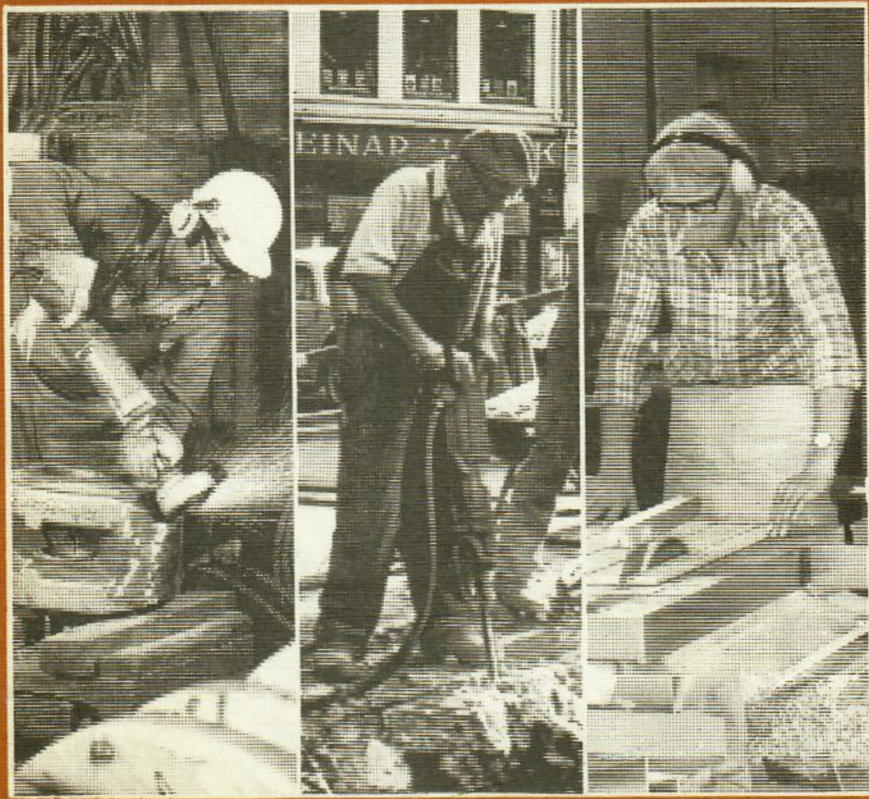


NOISE CONTROL

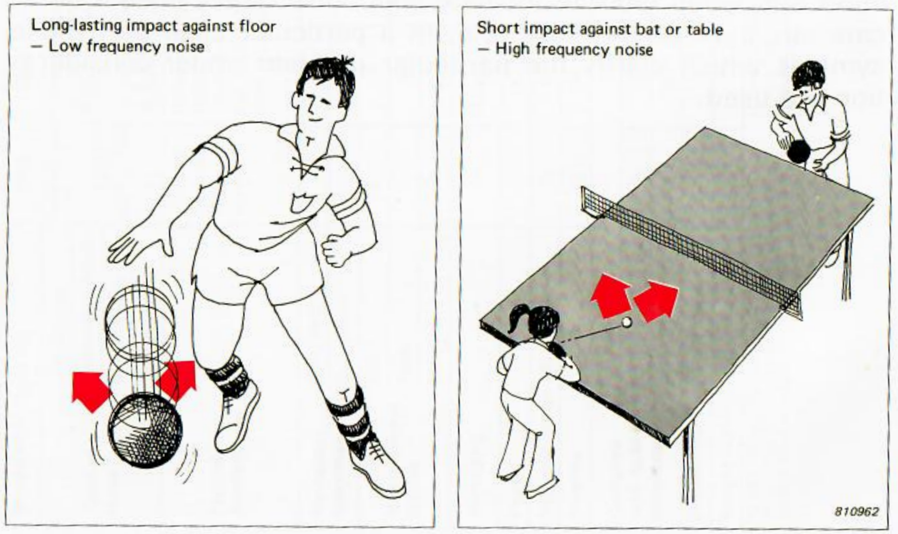
Principles and Practice

Brüel & Kjær

More rapid changes produce higher dominant frequencies

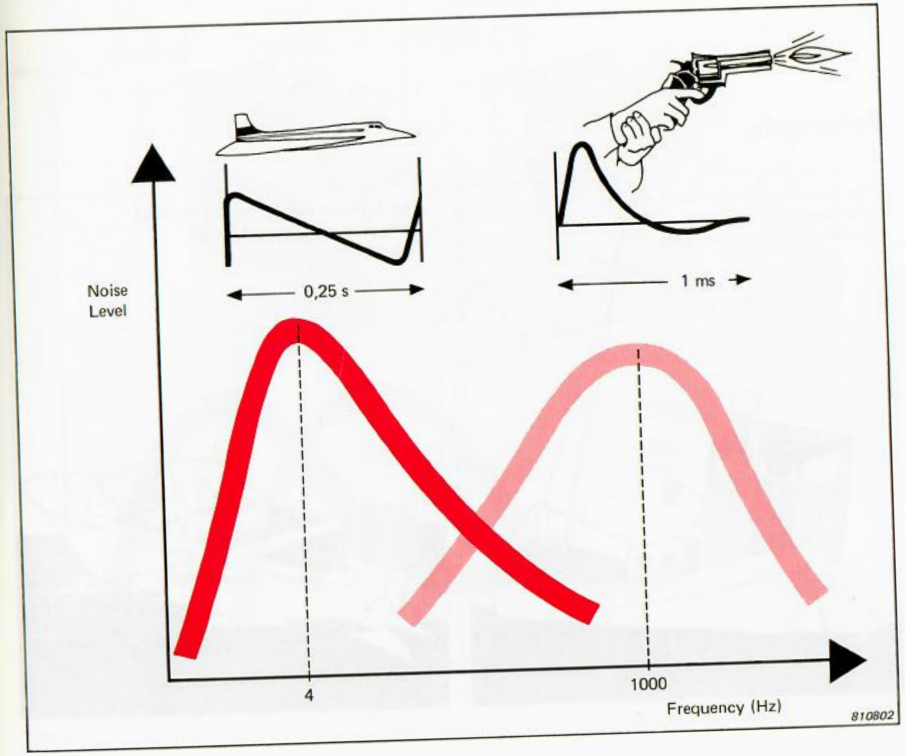
The dominant frequency of the noise produced by an impact is dependent upon the speed of the force, pressure, or velocity change which gives rise to the noise. A rapid change produces a shorter pulse which has higher dominant frequencies. The speed of this change is often determined by the resilience of the two impacting surfaces: The more they deform, the longer they are in contact and the lower the dominant frequencies are. When bouncing a basketball on the floor, the ball is in contact with the floor for a relatively long time. The dominant frequency is therefore low. When playing table tennis the ball is in contact with the bat or table for only a very short time. The dominant frequencies are therefore much higher.

Principle



Example

A sonic boom lasts approximately as long as it takes for the aircraft to fly through its own length. This may take e.g. 0,25 s. The dominant frequency is therefore about 4 Hz. A gunshot may last only 1 ms. Its dominant frequencies are therefore much higher, at about 1 kHz.

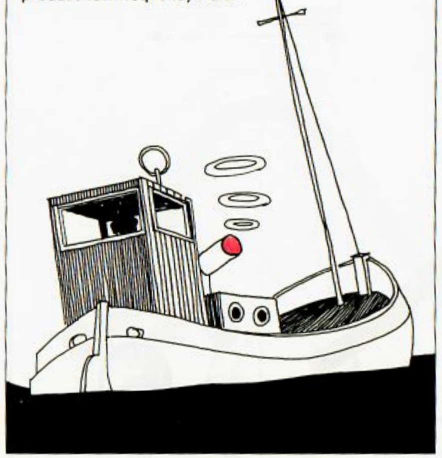


Slow repetitions give low frequencies, fast repetitions give high frequencies

A noise-producing event which repeats, generates frequencies which depend on the time between repetitions. A slowly repeating event gives rise to predominantly low frequencies and a rapidly repeating event gives rise to high frequencies. The level of the sound depends on the magnitude of the change which gave rise to it.

Principle

The distinctly separate beats of a low reving oil engine produce low frequency noise



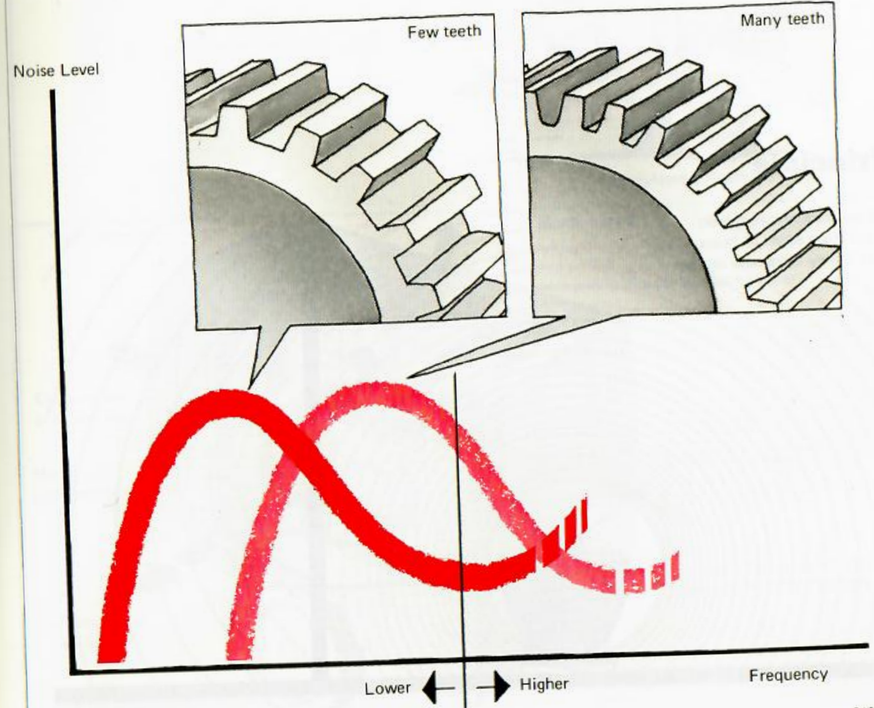
The outboard motors rapidly repeated firing gives predominantly high frequencies

810963

Example

Two gearwheels having the same size but one having twice as many teeth as the other will have predominant frequencies a factor of two apart. The main source of noise is the contact of one tooth on the corresponding tooth on the gearwheel in mesh with it. For the same diameter and speed of rotation the gearwheel with twice as many teeth will have twice as many tooth contacts per second and therefore radiate noise at twice the frequency of the other.

Two gearwheels have the same diameter but different numbers of teeth. At the same rate of rotation, the gearwheel with fewer teeth will produce lower dominant frequency than the other.



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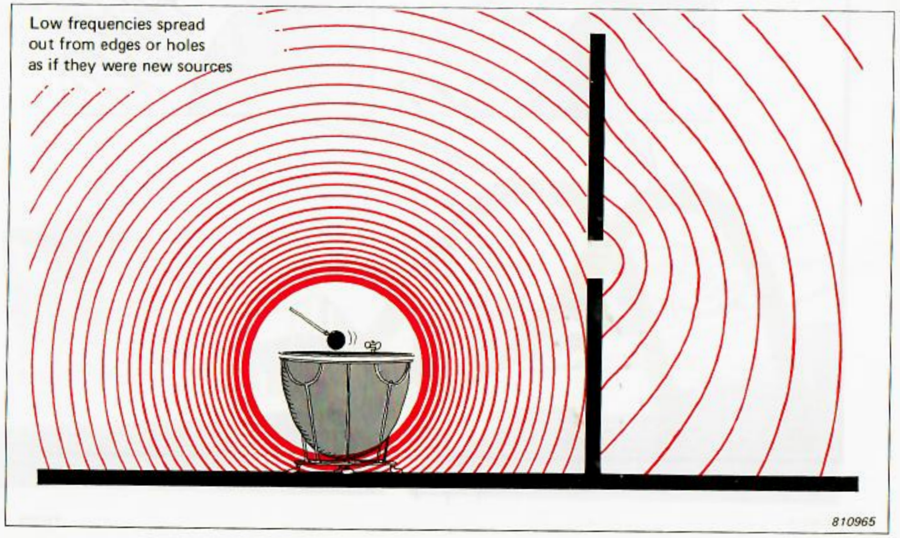
Low frequency sound bends round obstacles and through openings

Low frequency sound radiates approximately equally in all directions. It diffuses round edges and through holes without losing intensity, and reradiates from the edge or from the hole as if it were a new source, again equally in all directions. For this reason screens and barriers are not very effective against it unless they are very large.

