partial enclosure	4.3	V
	- Complete enclosure	4.3	IV
	- Replacement of bearing	3.2 & 4.3	--
	- Inertia block	4.4	VII
	- Vibration isolator	4.4	VIII
	- Flexible connector	4.4	--
Pipes	- Large radius bend pipe	4.1	--
	- Composite lagging	4.1	--
	- Low water flow velocities	4.1	--
	- Rigid mountings around the bend	4.1	--
	- Vibration isolator	4.2	VIII
	- Compressible material	4.2	--
	- Pressure reducing valve	4.2	--

3. PLANNING AGAINST NOISE PROBLEMS

3.1 Positioning of Equipment

The installation position of a pumpset is of critical importance in determining the noise level at the affected noise sensitive receivers (e.g. residential buildings or schools). Where practicable, the equipment should be placed in a plant room with thick walls or at a much greater distance from the receiver or behind some large enough obstruction (e.g. a building or a barrier) such that the line of sight between the receiver and the equipment is blocked. If noisy equipment has to be placed near a receiver due to spatial or other constraints (e.g. the pumpset is located inside a residential premises with noise sensitive receivers above or below), sufficient noise control measures should be considered. Figure 1 shows a pumping system of a new development, which has been placed in a pump room equipped with adequate noise control measures in the design stage to prevent noise problems.



(Pumps are located below residential units)

Figure 1 : Inertia Block, Spring, Isolation Pad and Flexible Connector

3.2 Selection of Quiet Equipment

On average, quieter equipment may generally be more expensive. However, it is almost always more economical in the long run to buy quieter equipment than to reduce noise by modification after purchase (e.g. silent type pumps). Most equipment has a range of readily available noise control devices that are able to deal with the noise problems. It is advisable that noise levels specification is included when ordering new equipment. This allows the equipment suppliers to select appropriate equipment and optional noise control devices to suit the acoustic requirements.

3.3 Scheduled Maintenance

In order to prevent increasing noise produced by existing equipment, it is necessary to put in place a regularly scheduled equipment maintenance programme so that equipment is properly operated and serviced in order to maintain controlled level of noise and vibration. Maintenance may include lubricating moving parts, tightening loosen parts, replacing worn-out components or inspecting equipment alignment, etc. Vibration measurements at various frequencies may help to detect causes of excessive vibration or noise of a machine. A guide to vibration identification is given in Appendix XII.

4. PROBLEMS AND PRACTICAL REMEDIES ON PUMPING SYSTEM NOISE

4.1 Air-borne Noise from Ringing Pipes

(A) Problems

Water flows in a pipe causing vibration at the pipe wall and generating broadband noise which may cause noise disturbance to nearby residents (see Fig. 2). When the water flow changes direction suddenly because of obstacles in the pipe such as sharp bends or valves, a loud noise is generated which becomes louder with increasing water flow rate and pipe size.

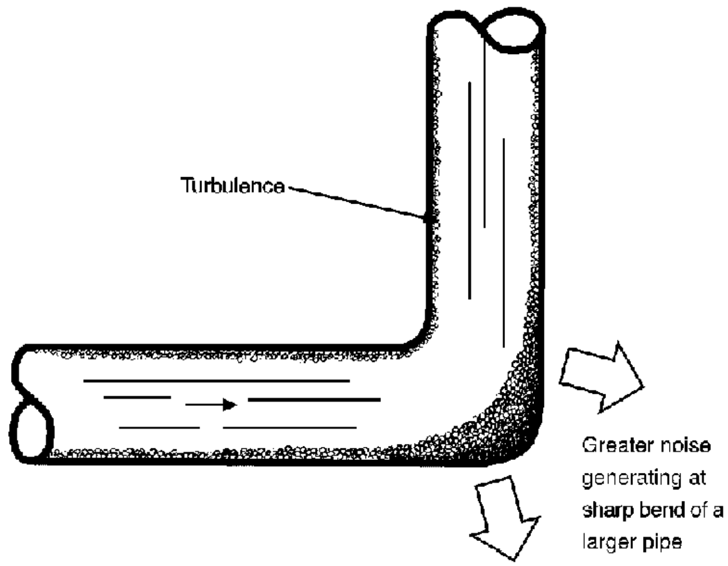


Figure 2 : Noise from Ringing Pipes

(B) Practical Remedies

- Use pipes with larger radius bends (see Fig. 3) so as to minimize vibration of pipe walls.
- Use rigid mountings around the bend with suitable vibration isolators (see Fig. 3) to minimize pipe vibration.
- Apply pipe lagging to damp the pipe ringing noise (see Fig. 3).
- Use a larger pipe or adjust water flow velocities to below 2m/sec to minimize pipe vibration.

(NOISE REDUCTION UP TO 10dB(A))

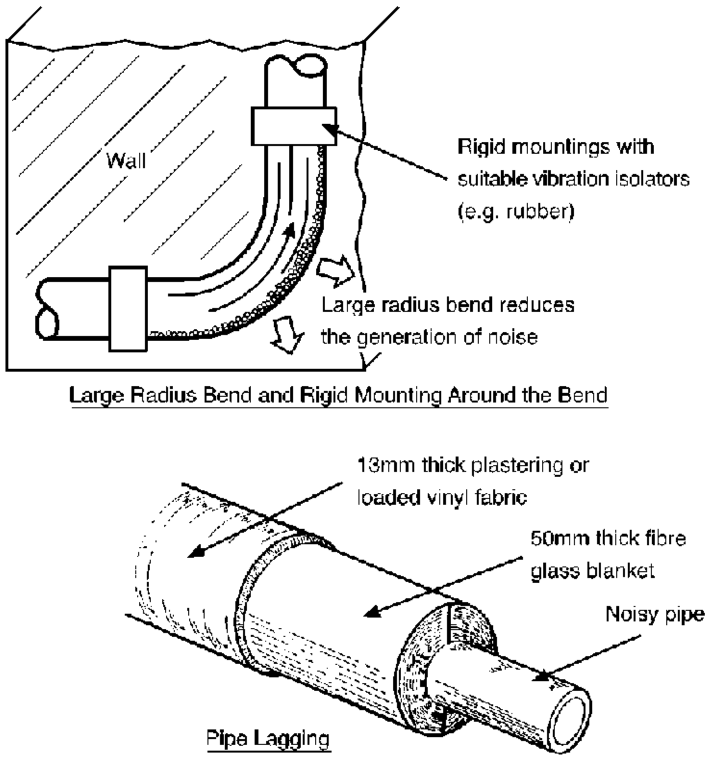


Figure 3 : Large Radius Bend and Pipe Lagging

4.2 Structure-borne Noise from Pipes

(A) Problems

Vibration from the water flow in pipes may be transmitted from the pipe runs to the interior of the building through building structure where the pipes are mounted. It becomes more severe when the pipes are in direct contact with large planes such as walls or slabs (see Fig. 4). The vibration transmitted may activate the building structure to generate noise which causes noise disturbance to residents inside the building.