Principle

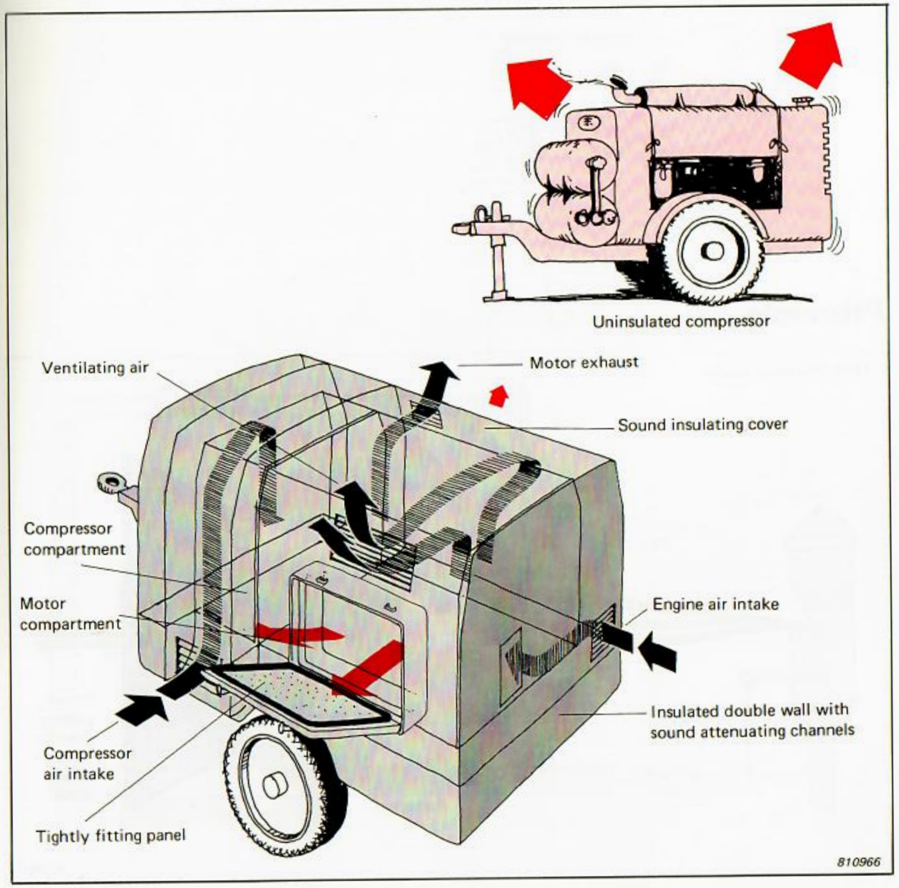


Example

Diesel driven compressors produce high levels of low frequency noise, even if they are furnished with efficient intake and exhaust silencers. Partly open or louvred covers for the intake of cooling air are of little use as noise attenuators. Noise easily radiates out through the openings and gaps.

Solution

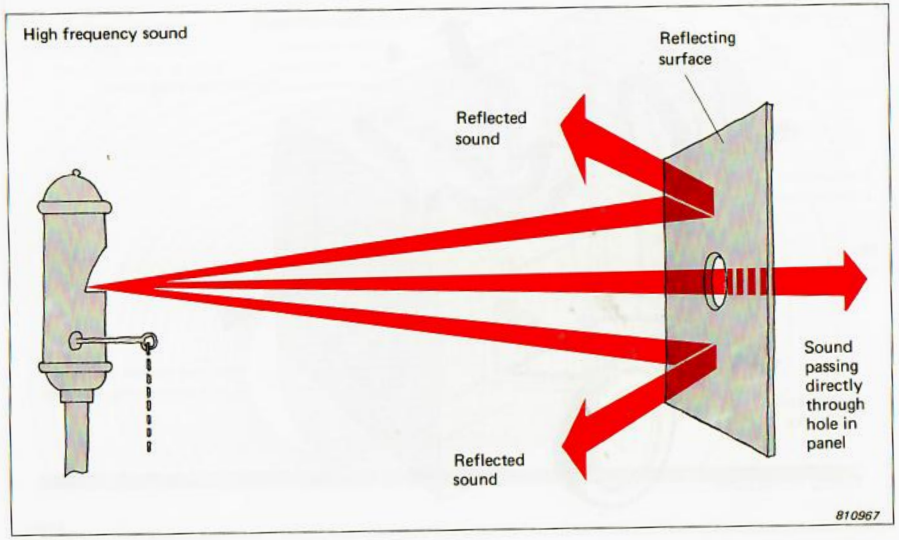
Effective quietening of a powerful compressor requires a well sealed cover eliminating air and noise leaks. The cover can be constructed as a double wall containing ducts with sound absorbent linings. Air for the compressor, for the engine, and for cooling purposes is carried through these ducts, entering and leaving via acoustic louvres. The exhaust silencer is also enclosed within the outer cover. All inspection hatches and access panels must also be tightly fitting and well sealed.



High frequency sound is highly directional and easy to reflect

High frequency sound is often produced by sources which radiate a high noise level in some directions but low levels in others. It can be reflected from a hard surface just as light is reflected by a mirror, and passes through holes in a panel like a beam without being diffused to the sides. Also it cannot diffuse around edges, so barriers are effective against it.

Principle

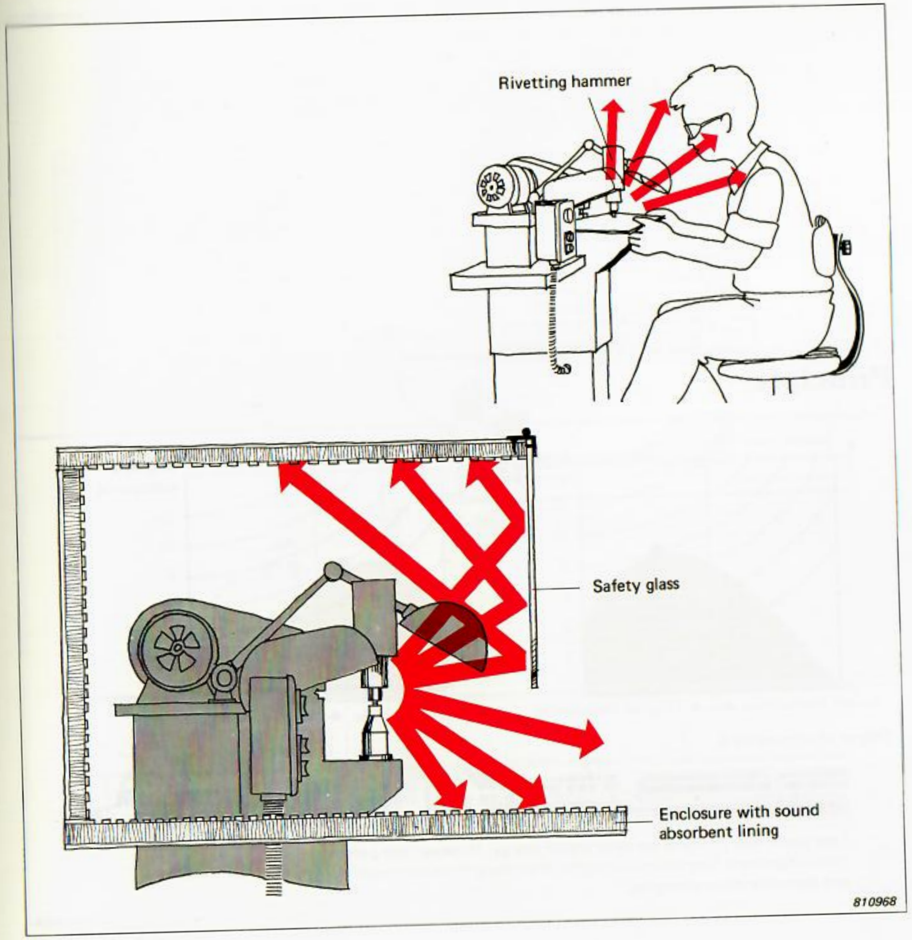


Example

Noise from processes which involve punching, hammering, or other forms of impact give rise to high levels of high frequency noise which can be dangerous to the operator.

Solution

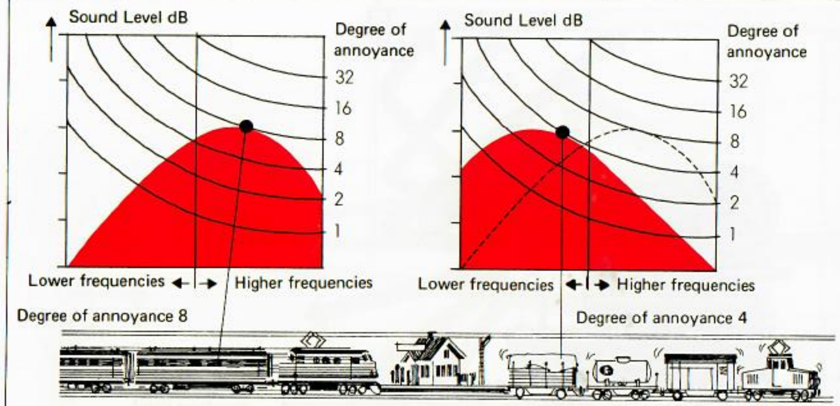
A local enclosure built around the noise source with an opening for access and safety glass to view the work protects the operator's ears from direct sound from the machine. Reflections from the safety glass and most direct sound in other directions are absorbed by the absorbent lining. The small area open for access emits sound only away from the operator's ears.



Close to the source high frequency noise annoys more than low frequency noise

The ear is more sensitive to high frequencies than to low frequencies; so to produce the same amount of annoyance, a low frequency noise must have a higher sound level than a high frequency noise. In some circumstances it may be possible to reduce the annoyance of a close noise source by moving the dominant sound energy to lower frequencies.

Principle



Two trains may produce the same sound energy. However, the passenger train's dominant frequencies are higher than those from the goods train and therefore more annoying.

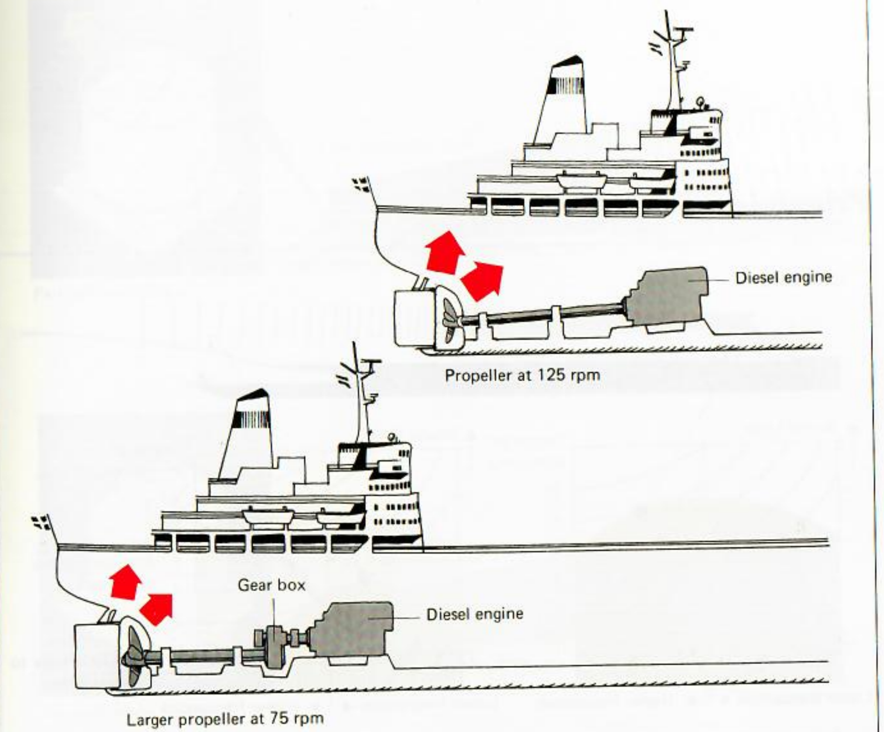
810969

Example

A ships propeller turns at the same speed as the motor, 125 revolutions per minute, and is the source of most noise on board.

Solution

A design with a larger propeller driven through a gearbox at a lower speed lowers the dominant frequencies and reduces the annoyance caused.



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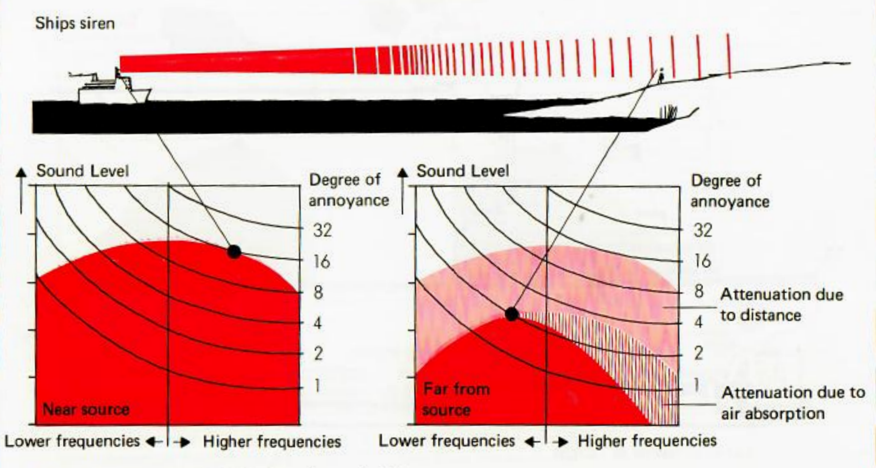
Far from the source high frequency noise annoys less than low frequency noise

High frequency noise is attenuated much more, by absorption in air, than low frequency noise is over large distances. This is because absorption is dependent on the number of cycles, and there are more cycles of a high frequency sound than a low frequency in a given distance. In addition, it is normally easier to reduce or shield a source of high frequency noise. If noise in the vicinity of the source is not a problem, it may be possible to shift the dominant noise to a higher frequency which is effectively absorbed by the time it reaches the problem area.

Principle



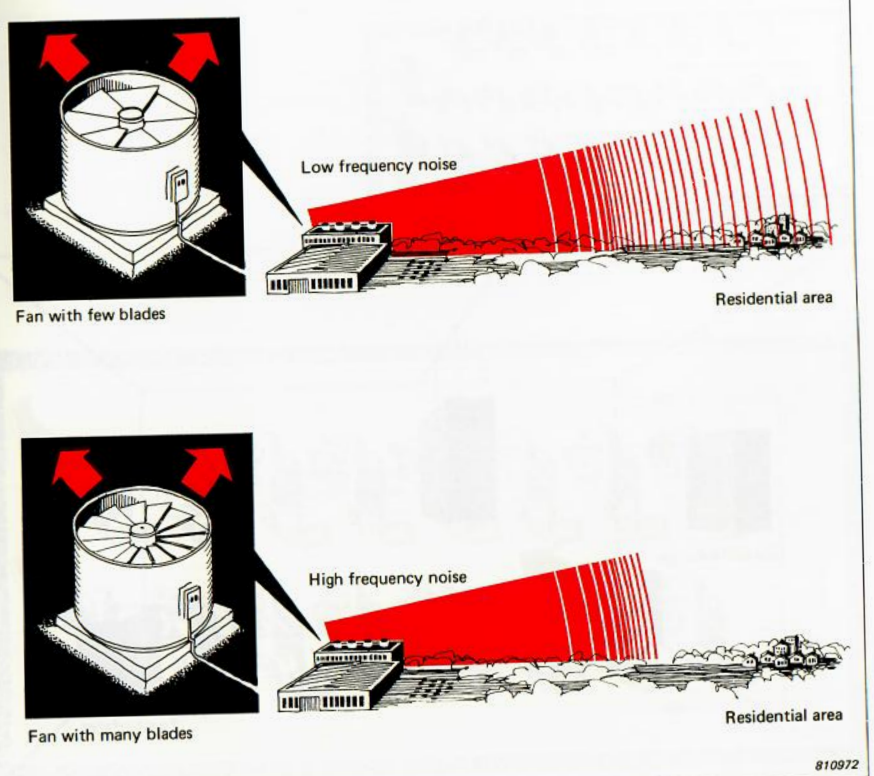
A ships siren which screams on board sounds dull at large distances

Example

Low frequency noise from industrial fans causes noise annoyance in a distant residential area. High frequencies are attenuated on the way.

Solution

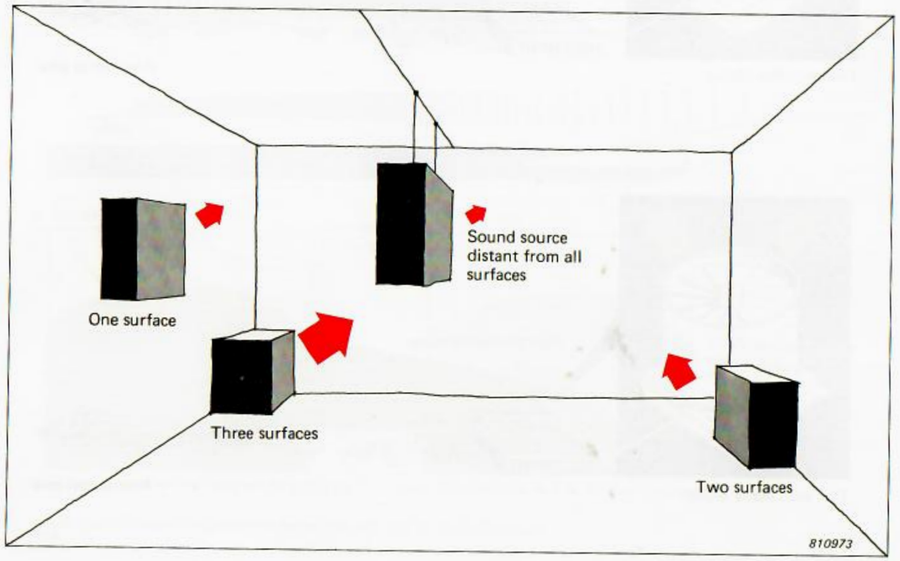
The fans can be exchanged with a type with more blades which shift the major sources of noise up in frequency. The higher tones are absorbed sufficiently by the atmosphere so that they are not a source of annoyance in the residential area, and the low frequency tones are no longer produced. The noise is also easier to attenuate at source.



Sound sources should be sited away from reflecting surfaces

The closer a sound source is placed to a reflecting surface, the more of the sound radiated is directed back into the room. The worst position is against three surfaces, i. e. in a corner. The best position is free-hanging: away from all reflecting surfaces.

Principle

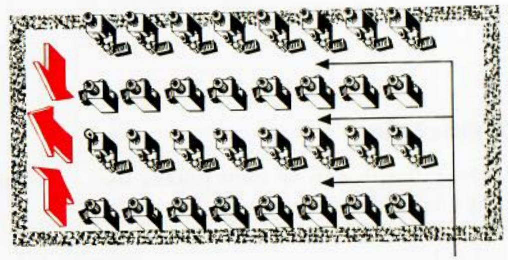


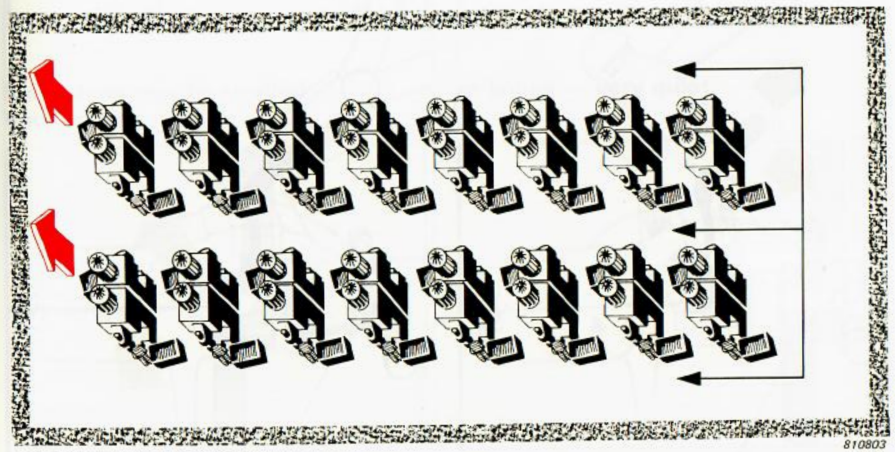
Example

In a machine hall a number of machine tools are placed in four lines, two of them against the walls, with three access lanes between them. This increases the noise from the two lines of machines placed next to the walls.

Solution

The machines along the walls are moved beside the other two lines so there are only two lines. The space along the walls is used as access lanes, of which there are still three, and the overall noise in the hall is reduced.



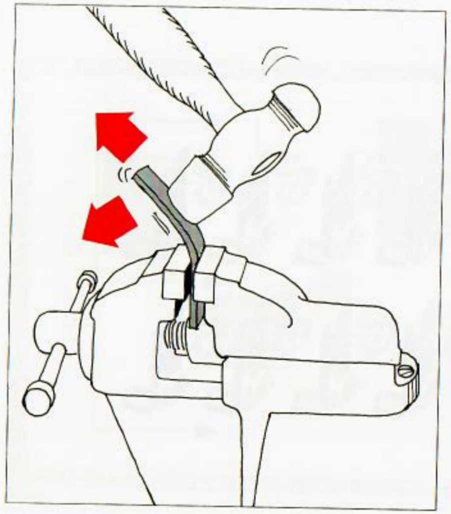


Changes in force, pressure, or speed, lead to noise

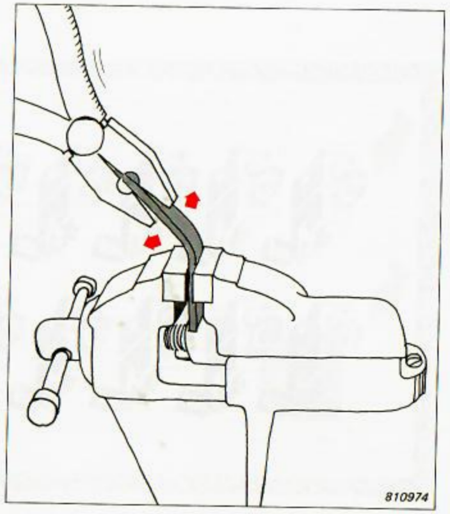
Noise always occurs where there is a change of force, pressure, or speed. Large changes produce the greatest noise, small changes produce less. In many cases the same result can be achieved either with the application of high power over a short period or with less power for a longer period. The first case causes high noise levels, the second, where the power required is small, produces much lower noise levels.

Principle

A metal strip can be bent noisily using a hammer



or quietly using pliers



Example

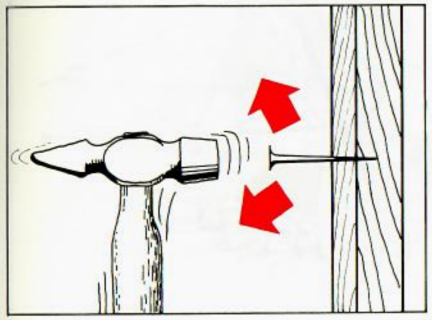
Panels and sheets can be fastened in a number of different ways, some of them very much noisier than others. Those involving impact e.g. nails and rivets are particularly bad from the point of view of hearing damage as they produce very high peak levels of noise.

Solution

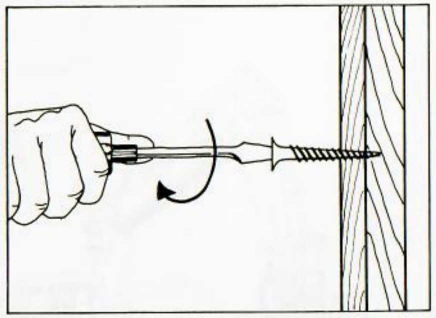
In many cases quiet methods such as screws and bolts can be substituted directly without loss of effectiveness or increase in cost, and with the advantage of improved access and ease of dismantling at a later date.

Two panels can be fixed together

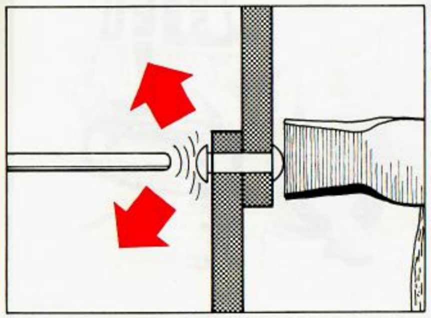
using nails — **noisy**



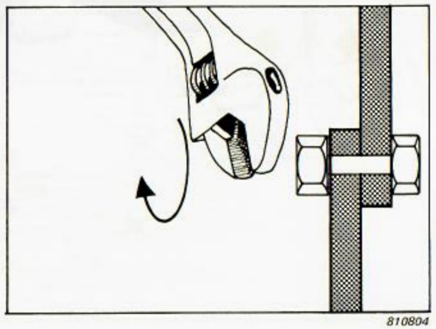
or screws — **quiet**



Steel sheet may be rivetted
Very noisy



or bolted — **very quiet**

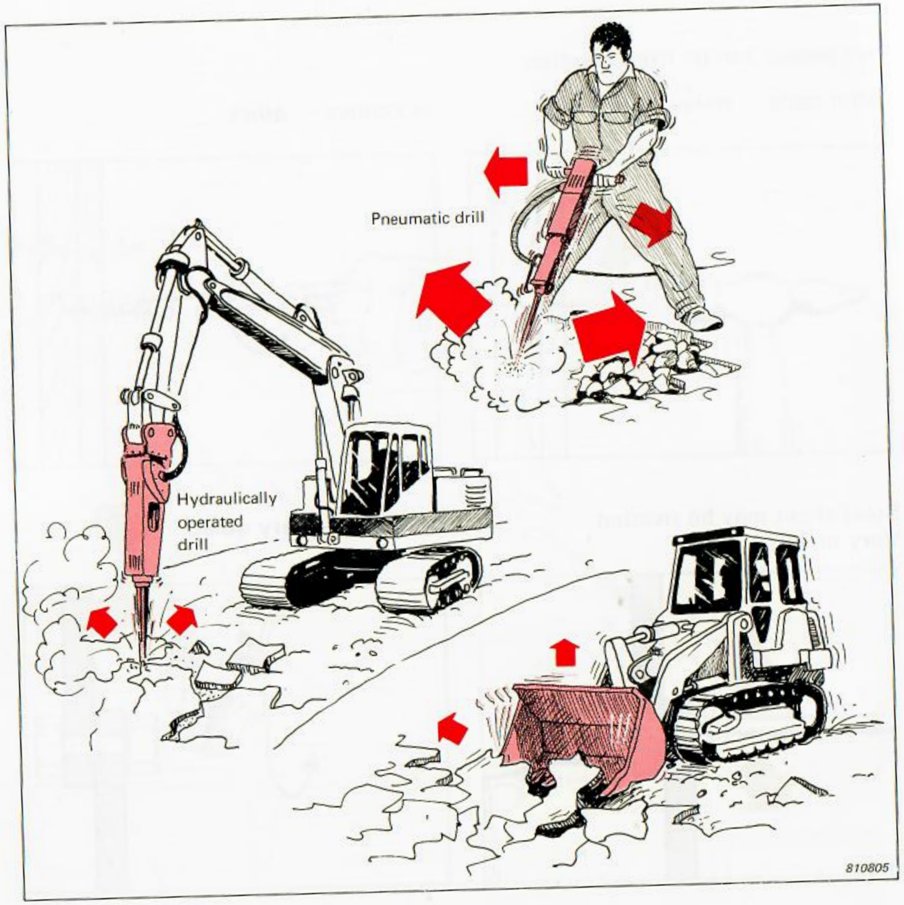


Example

Paving breakers have traditionally been handheld and usually pneumatically powered to reduce weight. High levels of impulse noise are produced both by the chipping process itself and from the exhaust. The operator is exposed to high levels of both noise and vibration.