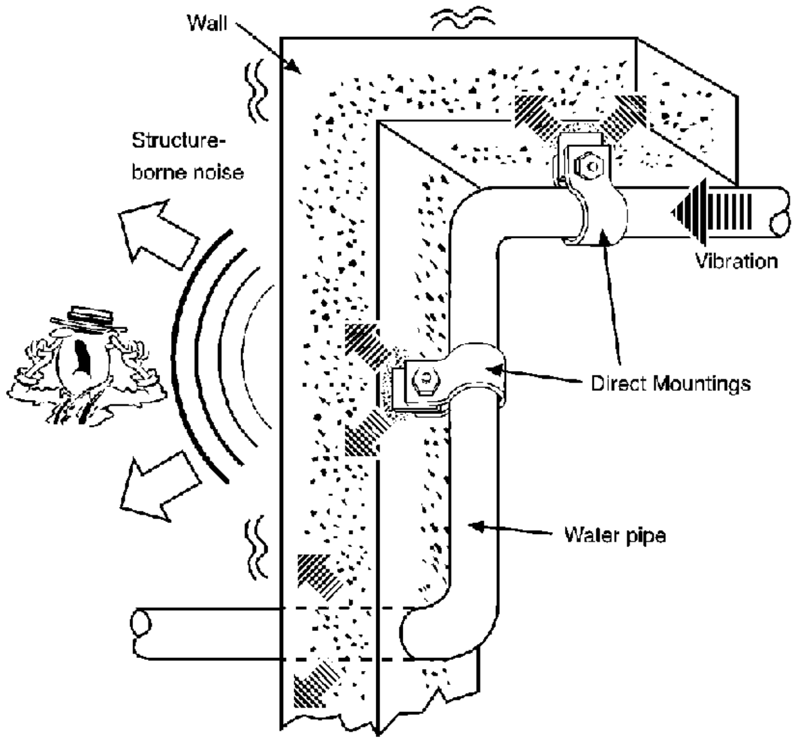


Figure 4 : Noise from Vibrating Pipes

(B) Practical Remedies

- Use vibration isolators for attaching pipes to walls, ceilings or floors (see Fig. 5), thereby isolating them from the building structure.
- Isolate pipes where they penetrate the slabs and walls by compressible materials, such as rubber sleeve or glass fibre packing (see Fig. 5), thereby isolating them from the building structure.
- Install pressure reducing valves to regulate water pressure and hence the water flow, thereby reducing vibration of pipes.

(NOISE REDUCTION UP TO 20dB(A))

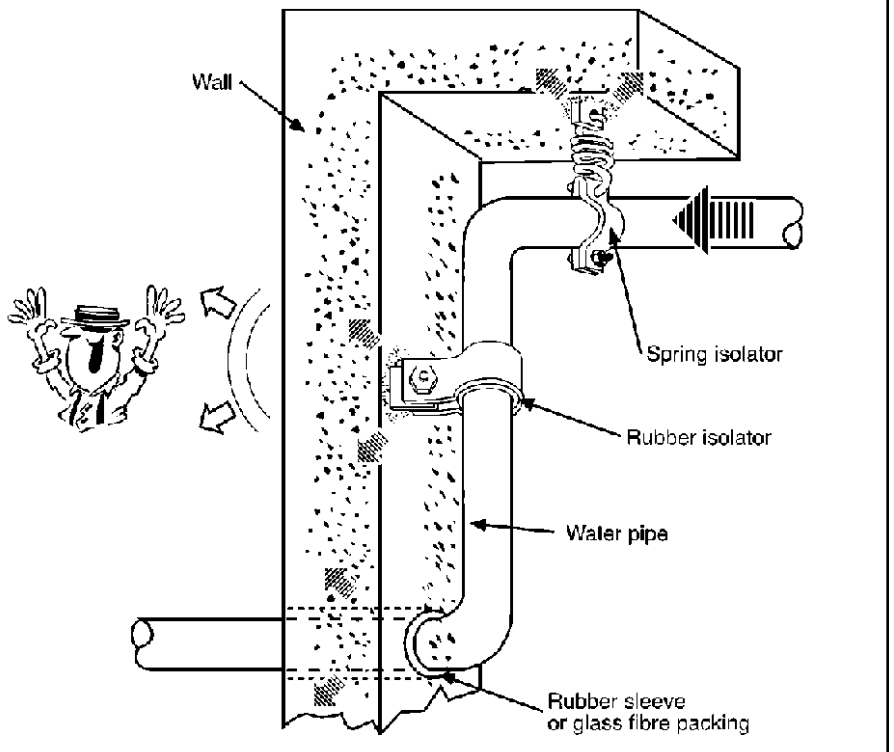


Figure 5 : Vibration Isolation of Pipes

4.3 Air-borne Noise from Pumpsets

(A) Problems

The major noise source of a pump is usually the bearing noise as a result of bearing worn-out. However, the noise contributed by the pump itself is small relative to that generated from its associated motor. The major noise source of a motor is usually the air movement induced by the cooling fan, which may cause noise disturbance to nearby residents (see Fig. 6).

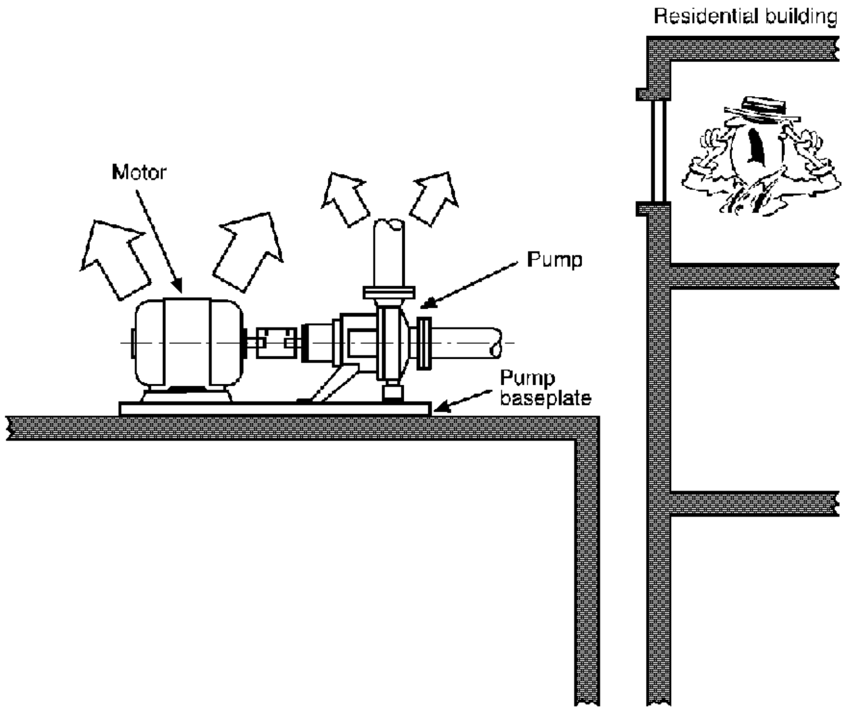


Figure 6 : Air-borne Noise from Pumpsets

(B) Practical Remedies

- Replace worn-out bearing so as to reduce the noise.
- Erect a barrier between the pumpset and nearby residential buildings (see Fig. 7) so as to block the noise propagation path (see App. VI).
- Fabricate a partial enclosure to contain and absorb the noise energy radiated by the source (see App. V).