Solution

A tractor-mounted hydraulic ram driving a hammer can exert a very large static force as well as vibrate. The paving is fractured and the cracked surface can then be levered up by a bucket loader. The noise levels are lower and the operators are further from the source, often in noise protecting cabins.

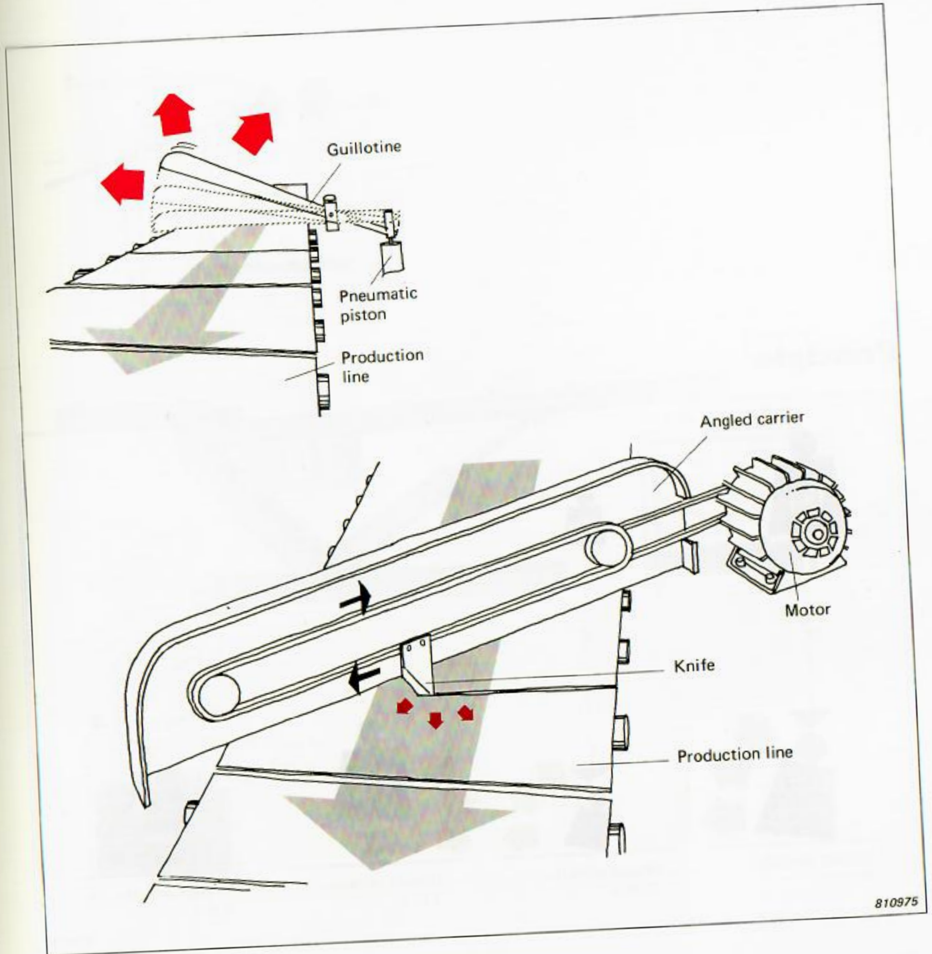


Example

Cardboard in a carton machine is chopped using a guillotine. The knife must fall very quickly using high power in order to cut perpendicular to the production line, causing high noise levels.

Solution

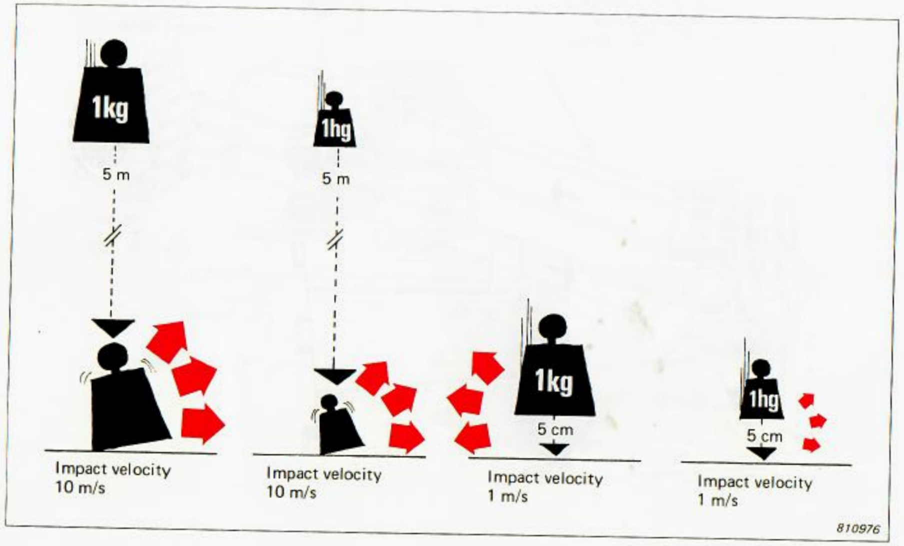
Using a knife which is driven across the production line, the material can be cut with a low force over a longer period, virtually silently. The knife must be set at an angle to the moving line of board to cut perpendicular to the direction of motion.



Low mass and low fall heights give least sound

The noise level generated when a panel is struck by a falling object depends primarily on the mass and velocity of the object. The greater the mass and fall height, the louder the noise, because greater energy is available for transfer into the panel via the impact. A reduction in height or in mass by a factor of ten reduces the noise generated by approximately 10 dB.

Principle

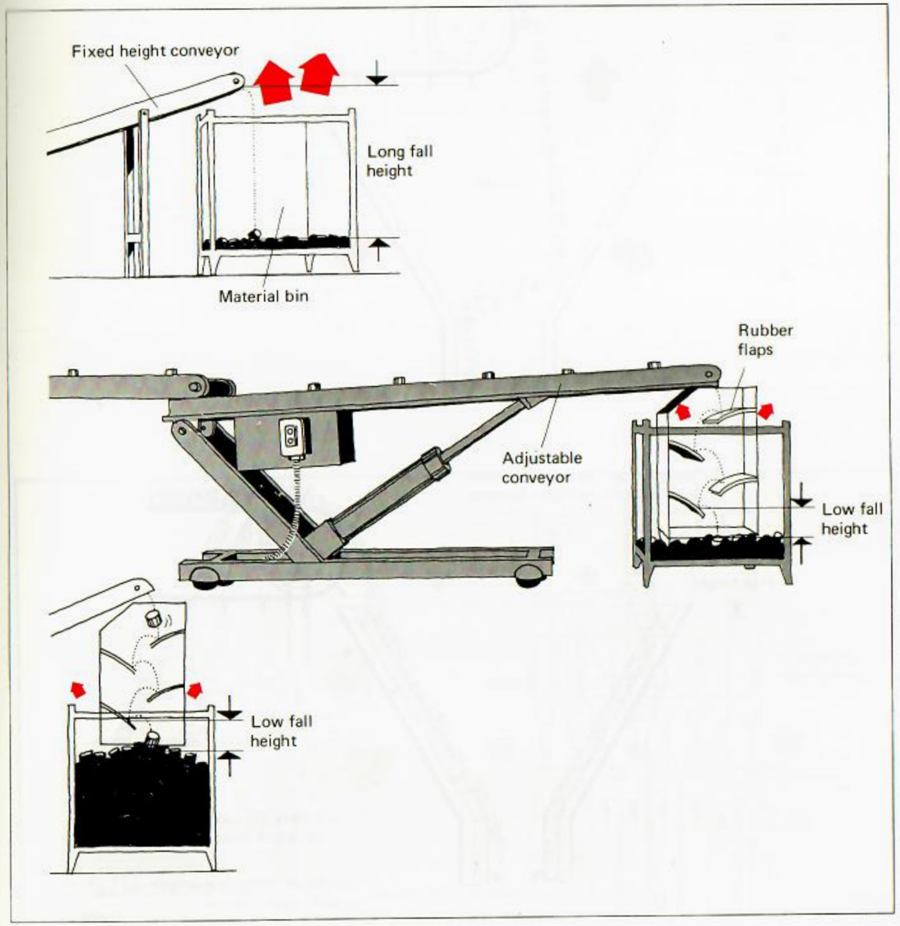


Example

Manufactured items are carried from the producing machine by conveyer and dropped into a collecting bin from a fixed height. When the bin is empty the fall height is large and the noise level is therefore high. There may also be danger of damaging the items.

Solution

The conveyer is constructed so that its height can be adjusted, and is supplied with a case with a number of rubber flaps inside to break the fall of the material. The fall height is therefore never greater than the distance from the collected material to the lowest rubber flap, the conveyer rising automatically as the bin fills.

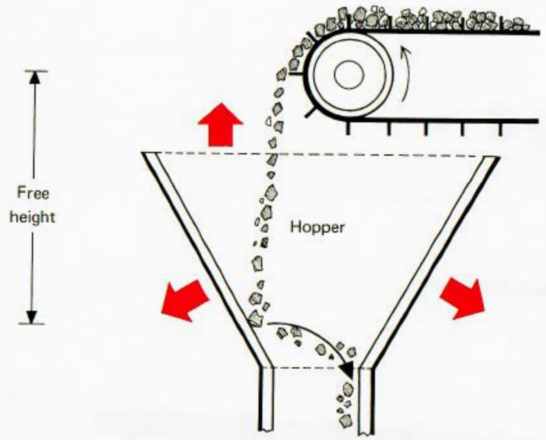


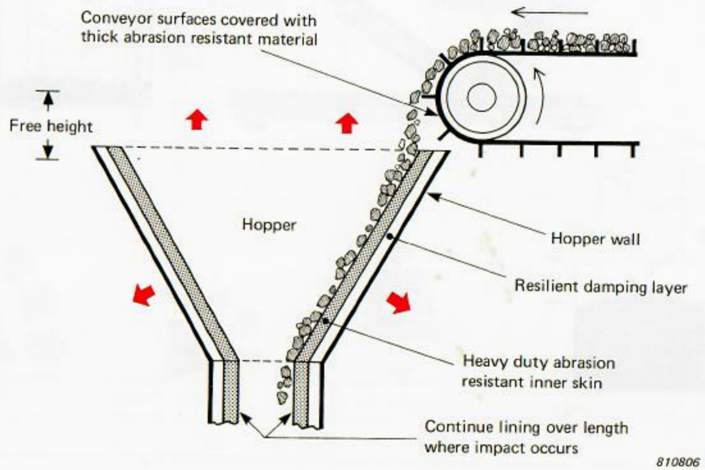
Problem

A material conveyer feeding a hopper deposits the material in the centre of the hopper and the fall height is therefore large. The hopper itself is also a very resonant structure.

Solution

Mount the conveyer so that the material falls on the edge of the hopper so that the free height is minimised. The interior of the hopper can be lined with wear-resistant material to absorb the impact better, and the external surfaces can be mounted with damping sheets to reduce resonances even further.



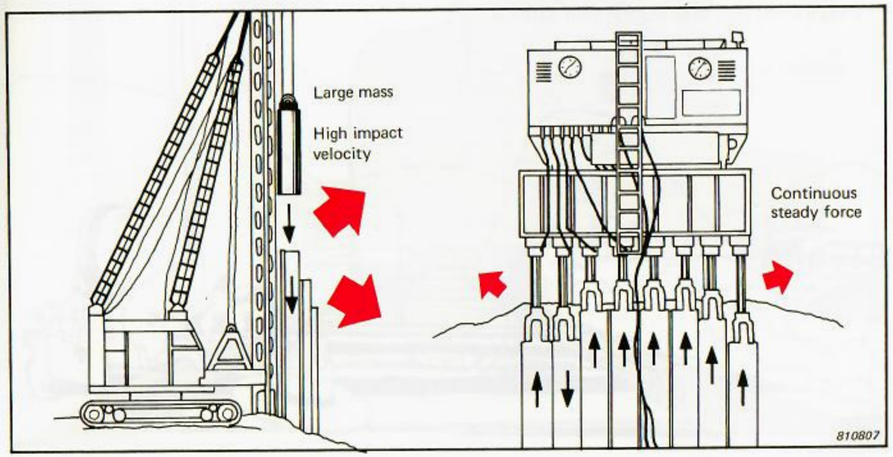


Problem

Sheet piles are normally driven via the impact of a heavy mass dropped from a great height, often powered up again by exploding a diesel charge. Dangerous local noise levels are generated both by the impact on the pile and from the explosion in this case, and annoyance may be caused at distances of up to several kilometers.

Solution

In many situations it is possible to use a completely different technique which avoids impact completely. A set of hydraulically operated rams grip a number of sheet piles simultaneously.
One pile is forced down at a time while the machine pulls upwards on all the rest, which anchor it to the ground. Vibration of the ram holding the pile being driven assists its progress. Impact is avoided completely and noise levels are as low as the hydraulic equipment allows.



Structure-borne sound travels long distances

Vibration which gets into a structure, especially homogenous structures such as concrete buildings or ships, travels a very long way because of the very low internal damping of the structure. The energy does not reduce and as soon as a large surface, which acts as a loudspeaker, is connected to the vibrating structure, a high noise level is generated. It is best to isolate the structure from the source of vibration as near to the source as possible.