(NOISE REDUCTION UP TO 10dB(A))

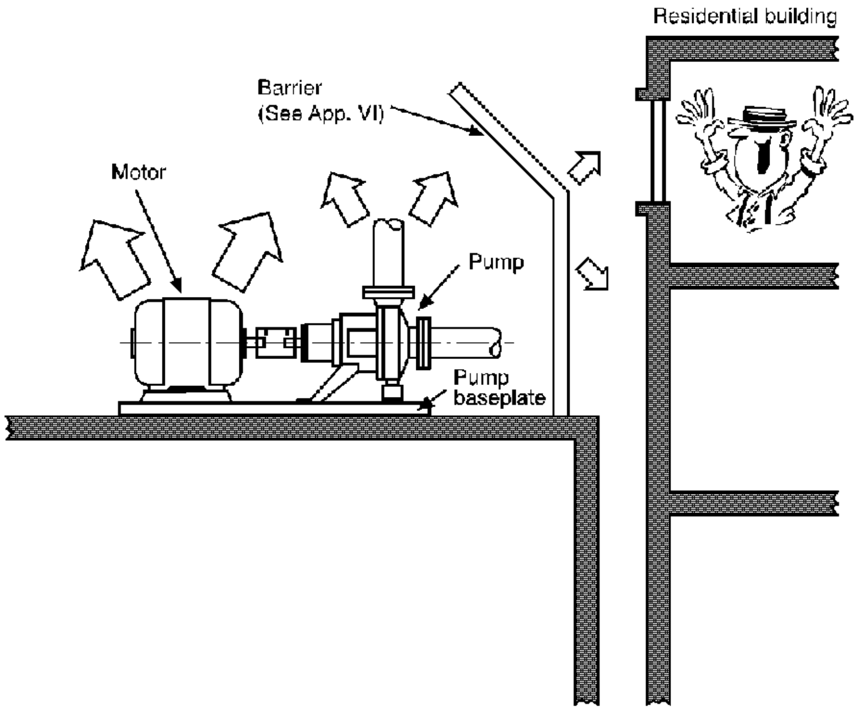


Figure 7 : Barrier for Pumpsets

(B) Practical Remedies (Cont'd)

- Fabricate a complete enclosure with silencers at outlet and inlet of the enclosure (see Fig. 8) so as to contain and absorb the noise energy radiated by the source (see App. IV).

(NOISE REDUCTION UP TO 30dB(A))

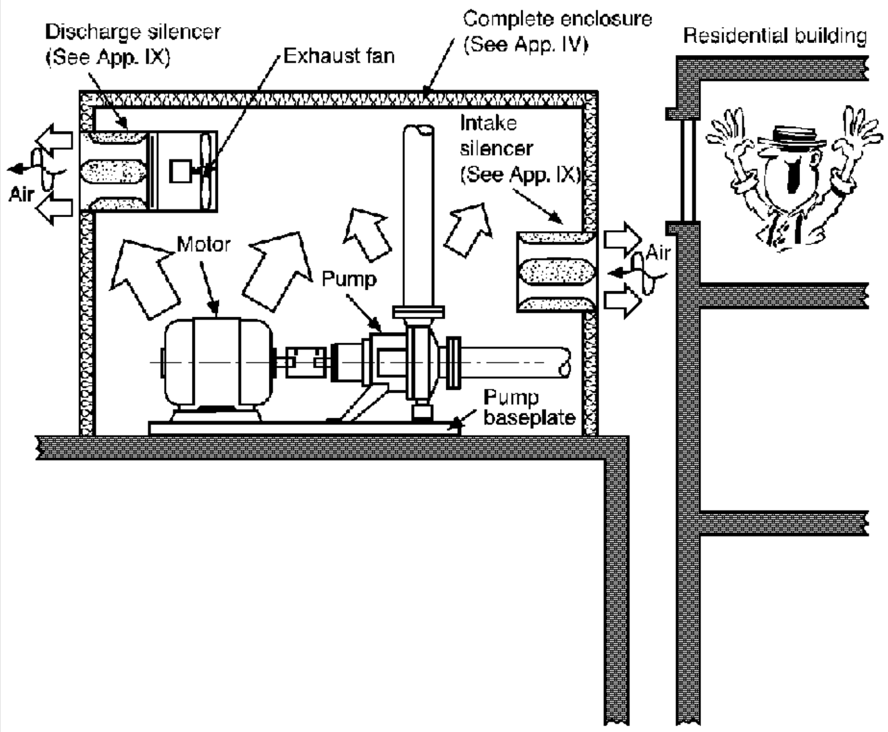


Figure 8 : Complete Enclosure for Pumpsets

(B) Practical Remedies (Cont'd)

- Locate the pumpset inside a plantroom (see Fig. 9) with silencers at air inlet and outlet, and a soundproof door (see App. XI).

(NOISE REDUCTION UP TO 30dB(A))

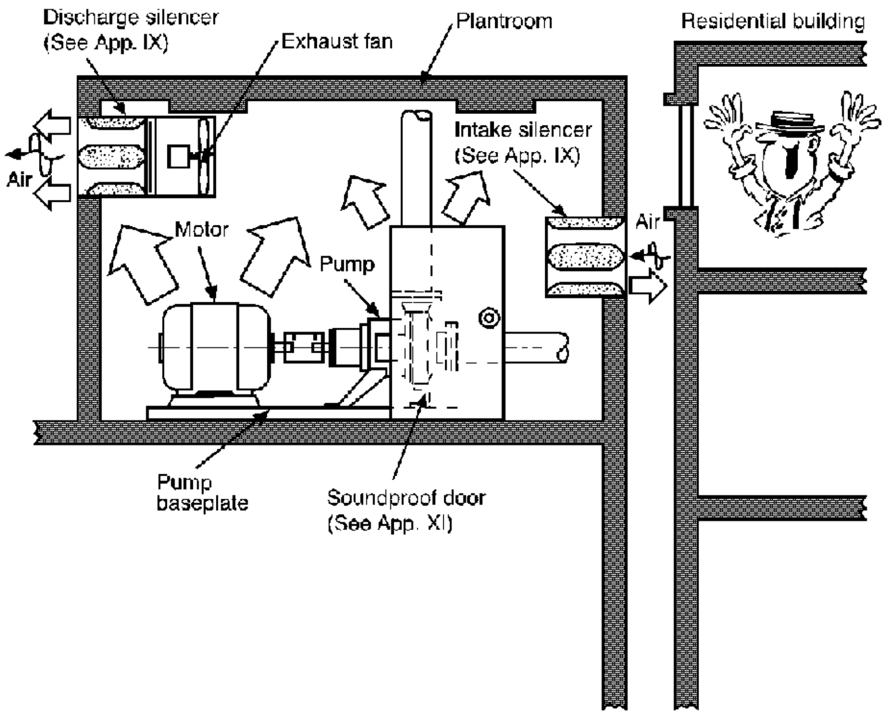


Figure 9 : Plantroom for Pumpsets

4.4 Structure-borne Noise from Pumpsets

(A) Problems

Vibration from an operating pumpset may be transmitted to the interior of the building through building structure when the pumpset is directly mounted on a supporting structure without proper isolation (see Fig. 10). The vibration transmitted may activate the building structure to generate noise which causes noise disturbance to residents inside the building.

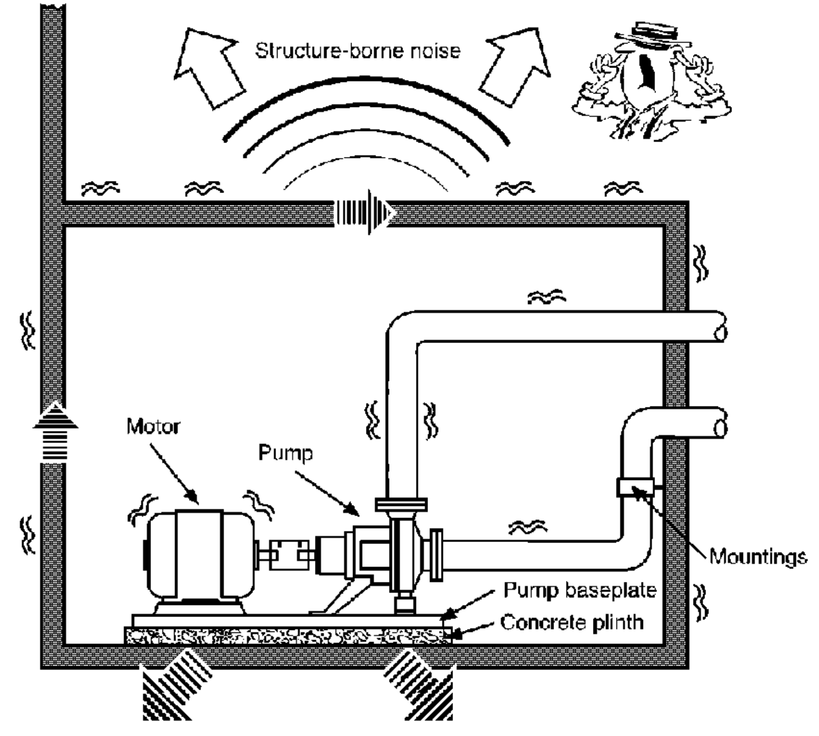


Figure 10 : Structure-borne Noise from Pumpsets

(B) Practical Remedies

- Provide an inertia block to support the pumpset (see Fig. 11) so as to add rigidity and stability to the pumping system, and provide vibration isolators (see Fig.11) to support the inertia block, thereby isolating it from the building structure (see App. VII and VIII).
- Provide flexible connectors between the pump and associated pipework, thereby preventing the vibration of the pumpset being transmitted to the pipework (see Fig. 11).

(NOISE REDUCTION UP TO 20dB(A))

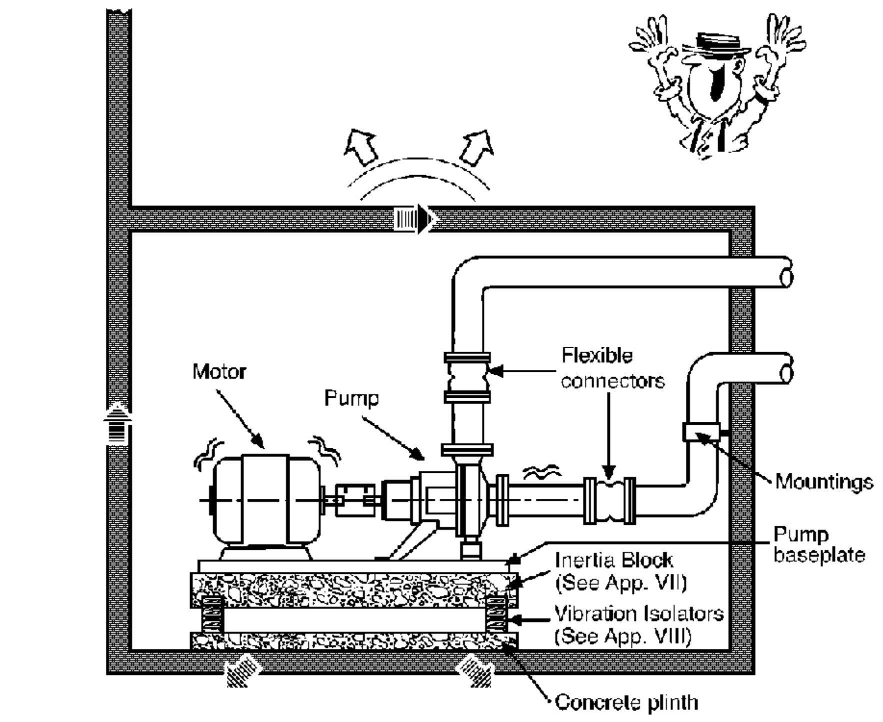
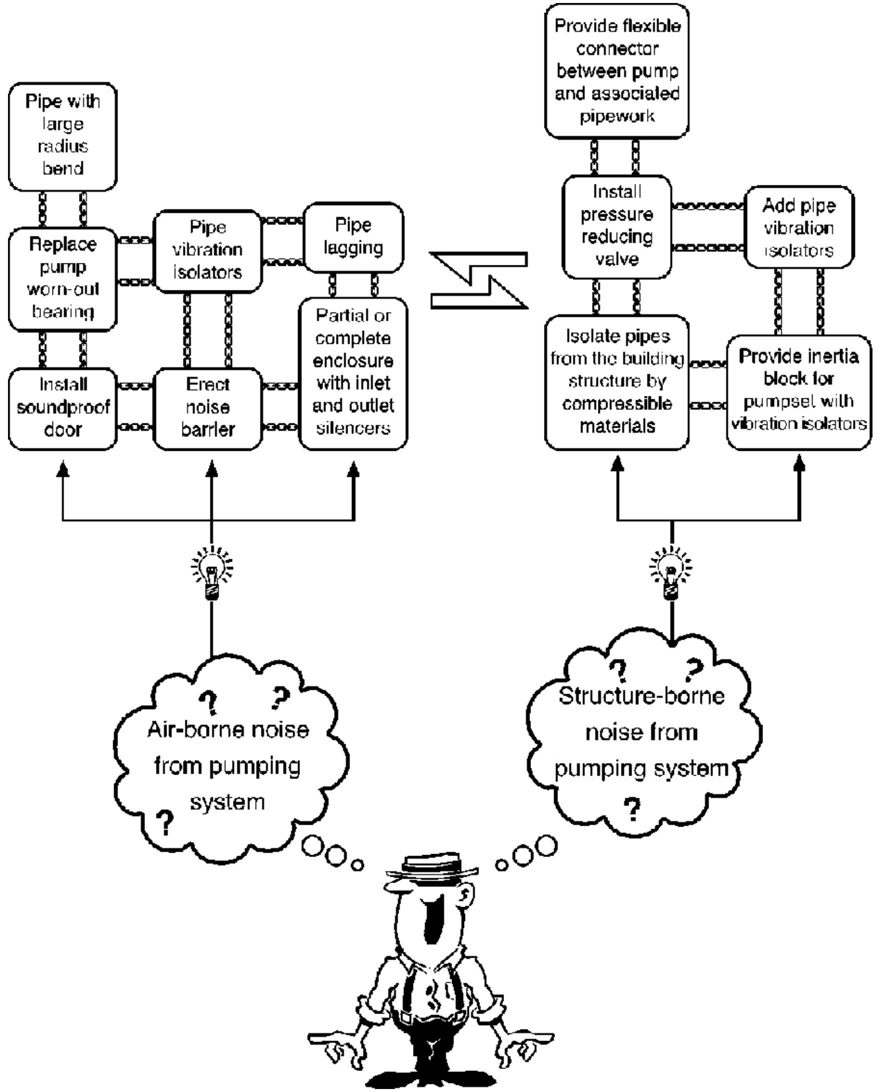


Figure 11 : Vibration Isolation of Pumpsets

4.5 Important Note

The above only suggests solutions for a particular noise problem. In real life, the noise may be caused by more than one source. In those cases, several remedies may be required simultaneously to solve the problem.