Principle

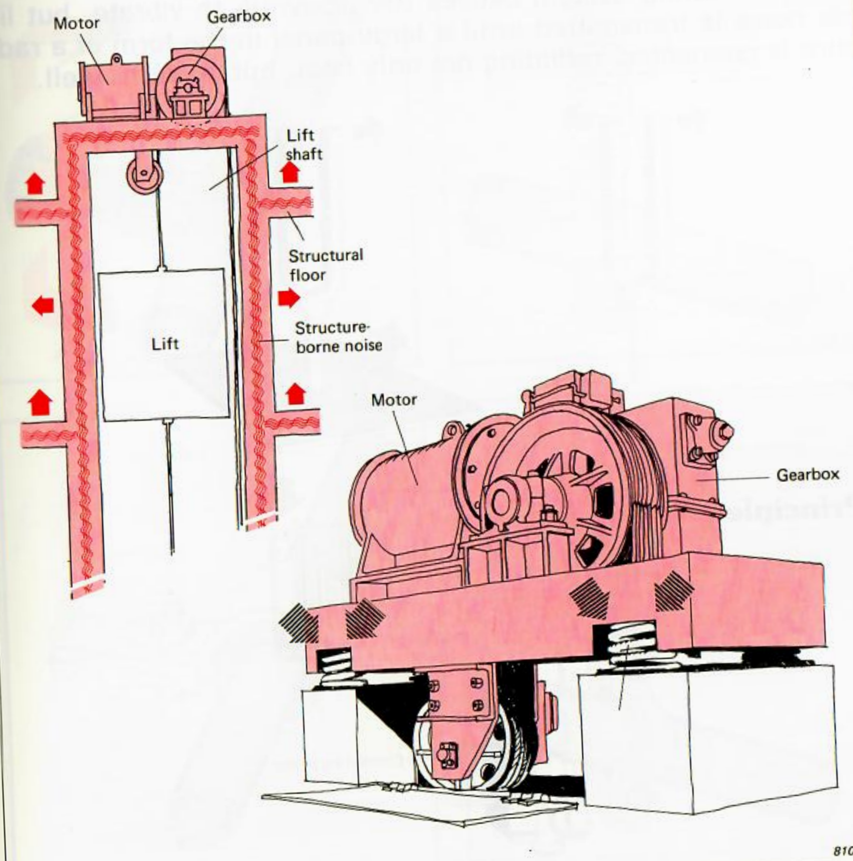
Vibration from the train is transmitted directly along the rails and can be heard at great distances

Example

Vibration and stop/start shocks from an elevator can be heard throughout a building. The sound is carried for large distances virtually unattenuated via the concrete slabs.

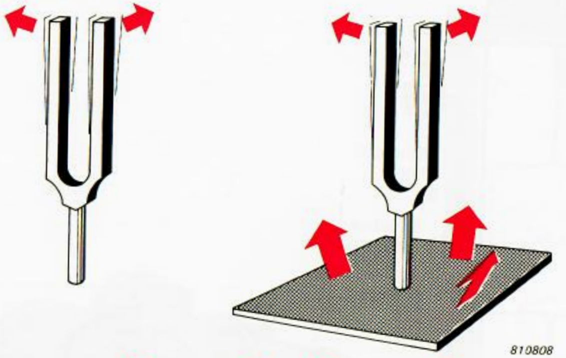
Solution

The winding machinery must be isolated completely from the building structure using a spring support. Further reduction can be achieved by building the lift shaft and driving mechanism separately from the rest of the building structure.

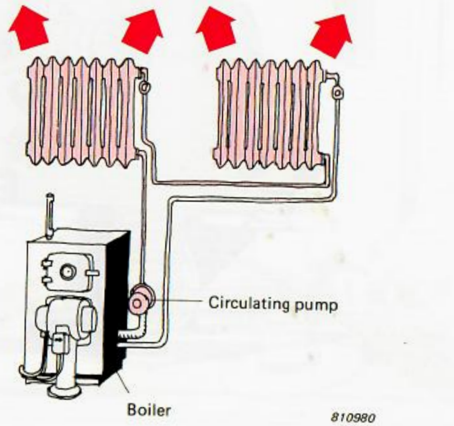


Structure-borne vibration needs large areas to convert it to airborne sound

The vibration of a small object will not generally give a high noise level because the area of air set in motion by the object will also be small. The vibration is thus badly matched to the air. However, connecting a large panel transfers the vibration energy into airborne sound much more effeciently by spreading the vibration over a much greater area which gives a high noise level. A tuning fork generates hardly any noise unless connected to a "sounding board". The circulation pump of a central heating system causes the pipework to vibrate, but little noise is transmitted until a large panel in the form of a radiator is connected; radiating not only heat, but noise as well.



Principle

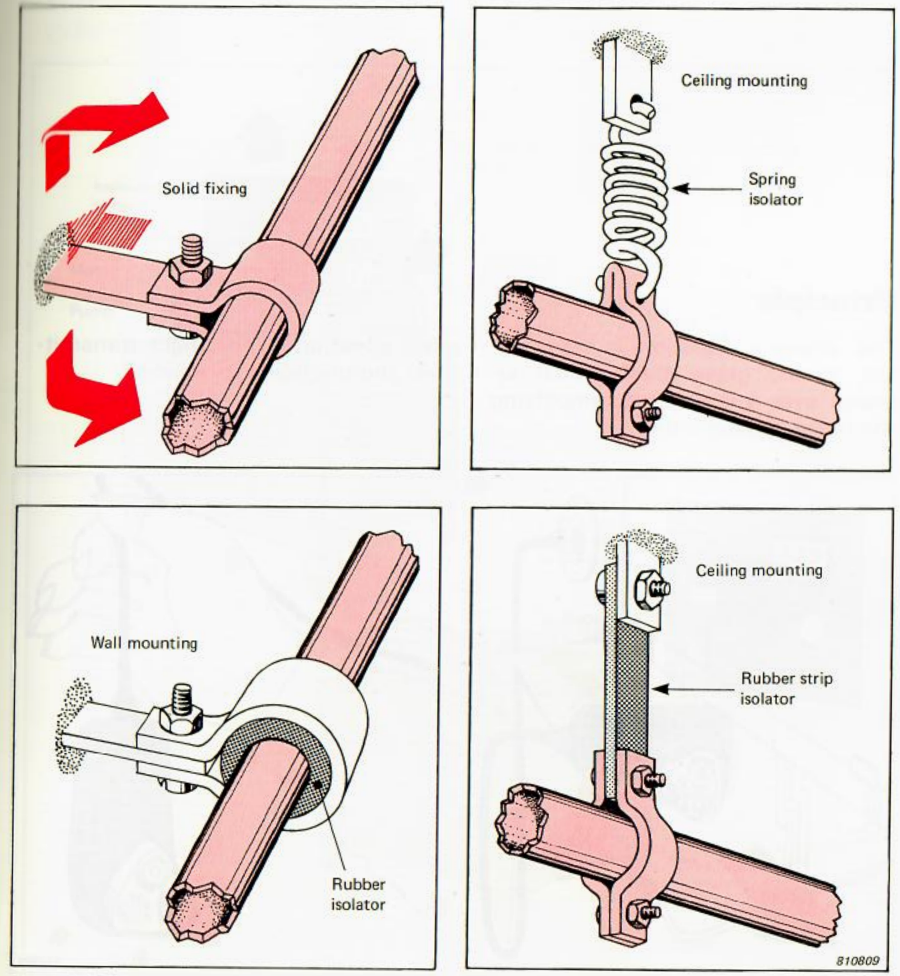


Example

Structure-borne sound in a pipe, perhaps vibration from the circulation pump or noise from the fluid itself, has little opportunity to develop airborne sound as it is of small area. Fixing the pipe to a wall or panel gives the vibration a chance to excite a large area and therefore generate a high airborne sound level.

Solution

The pipework must be properly mounted and isolated from the wall or panels so that they are not set into vibration. This may be done using one of a number of different types of isolator employing springs, rubber strips, foam rubber washers, etc.



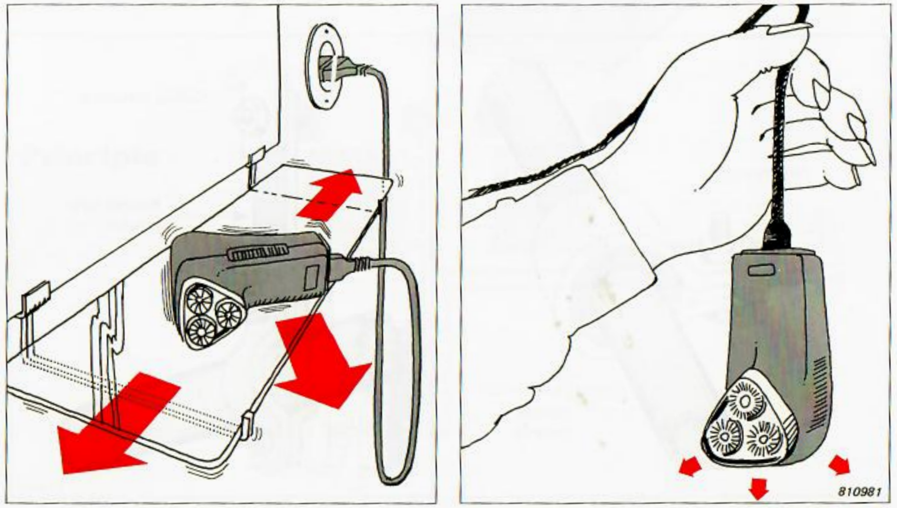
Small vibrating objects radiate less noise than large

A small object may vibrate without giving rise to high noise levels because the surface cannot transfer the vibration energy into sound energy efficiently. Connecting a large panel to the object increases its ability to convert vibration to sound. As most machines produce some vibration, the size of the machine and its panels should be kept as small as possible.

Principle

The shaver's vibration is transmitted to the glass shelf which vibrates over a large area, amplifying the noise substantially.

The vibration is no longer transmitted and the noise is reduced.

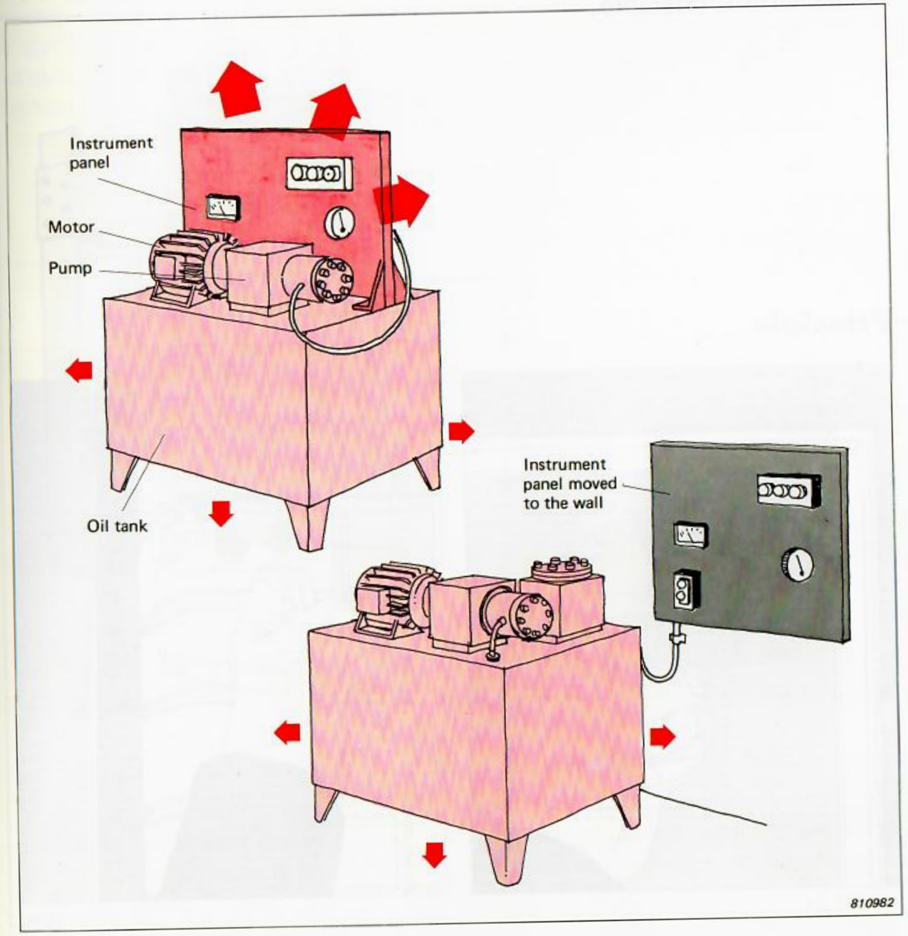


Example

A hydraulic supply system was a significant sound source even though the panels of the oil tank were damped by the oil inside. The chief source of noise was found to be the instrument panel which was set into vibration by the motor.

Solution

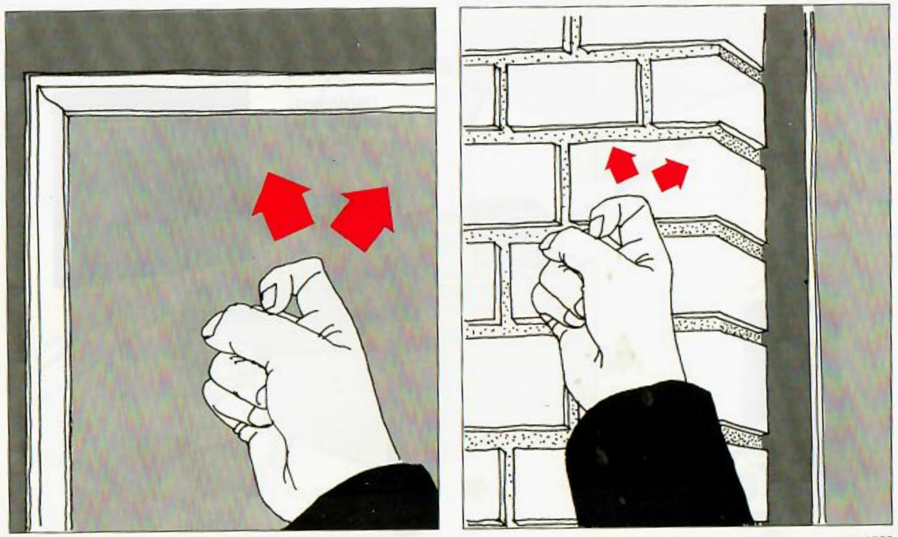
Removal of the panel from the machine uncoupled the source of sound from the source of vibration and reduced the sound level.