5. RECOMMENDED PRACTICAL REMEDIES FOR DIFFERENT EXCEEDANCE LEVELS

The following recommended practical remedies for different noise exceedance levels are for reference purpose only. No guarantee is given to the performance of the application of the recommended remedies. The reader is advised to seek professional advice from independent experts in case of doubts or complicated problems.

Table 2 : Recommended Practical Remedies

Cause of Problem	Noise Exceedance Level (dB(A))	Recommended Practical Remedies
Bearing Noise	< 15	- Bearing replacement
	> 15	- Quieter pump or pump relocation
Whining Pump Noise	< 10	- Barrier
	10 to 20	- Partial enclosure
	> 20	- Complete enclosure and silencers
Structure-borne noise from Pumps	< 20	- Inertia block and vibration isolators - Flexible connectors
	> 20	- Pump relocation
Ringing pipe noise	< 10	- No sharp bend - Pipe lagging - Low water flow velocities - Rigid mountings around the bend
	> 10	- Partial enclosure
Structure-borne noise from Pipes	< 20	- Isolation of pipes - Vibration isolators - Pressure reducing valve
	> 20	- Piping system relocation

6. GLOSSARY OF ACOUSTIC TERMINOLOGY

A-Weighted Decibel (dB(A)) - The A-weighted decibel is a unit for measuring noise taking into account the way human ear responds to sound.

Air-borne Noise - Noise arrives at a point of interest by propagation through air.

Frequency - The number of repetitive variations of sound pressure per unit of time which is usually stated in Hertz (Hz).

Noise - Noise is any sound which at the time of reception is unwanted or disturbing.

Sound Power Level - A measure, in decibels, of the total acoustic power radiated by a given sound source. It is independent of any reference distance or other extraneous factors.

Sound Pressure Level - A measure, in decibels, of the sound pressure at a particular point. It is dependent upon distance from the source and many other extraneous factors.

Structure-borne Noise - Noise arrives at a point of interest by propagation through a solid structure.

STATUTORY CONTROL OVER NOISE

Noise generated from pumping systems is controlled by means of Noise Abatement Notices which may be served on owners or operators of the systems if the emitted noise at a given Noise Sensitive Receiver (NSR), such as a residential building or a school, does not comply with the objective technical criteria in the form of Acceptable Noise Levels (ANL) as set out in the "Technical Memorandum for the Assessment of Noise from Places other than Domestic Premises, Public Places or Construction Sites"(TM).

For a given NSR, with the assessment point at 1m from the exterior of the building facade the ANL in dB(A) is presented in Table 3. However, under certain conditions specified in the TM, when the assessment point is at an internal location of a building, the ANL shall be 10 dB(A) less than that shown in Table 3 and is presented in Table 4. Most of the pumping system noise problems are due to vibration transmitted through building structure and Table 4 is usually applicable. For details of determination of appropriate ANL, the reader is advised to make reference to the aforementioned TM.

Table 3 : Acceptable Noise Level (dB(A)), at 1 m Facade

Time Period / **Type of Area Containing the NSR**	**Day and Evening (0700 to 2300 hours)**	**Night (2300 to 0700 hours)**
Urban Area	65 – 70	55 – 60
Rural Area	60 – 65	50 – 55

Table 4 : Acceptable Noise Level (dB(A)), at an Internal Location

Time Period / **Type of Area Containing the NSR**	**Day and Evening (0700 to 2300 hours)**	**Night (2300 to 0700 hours)**
Urban Area	55 – 60	45 – 50
Rural Area	50 – 55	40 – 45

NOISE PREDICTION

A simplified air-borne noise prediction method is given below. The reader is reminded that the results obtained from the following procedures should be regarded as indicative data only. The prediction method is inapplicable to noise transmitted through building structure. In case of any doubts, the reader is advised to seek independent experts for technical advice.

Step 1 – Identification of the Most Affected Noise Sensitive Receivers (NSR)

Any domestic premises, hotel, hostel, temporary housing accommodation, hospital, medical clinic, educational institution, place of public worship, library, court of law or performing arts centre is considered to be a NSR. In general, the nearest NSR facade with windows, doors or other openings with respect to the concerned noise sources shall be identified.

Step 2 – Sound Power Levels (SWLs) for Noise Sources

Typical SWLs of pumpsets are given in Appendix III for reference. Where practicable, sound power level of individual noise source should be referred to the information provided by the respective manufacturers.

Step 3 - Distance Attenuation

The plan distance or where appropriate, the slant distance between individual noise source and the most affected NSR shall be determined and the corresponding distance attenuation shall be obtained from Table 5. These values shall be subtracted from the individual sound power levels for each noise source to give the individual sound pressure levels for each noise source at the NSR.

Step 4 - Summation of Noise Levels

All individual sound pressure levels for each noise source at the NSR shall be added logarithmically in accordance with Table 6 to give a summed noise level.

Step 5 - Correction for Acoustic Reflections

In case the NSR is a building, a positive correction of 3dB(A) shall be applied to the noise level obtained in step 4.

Please note that a correction of 3dB(A) or 6dB(A) for tonality, impulsiveness or intermittency may be required to apply to the noise level obtained in step 5. For details, please refer to the Technical Memorandum for the Assessment of Noise from Places other than Domestic Premises, Public Places or Construction Sites.

Table 5 : Distance Attenuation at Given Distances

Distance (m)	Attenuation (dB(A))	Distance (m)	Attenuation (dB(A))
1	8	30 to 33	38
2	14	34 to 37	39
3	18	38 to 41	40
4	20	42 to 47	41
5	22	48 to 52	42
6	24	53 to 59	43
7	25	60 to 66	44
8	26	67 to 74	45
9	27	75 to 83	46
10	28	84 to 93	47
11	29	94 to 105	48
12	30	106 to 118	49
13	30	119 to 132	50
14	31	133 to 148	51
15 to 16	32	149 to 166	52
17 to 18	33	167 to 187	53
19 to 21	34	188 to 210	54
22 to 23	35	211 to 235	55
24 to 26	36	236 to 264	56
27 to 29	37	265 to 300	57

For distances greater than 300m, calculation of distance attenuation should be based on standard acoustical principles and practices.

Table 6 : Summation of Noise Levels

Difference in dB(A) Between Two Noise Levels Being Summed	Amount in dB(A) to Add to the Higher Noise Level
0 to 0.5	3.0
1.0 to 1.5	2.5
2.0 to 3.0	2.0
3.5 to 4.5	1.5
5.0 to 7.0	1.0
7.5 to 12.0	0.5
more than 12.0	0

Noise levels should be summed in a pairwise fashion when Table 6 is used and the final total rounded to the nearest whole dB(A), with values of 0.5 or more being rounded upwards.

Example:
Two pumpsets (A and B) having sound power levels of 100dB(A) and 105dB (A) respectively are installed outdoors. The most affected noise sensitive receiver is identified to be a residential flat which is at 20m and 25m away from A and B, respectively. The sound pressure level at the residential flat contributed by the two equipment is estimated below.