Vibrating machinery or parts of machinery should be mounted on a heavy foundation wherever possible

Tapping on a light partition generates noise because the partition is easily moved by the force of the tap and therefore transmits the sound. Tapping on a heavy masonary wall produces little noise because the force available is so small it cannot have much effect on the wall. To avoid noise transmission from motors, pumps, etc., they should not be mounted on the relatively flexible equipment which they serve but separately on heavy bases where possible.

Principle



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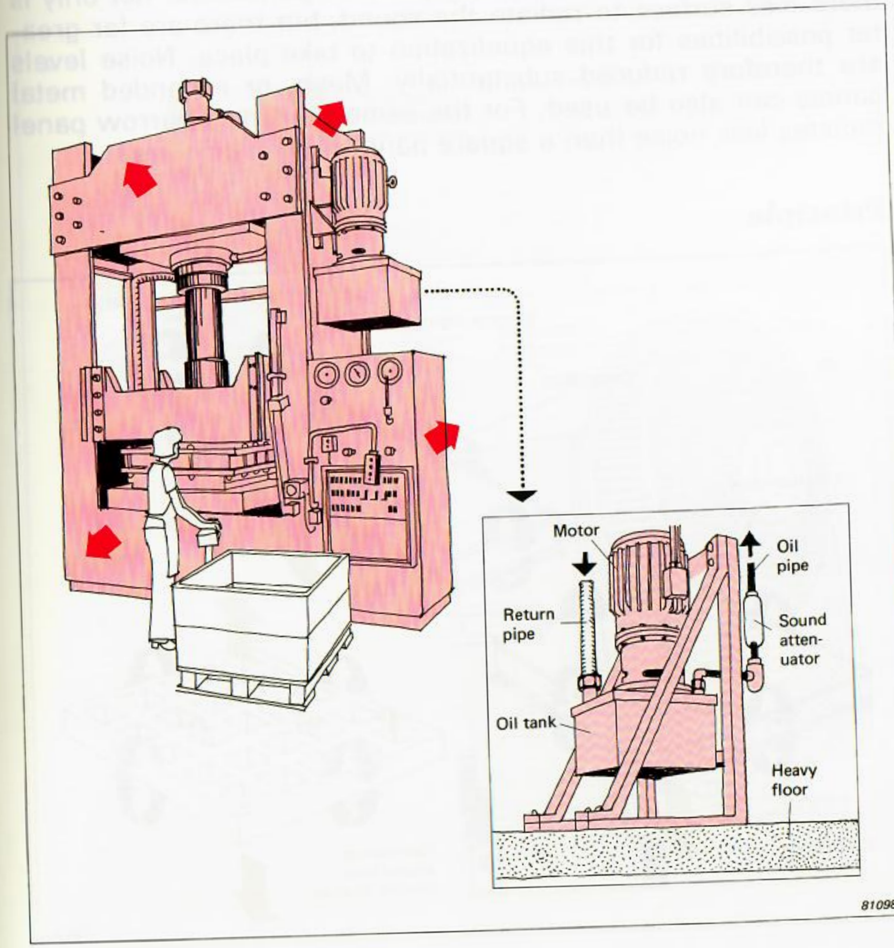
Example

Pumps and motors serving large pieces of equipment such as hydraulic presses, machine tools, and turbines are often mounted directly on structural panels. These are set into vibration, radiating high noise levels from the entire area of the machine.

Solution

The services should be mounted, on isolators, away from the main frame of the equipment, on a solid floor whereever possible. Pipework carrying fluids should be connected via flexible piping and include attenuators to avoid the transfer of vibrations via these connections back to the main structure of the equipment.



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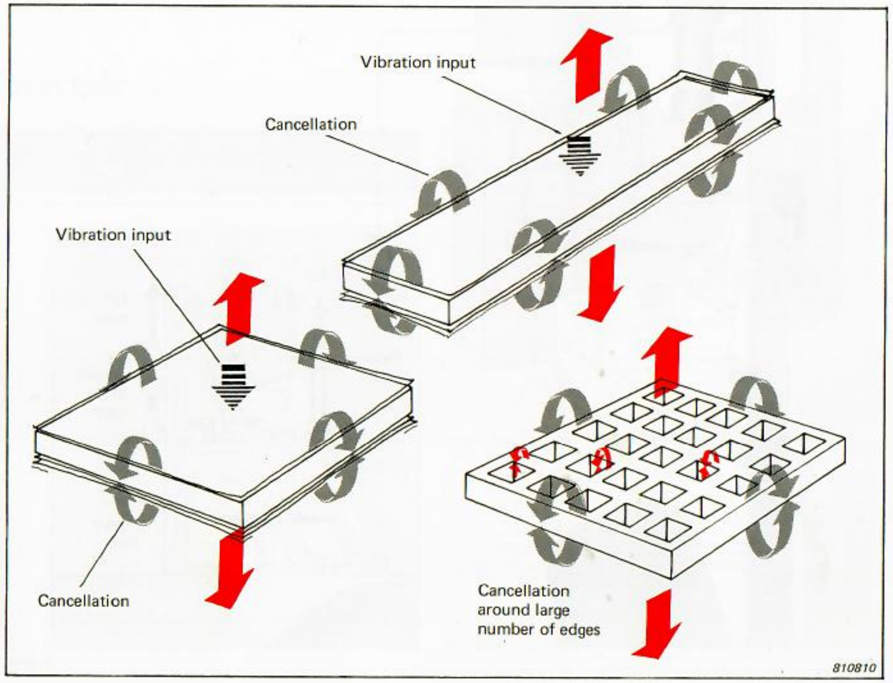
Free edges on panels allow pressure equalization around them and reduce radiated noise levels

It is not always possible to avoid the use of large vibrating panels which give rise to high noise levels. In many cases these may be replaced by a perforated panel or another type with a broken surface. A plain panel radiates noise from all its area efficiently as there are only four sides along which the sound pressure can be partially cancelled out by the negative pressure from the other face. If the panel is perforated, not only is there less surface to radiate the sound, but there are far greater possibilities for this equalization to take place. Noise levels are therefore reduced substantially. Mesh, or expanded metal panels can also be used. For the same reason, a narrow panel radiates less noise than a square panel of the same area.

Principle

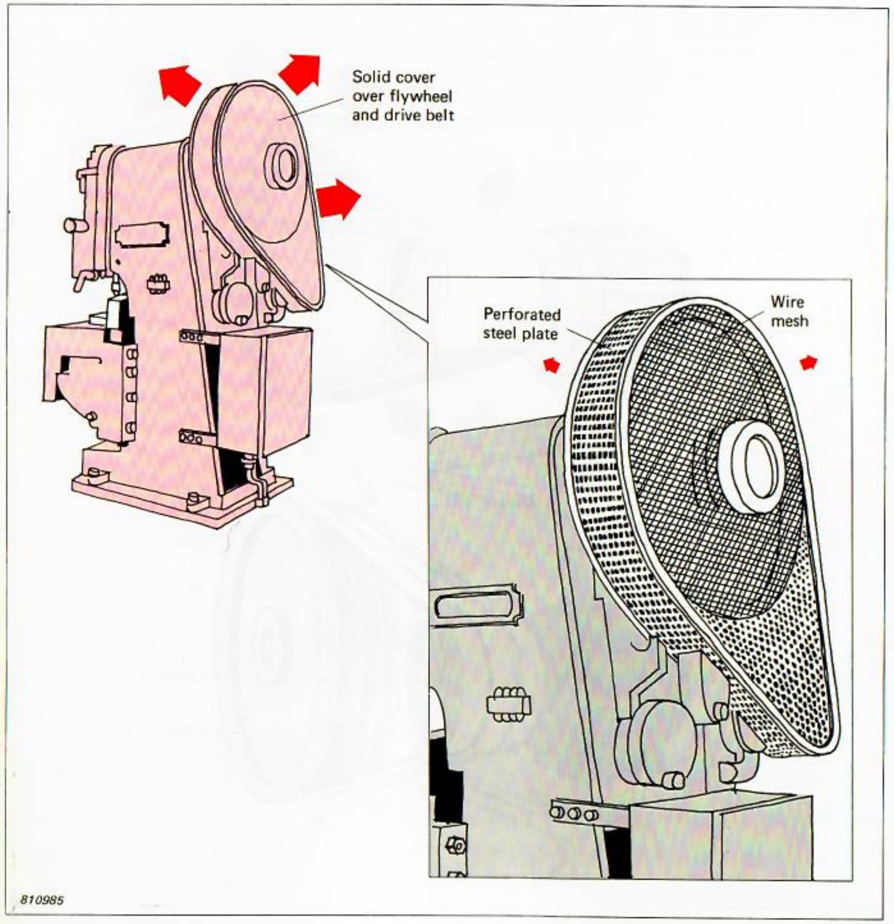


Example

The protective cover over the flywheel and belt drive of a punch press radiates noise efficiently.

Solution

A replacement cover of wire mesh reduces the noise radiation.

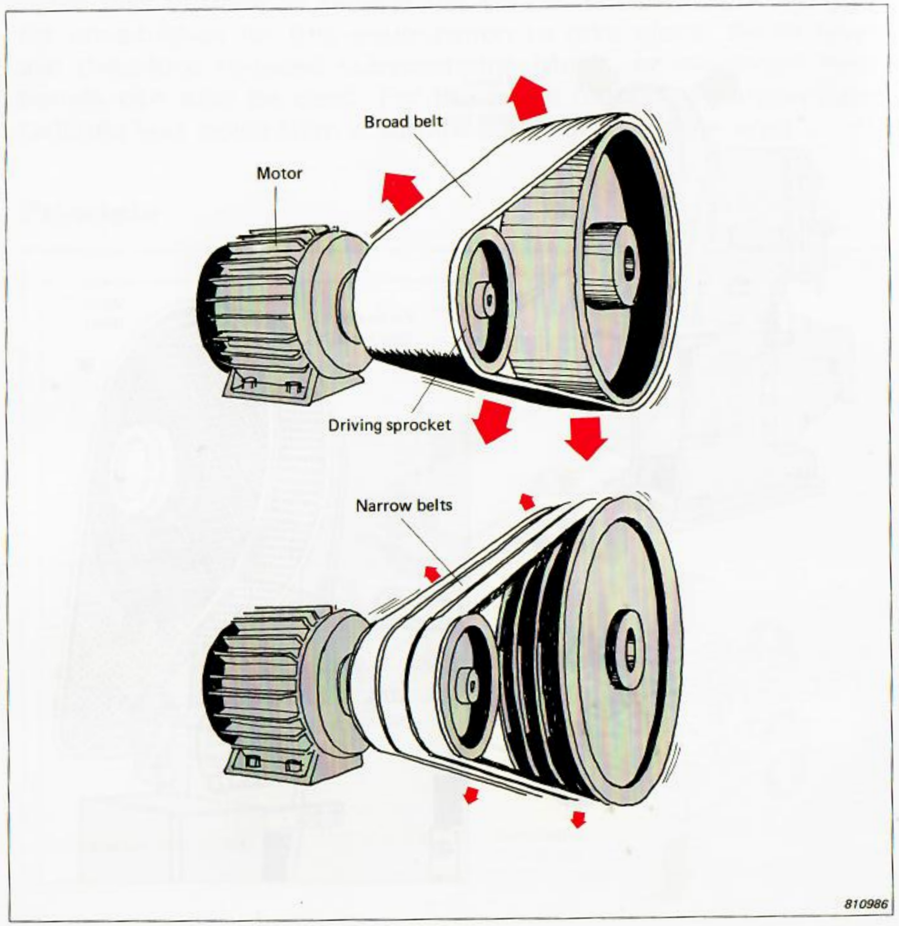


Example

Vibration of wide drive belts on industrial drives can lead to high levels of low frequency noise.

Solution

Replacing the single drive belt with a number of narrower drive belts with gaps between them increases the amount of cancellation which is possible between the top and bottom of each belt and between one belt and the next one. The noise level is therefore reduced.