NSR (step 1)	Noise Sources	SWL (dB(A)) (step 2)	Distance (m)	Distance Attenuation (dB(A)) (step 3)	Noise Level (dB(A))
Residential Flat	Pump " A "	100	20	34	66
	Pump " B "	105	25	36	69
Summed Noise Level (dB(A)) (step 4)					71
Correction for Acoustic Reflection (dB(A)) (step 5)					3
Noise Level at NSR (dB(A))					74
ANL (see Table 3)					60
Noise Exceedance					14
Recommended Practical Remedies (see Table 2 in section 5): - partial enclosures					

TYPICAL SOUND POWER LEVELS OF PUMPSETS

The following sound power levels for various rating of pumpsets are given in Tables 7a and 7b for reference purpose only. Where practicable, the sound power level of the concerned pumpset should be referred to the respective manufacturers.

Table 7a : Typical Sound Power Levels of Pumpsets at 3600 rpm

Horsepower of Pumpset (hp)	Sound Power Level (dB(A))
5 to 10	100
11 to 20	103
21 to 30	105
31 to 50	107
51 to 100	109

Table 7b : Typical Sound Power Levels of Pumpsets at 1800 rpm

Horsepower of Pumpset (hp)	Sound Power Level (dB(A))
5 to 10	92
11 to 20	92
21 to 30	94
31 to 50	97
51 to 100	100

COMPLETE ENCLOSURES

When a noise reduction of 20dB(A) or more is required, it is generally necessary to use a complete enclosure if the noise problem is a result of air-borne noise transmission. The enclosure should be internally lined with 50mm thick sound absorbing material (e.g. fibre glass). A variety of materials can be utilized for fabricating an enclosure. The sound transmission loss for enclosures using different materials are given in Table 8. Ventilation of enclosures should not be overlooked as most equipment, such as motors, requires an adequate air supply either to prevent overheating or to enable them to function efficiently. A silenced ventilation system incorporating silencers at the air intakes and discharge openings should be employed (see Figure 8).

Table 8 : Sound Insulation Materials for Enclosures

Material	Thickness (mm)	Surface Density (kg/m^2)	Sound Transmission Loss (dB)		
			125Hz	500Hz	2,000Hz
Plastered Brick Wall	125	240	36	40	54
Compressed Strawboard	56	25	22	27	35
Acoustic Panel (Sandwich type steel sheet with fibre glass)	50	27	19	31	44
Chipboard	19	11	17	25	26
Plaster Board	9	7	15	24	32
Plywood	6	3.5	9	16	27

PARTIAL ENCLOSURES

Partial enclosures are structures erected around a source of noise, but not fully enclosing the source and leaving space for natural ventilation, which will be effective only when there is no line of sight between the noise source and the receiver. The use of partial enclosures has advantages over complete enclosures in terms of cost, accessibility, and ventilation, but design and construction should be done carefully. Ideally, a reduction of up to 20dB(A) can be achieved.

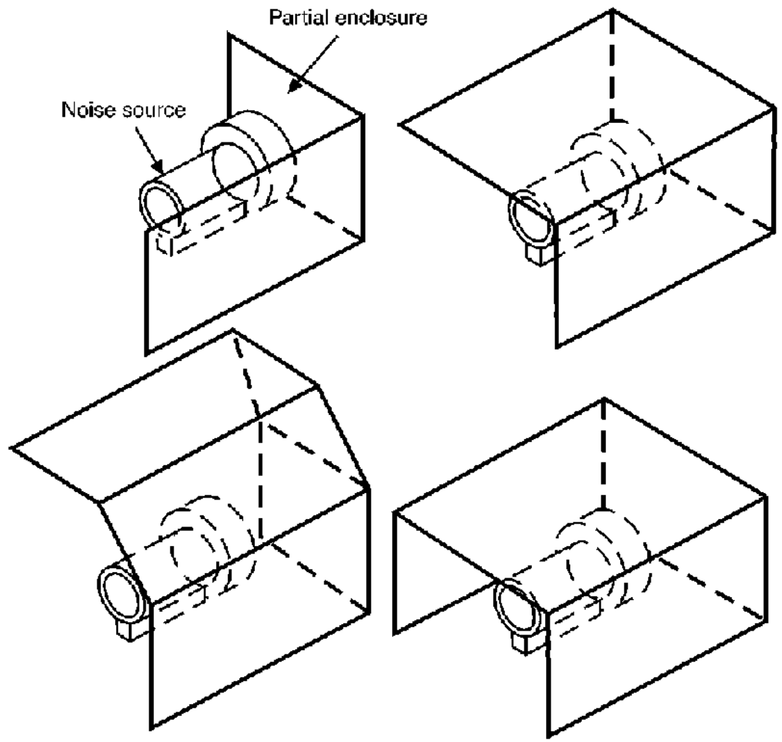


Figure 12 : Partial Enclosures

BARRIERS

To be effective, an acoustic barrier needs to be placed as close as possible either to the noise source or the receiving position. There should be no gap or joint in the barrier through which noise will leak. The surface density of the barrier must be at least 10kg/m^2. Ideally, the length of the barrier should be at least 5 times its height. Line of sight between the source and the receiver must be cut off completely.

A reduction of noise level of between 5dB(A) to 10dB(A) can generally be resulted. Noise reduction will be greater if the barrier is lined with sound absorbing material at the surface of the barrier facing the noise source or is extended as high as possible above the line of sight.

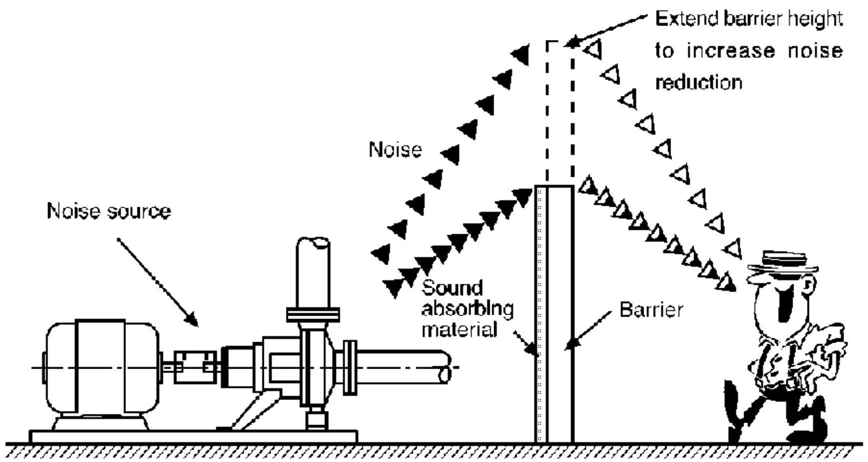


Figure 13 : Barriers

INERTIA BLOCKS

A heavy and rigid inertia block is often used as the base for equipment in order to reduce motion, lower the centre of gravity, minimize the effect of unequal weight distribution of the support equipment, and stabilize the entire vibration isolation system. Generally an inertia block should be at least 15cm thick and very stiff and rigid to avoid significant flexure in any direction. Table 9 shows a recommended weight of inertia block for various rating of pumpsets.

However, when the mass of the supported equipment is enormous, there may be no need for additional mass in the form of inertia blocks; a rigid frame to support (e.g. Reinforced Concrete Beam) the entire assembly may be sufficient.