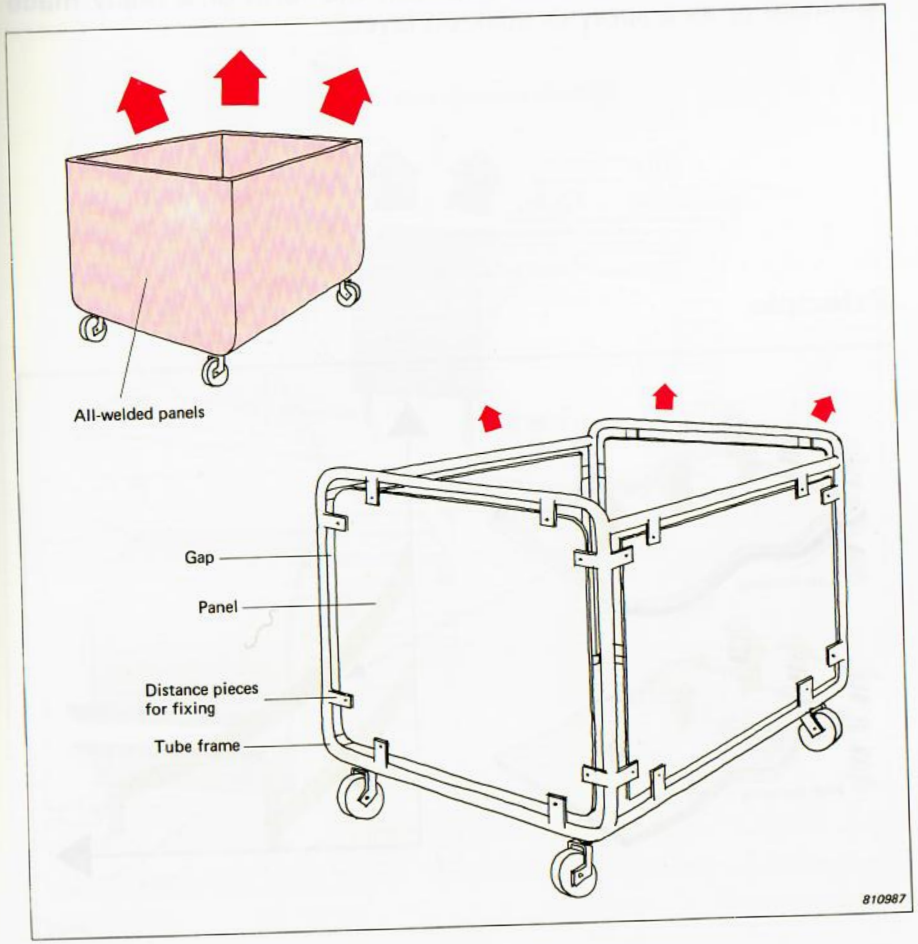


Example

Bins for the transport of material radiate noise when being loaded and emptied and when being transported over uneven surfaces. With this type of construction, pressure equalization can only occur around the upper edges.

Solution

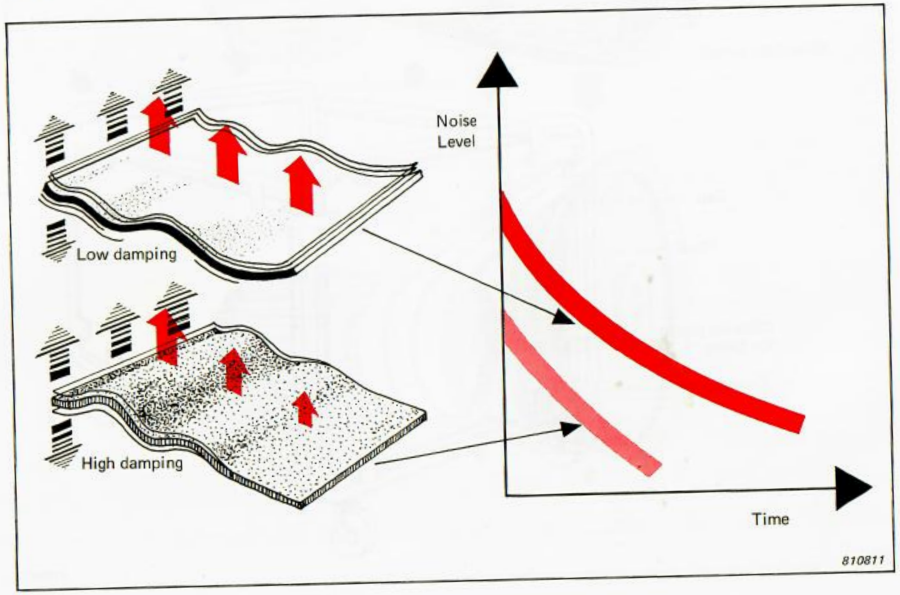
The side panels can be fixed to edge frames with narrow brackets so that there is a much greater length of free edge around which pressure equalization can take place. If the size of the material or components allows, the side panels may be made of wire mesh to reduce radiation further.



Damped structures give rise to less noise

If a panel is set into vibration, the level of vibration, and therefore the noise level will dimminish with time. The speed of this reduction depends on the material's internal damping. The higher the damping the quicker the drop in level. The damping also has an effect on the maximum level that can be generated from a given excitation; a well damped panel cannot be excited as much, as the resonances are reduced. Unfortunately most common metals have very low internal damping and a damping layer must usually be introduced in the form of a ready made laminate or as a spray or stick-on layer.

Principle

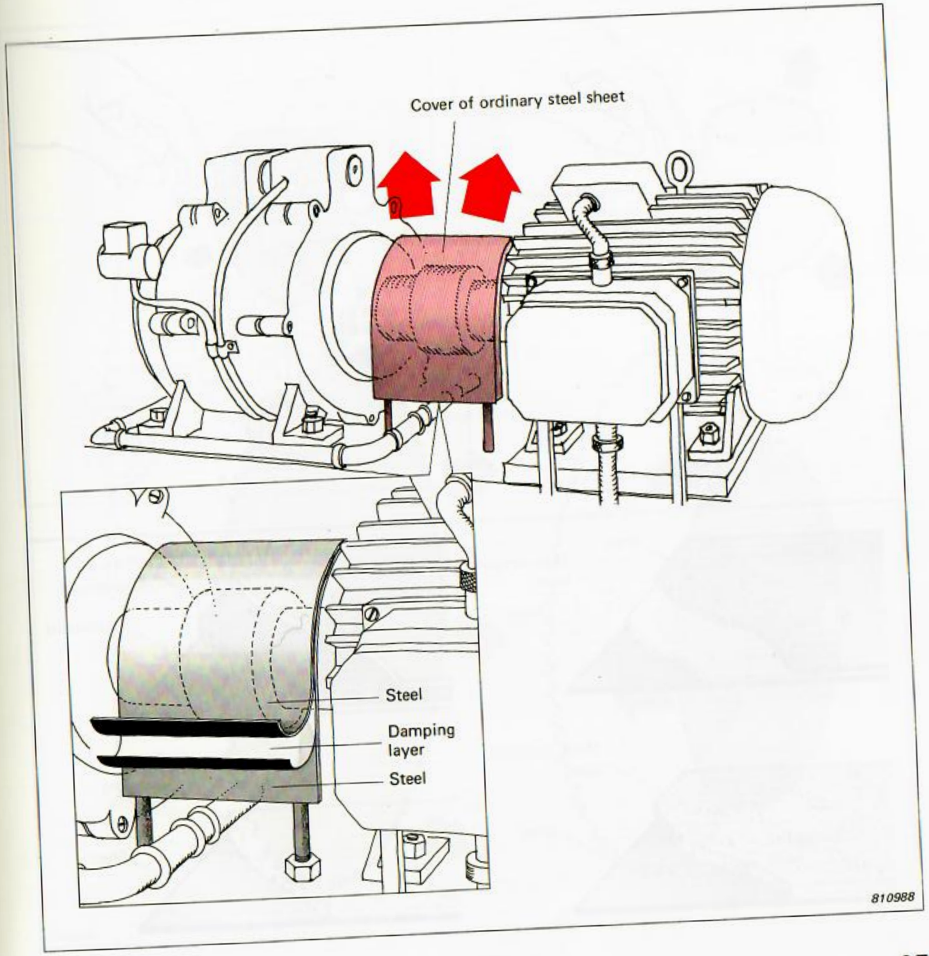


Example

Panels on machinery containing motors or pumps are prone to vibration and are therefore a normal source of radiated noise.

Solution

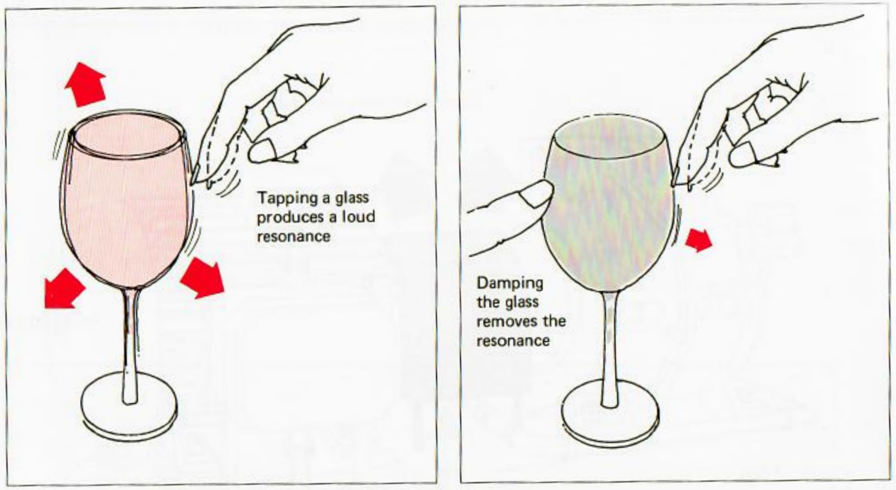
By using a laminated panel with high damping properties the noise can be reduced signficantly.

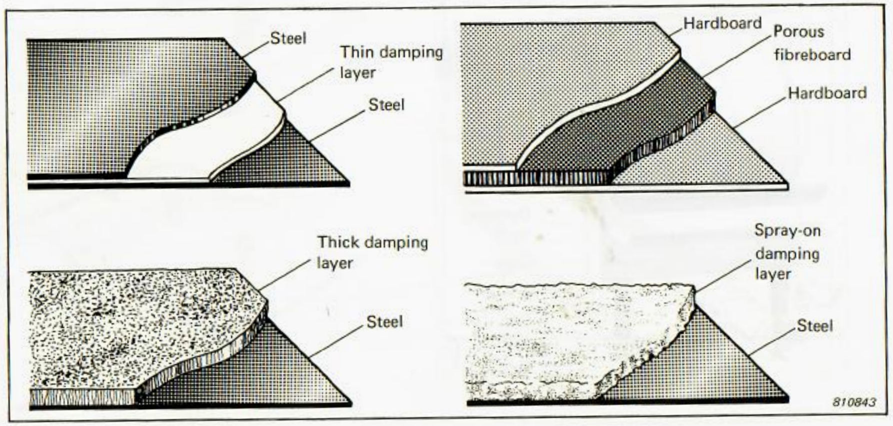


Resonances amplify noise radiation but can be damped easily

Resonances strongly amplify the noise emitted by vibrating panel and plates, especially in homogenous structures. However, relatively small additions of extra damping can reduce the resonance peaks, and therefore the noise radiated, enormously. Pieces of damping material, fixed to a work piece temporarily, are also very effective.

Principle



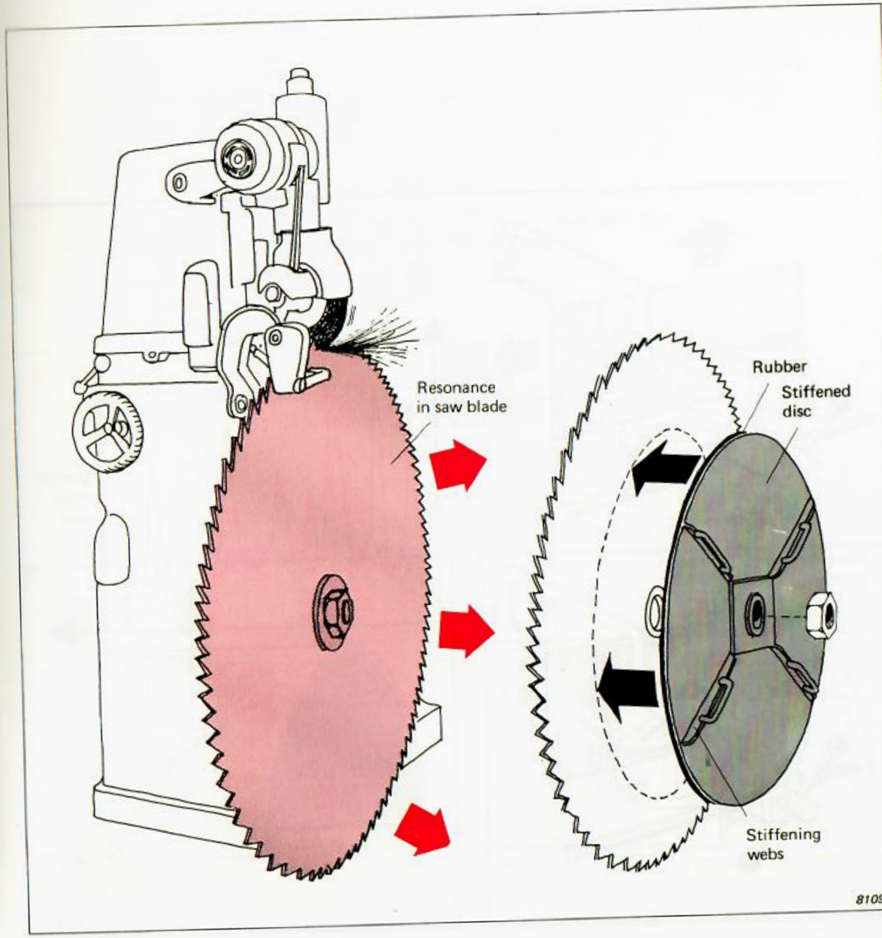


Example

A circular saw blade in a sharpening machine generates a high level of noise because of resonance and very low internal damping.

Solution

A disc of rubber damping material fastened to the blade by a stiff disc during sharpening, adds both mass and damping to the blade and reduces the amplification of the resonances.