Table 9 : Guide for Inertia Block Selection

Equipment	Power	Speed (rpm)	Weight Ratio(1) at		
			Min Area(2)	Normal Area(3)	Critical Area(4)
Pumpset	<20hp	450-900	1.5	2-3	3-4
		900-1800	2.5	1.5-2.5	2-3
		>1800	2.5	1.5-2.5	2-3
	20-100hp	450-900	2-3	2-3	3-4
		900-1800	1.5-2.5	2-3	2-3
		>1800	1.5-2.5	1.5-2.5	2-3
	>100hp	450-900	2-3	3-4	3-4
		900-1800	2-3	2-3	2-3
		>1800	1.5-2.5	2-3	2-3

Note

1. Weight Ratio : Weight of inertia block over weight of equipment mounted on inertia block.
2. Minimum Area : Basement or on-grade slab location.
3. Normal Area : Upper floor location but not above or adjacent sensitive areas.
4. Critical Area : Upper floor location above or adjacent sensitive areas.

VIBRATION ISOLATORS

Motordriven equipment vibrates during operation. The method of reducing vibration transmission to other sensitive areas is to separate the equipment from the supporting structure by vibration isolators. Generally, there are two types of vibration isolators, metal springs and isolation pads, that are widely used for vibration isolation.

i) Metal Springs

Springs are particularly applicable where heavy equipment is to be isolated or where the required static deflections exceed 12.5mm. Static deflection of a spring is a value specified by the suppliers. Selection of appropriate springs is important as this may result in poor isolation efficiency or even amplification of vibration, especially in the case that the vibration frequency is extremely low.

The most important feature of spring mounts is to provide good isolation due to its ability of withstanding relatively large static deflection. Metal springs however have the disadvantage that at very high frequencies vibration can travel along the spring into the adhered structure. This is normally overcome by incorporating a neoprene pad in the spring assembly so that there is no metal-to-metal contact. Most commercially available springs contain such a pad as a standard feature. Figure 14 shows some common spring mountings. Table 10 provides the minimum static deflection required for achieving particular isolation efficiency at different equipment speeds.

Table 10 : Minimum Static Deflection for Various Speeds of Machines

Machine Speed (rpm)	Minimum Static Deflection at Various Isolation Efficiency (mm)			
	1%	5%	10%	15%
3600	14.0	1.5	1.0	0.5
2400	30.5	3.5	2.0	1.5
1800	56.0	6.0	3.0	2.0
1600	71.5	7.5	4.0	3.0
1400	91.5	10.0	5.5	4.0
1200	124.5	13.5	7.0	5.0
1100	150.0	15.5	8.5	6.0
1000	180.5	19.0	10.0	7.0
900	223.0	23.5	12.5	9.0
800	282.0	30.5	15.5	11.0
700	--	38.5	20.5	14.0
600	--	53.5	28.0	19.5
550	--	63.5	33.0	23.0
400	--	117.0	61.0	43.5
350	--	155.0	81.5	56.0
300	--	211.0	109.5	76.5
250	--	--	157.5	109.5

Note

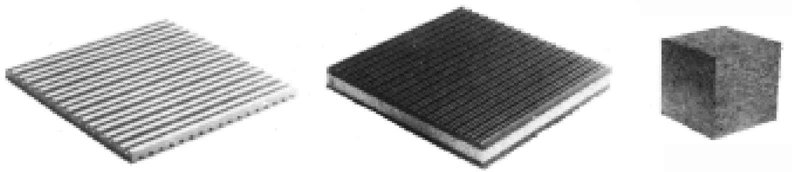
1. The above static deflections are obtained by theoretical calculations, which are for reference only. Commercial products with static deflections greater than about 100mm may not be available in the market.
2. The reader is also recommended to consult independent experts for installation involving vibration isolators with high static deflections.

ii) Isolation Pads

Isolation pads can be made of rubber, neoprene, glass fibre or combination of them. They are relatively cheap, easy for installation and replacement, and have the advantage of good high-frequencies isolation. However, attention should be given to the life of the isolation pads as some of them can be damaged by overload or low temperature. Figure 15 shows some common isolation pads.

(Courtesy of Builders Federal (HK) Limited)

Figure 14 : Metal Springs



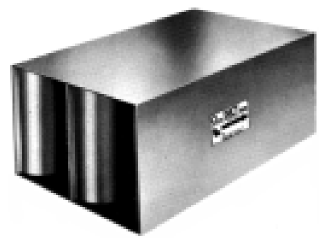
(Courtesy of CEMAC (HK) Limited)

Figure 15 : Isolation Pads

SILENCERS

Silencers are commercially available devices that allow the passage of air while restricting the passage of sound generated from air distribution equipment. They subdivide the airflow into several passages each lined with perforated sheet backed by mineral wool or glass fibre. A silencer usually has a cross section greater than the duct in which it is installed such that noise induced by high air flow velocity passing through the silencer can be avoided. Silencers are available for circular or rectangular ducts, as shown in Figure 16, and are fabricated in modular form in cross section, and in lengths of 0.6, 0.9, 1.2 and 1.5m, etc. They are generally specified by the insertion loss in decibels (dB) in each octave band, so that the degree of match with the sound power distribution of the noise source over the frequencies may be judged. The other important parameter associated with silencers is the resistance to airflow. The use of silencer will inevitably increase the load of the fan and it is essential for engineers to consider both the acoustic and air flow performances during the design stage.

Circular Silencer
(Courtesy of NAP Acoustic (Far East) Limited)



Rectangular Silencer
(Courtesy of Industrial Acoustic Company)

Figure 16 : Silencers

ACOUSTIC LOUVRES

Similar to silencers, acoustic louvres are also commercially available devices that allow the passage of air while restricting the passage of sound generated from noisy spaces. They act much the same as ordinary louvres but consist of hollow acoustic vanes instead of flat sheet vanes. The acoustic vanes, with the underside (the side facing the noise source) formed from perforated sheet, are filled with sound absorptive material. A typical construction of an acoustic louvre is shown in Figure 17. The acoustic performance of an acoustic louvre is specified by the transmission loss in decibels (dB) in each octave band. This enables a direct comparison to be made between the performance of the louvre and a solid wall/structure which it probably replaces. Since an acoustic louvre is a very short attenuator, it is appropriate only where the length of space is restricted and the noise reduction requirement is low. Acoustic louvres are frequently installed in the facades of buildings where they are architecturally acceptable and provide a requisite amount of noise attenuation to prevent creating unacceptably high noise levels outside.

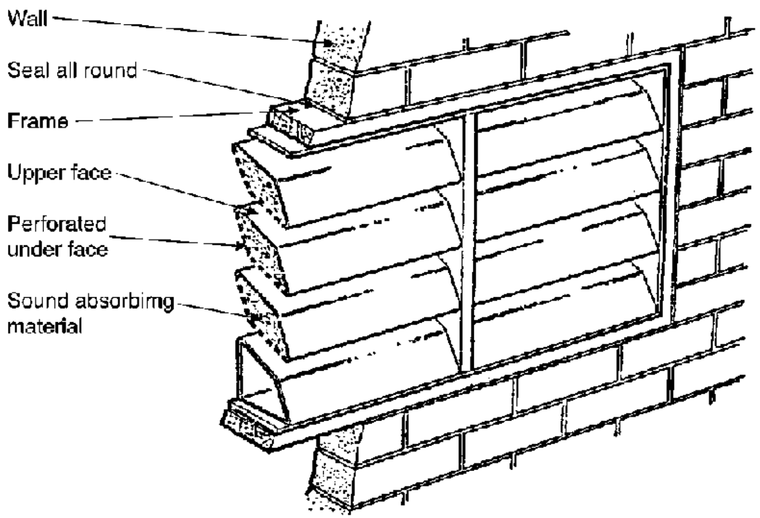


Figure 17 : Acoustic Louvres

SOUNDPROOF DOORS

The sound insulation provided by a door depends not only on the type of door but also on installation details (e.g. the gaskets around the perimeter). Generally, rubber or plastic compression seals, which are set around the door edges, provide the best result of insulation when closing the door. The degree of sound insulation of a door is usually specified by sound transmission class (STC). Table 11 gives typical STC values of some conventional types of doors. However, if doors are required to have STC values greater than 30, it is recommended that packaged soundproof door units are to be employed. They are usually supplied with them fixed in a frame together with suitable seals. A variety of soundproof doors is available in the market, offering average STC values up to 45 which is equivalent to a 112mm brick wall.

Table 11 : Sound Transmission Class of Doors

Type of Door (45mm Thick)	Surface Density (kg/m^2)	Sound Transmission Class
Hollow-core wood	7	20
Solid-core wood	17	26
Steel-faced door	16	26
Fiberglass-reinforced plastic door	12	24

VIBRATION IDENTIFICATION GUIDE

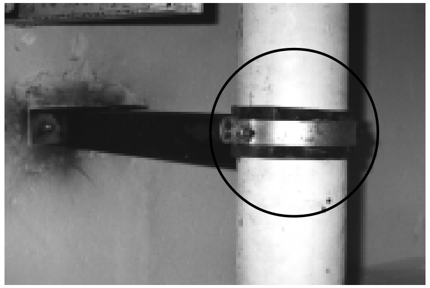
The causes of excessive vibration or noise of a machine can be detected by vibration measurements at various frequencies. A vibration identification guide is given in Table 12.

Table 12 : Vibration Identification Guide

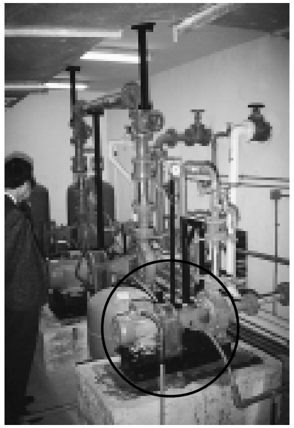
Cause of Excessive Vibration	Frequency Relative to Machine Speed(rpm)
Unbalance	1 x rpm
Defective sleeve bearing	10 to 100 x rpm
Misalignment of coupling or bearing	2 x rpm, sometime 1 or 3 x rpm
Bent shaft	1 or 2 x rpm
Mechanical looseness	1 or 2 x rpm
Defective belt	1 or 2 x belt rpm

EXAMPLES OF PRACTICAL NOISE CONTROL MEASURES

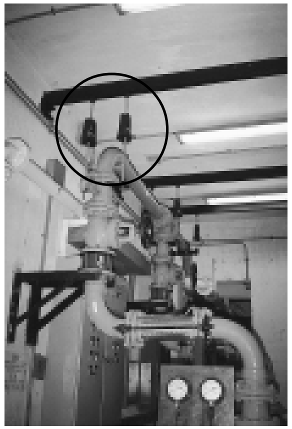
Successful noise control measures and the corresponding noise reductions are shown in Figure 18 for reference.



Installation of Mountings with Rubber for Isolation
(Noise Reduction: 5dB(A))



Installation of Isolation Pads
(Noise Reduction: 16dB(A))



Installation of Spring Hangers
(Noise Reduction: 8dB(A))

Figure 18 : Examples of Noise Control Measures

REFERENCE:

1. Ann Arbor Science (1980), *Reference Data for Acoustic Noise Control.*
2. Atkins Research and Development (1977), *The Control of Noise in Ventilation Systems - A Designers' Guide.*
3. Bruel & Kjaer (1986), *Noise Control Principles and Practice.*
4. Cyril M. Harris (1991), 3rd Edition, *Handbook of Acoustical Measurements and Noise Control.*
5. David A Harris (1991), *Noise Control Manual - Guidelines for Problems-Solving in the Industrial/Commercial Acoustical Environment.*
6. Federation of Hong Kong Industries (1989), *Handbook on Industrial Noise.*
7. John Roberts and Diane Fairhall (1993), *Noise Control in the Built Environment.*
8. L.L. Faulkner (1976), *Handbook of Industrial Noise Control.*
9. Lewis H. Bell (1982), *Industrial Noise Control Fundamentals and Applications.*
10. Lyle F. Yerges (1978), 2nd Edition, *Sound, Noise & Vibration Control.*
11. Mark E. Schaffer (1991), *A Practical Guide to Noise and Vibration Control for HVAC Systems.*
12. Paul N. Cheremisinoff (1978), *Industrial Noise Control Handbook.*
13. Sound Research Laboratories Ltd (1991), 3rd Edition, *Noise Control in Industry.*
14. Trade and Technical Press Ltd (1983), 5th Edition, *Handbook of Noise and Vibration Control.*

OTHER RELEVANT NOISE CONTROL MATERIALS

Description	Place where the Hard Copy is Obtainable	Web Site Address
Noise Control Ordinance, Cap. 400	For sale at Government Publications Centres	http://www.justice.gov.hk/blis.nsf/curengord?OpenView&Start=400&Count=25&Expand=400
A Concise Guide to the Noise Control Ordinance	Environmental Protection Department's Offices (Refer to Appendix XVI)	http://www.info.gov.hk/epd/E/epdinhk/noise/index.htm
Technical Memorandum for the Assessment of Noise from Places other than Domestic Premises, Public Places or Construction Sites	Environmental Protection Department's Offices (Refer to Appendix XVI)	http://www.info.gov.hk/epd/E/epdinhk/noise/index.htm
Good Practices on Ventilation System Noise Control	Environmental Protection Department's Offices (Refer to Appendix XVI)	http://www.info.gov.hk/epd/E/epdinhk/noise/index.htm
Good Practices on Pumping System Noise Control	Environmental Protection Department's Offices (Refer to Appendix XVI)	http://www/info/gov.hk/epd/E/epdinhk/noise/index.htm

Appendix XVI

ADDRESSES AND TELEPHONE NUMBERS OF ENVIRONMENTAL PROTECTION DEPARTMENT'S OFFICES

District Covered (Following District Council Boundary)	Address	Enquiry Telephone No.
Kwun Tong, Wong Tai Sin, Sai Kung, Yau Tsim Mong & Kowloon City	Regional Office (East) 5/F., Nan Fung Commercial Centre, 19 Lam Lok Street, Kowloon Bay, Kowloon.	2755 5518
Hong Kong Island & Islands	Regional Office (South) 2/F., Chinachem Exchange Square, 1 Hoi Wan Street, Quarry Bay, Hong Kong.	2516 1718
Tuen Mun, Tsuen Wan, Kwai Tsing & Sham Shui Po	Regional Office (West) 8/F., Tsuen Wan Government Offices, 38 Sai Lau Kok Road, Tsuen Wan, New Territories.	2417 6116
Yuen Long, Sha Tin, Tai Po & North	Regional Office (North) 10/F., Sha Tin Government Offices, 1 Sheung Wo Che Road, Sha Tin, New Territories.	2158 5757
	Revenue Tower Office 33/F., Revenue Tower, 5 Gloucester Road, Wan Chai, Hong Kong.	2824 3773
	Branch Office 28/F., Southorn Centre, 130 Hennessy Road, Wan Chai, Hong Kong.	2573 7746
	Branch Office 8/F., Cheung Sha Wan Government Offices, 303 Cheung Sha Wan Road, Kowloon.	2402 5200