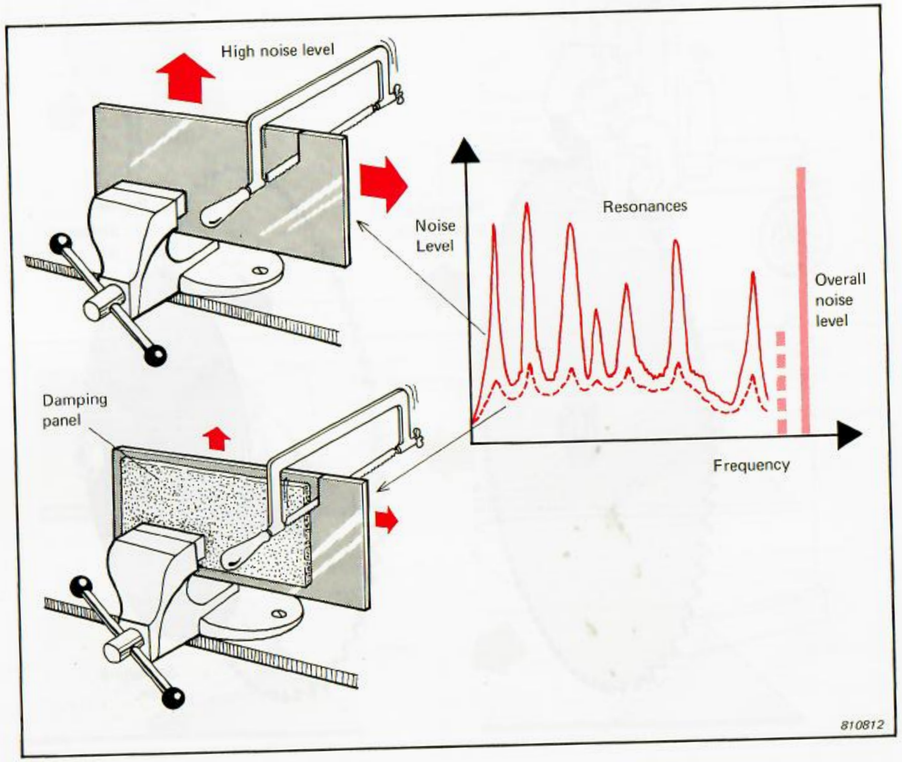


Example

During sawing operations on steel plate the sawing motion induces strong resonances in the work piece whose large area radiates a high level of screeching unpleasant noise.

Solution

Temporary addition of a magnetically held damping panel reduces the intensity of the resonances and reduces the noise to an acceptable level.

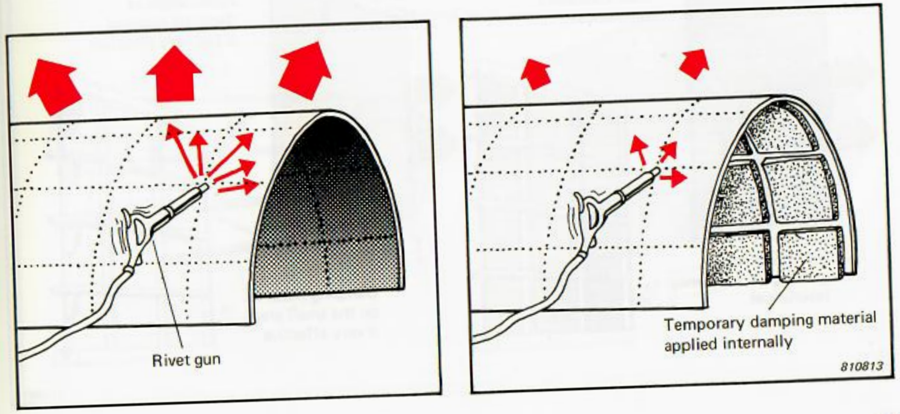


Example

The process of rivetting large structures such as aircraft, ship, or process plant components leads to high noise levels because of the impact caused and the large size of the component which efficiently converts the vibration energy into noise.

Solution

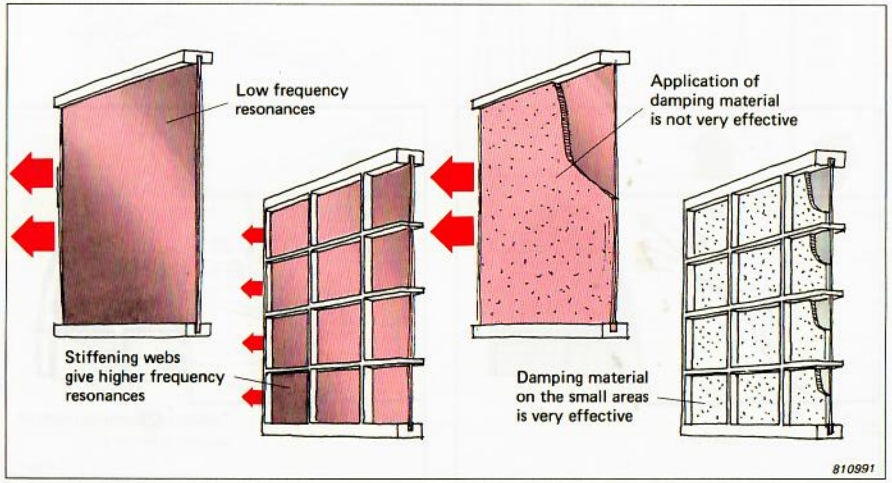
The application of temporary damping pads to the structure as it is rivetted reduces the intensity of the resonances and attenuates the vibration as it travels from the rivetting site to the rest of the panel.



Resonances transferred to a higher frequency are easier to damp

Large vibrating plates and shells often have low frequency resonances which are difficult to damp out. If the plate or shell can be stiffened, the resonance is shifted to a higher frequency which is easier to damp. In some cases it may still be difficult or expensive to apply the damping material to the separate areas, and therefore advantageous to mount a thin damped panel over the stiffening webs.

Principle

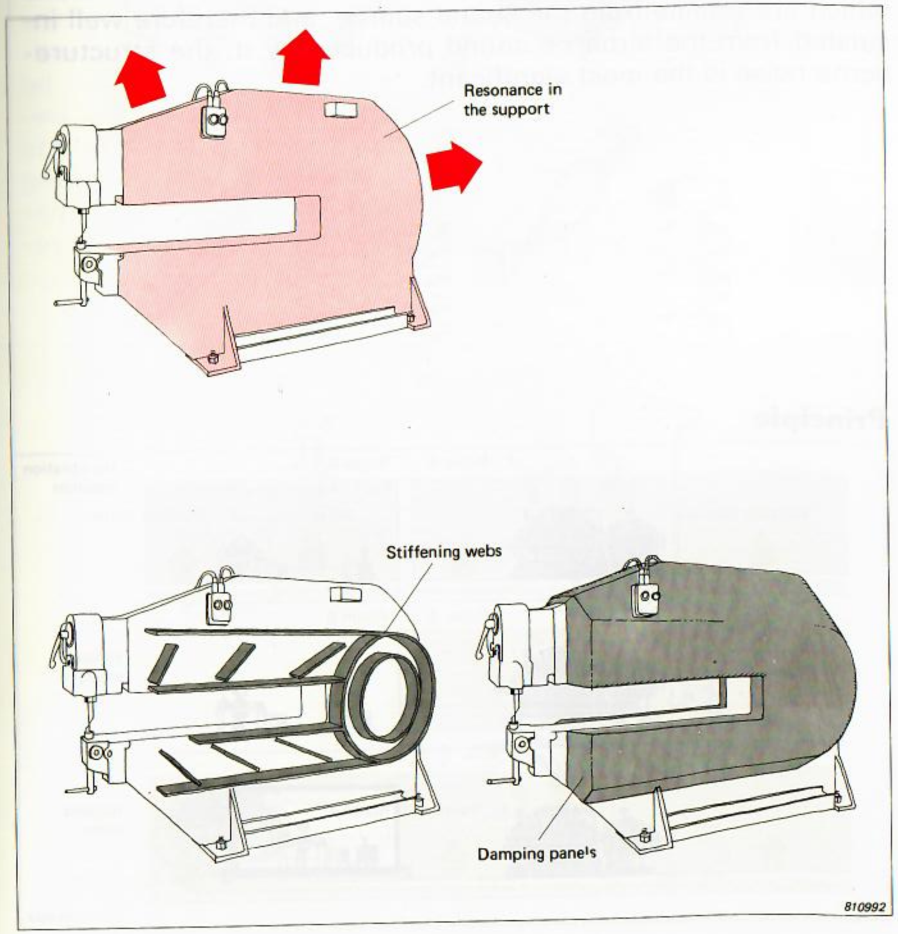


Example

The chief source of noise from a shearing machine proved to be radiation from the support and not from the workpiece as expected.

Solution

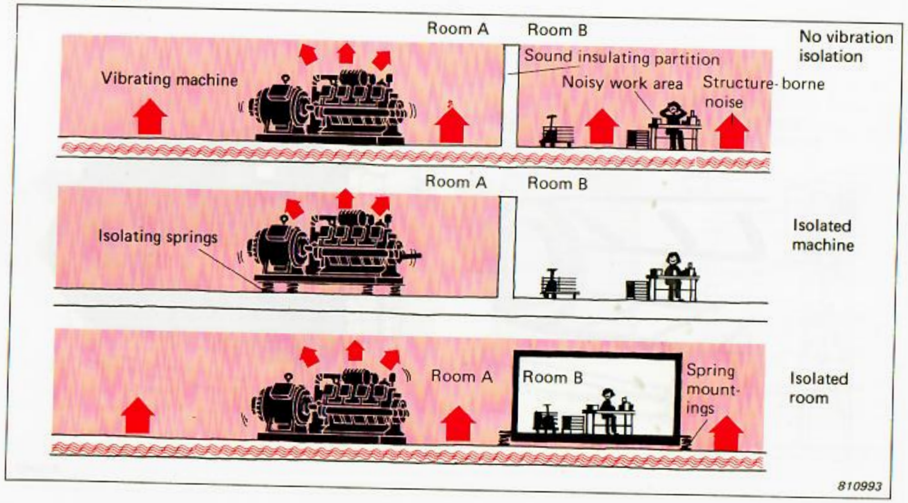
Stiffening webs were fitted to the support panels, and damped panels mounted on them.



Flexible mountings isolate machine vibration

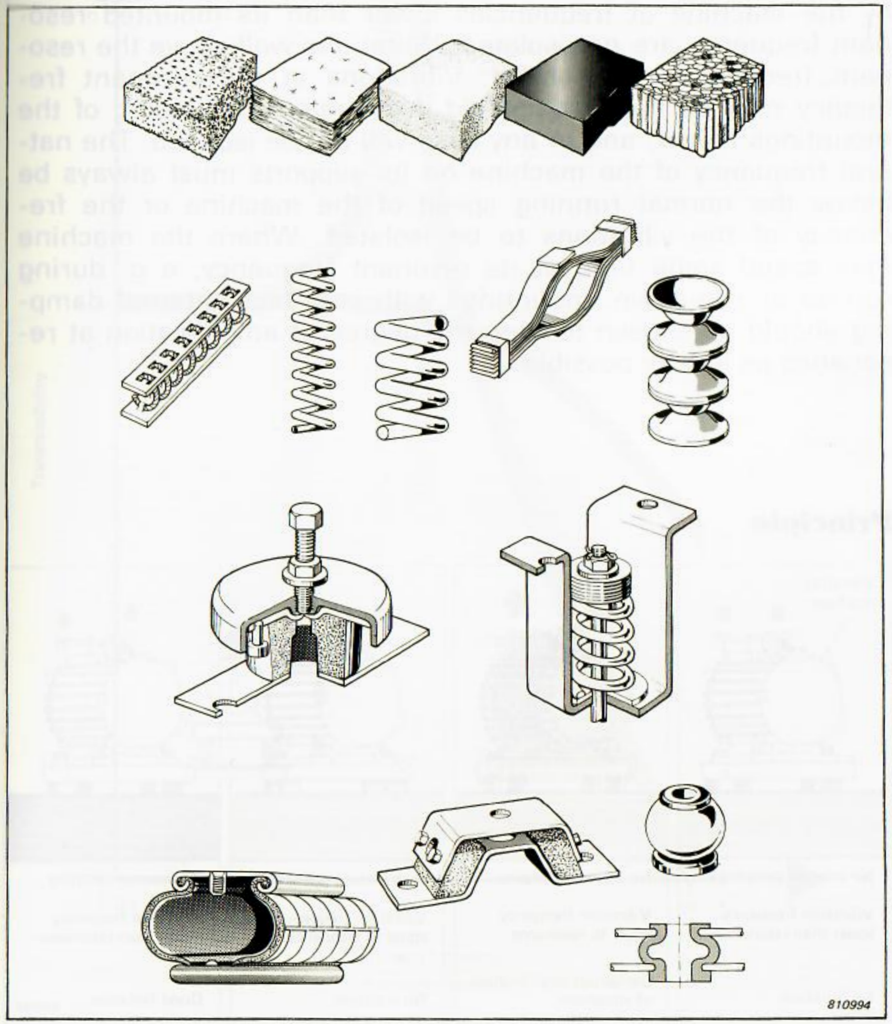
Nearly all structure-borne noise can be eliminated or at least significantly reduced by mounting vibration sources on flexible supports. In some cases it may be necessary to mount the receiver room on flexible mountings as well, e. g. where sensitive apparatus is used or for low level acoustic measurements. Normally it is preferable to isolate the source, or at least as near to the source as practically possible. In this way every region of the building is protected from structure-borne noise caused by the source. In many cases, especially in locations which are remote from the sound source, and therefore well insulated from the airborne sound produced by it, the structure-borne noise is the most significant.

Principle



Example

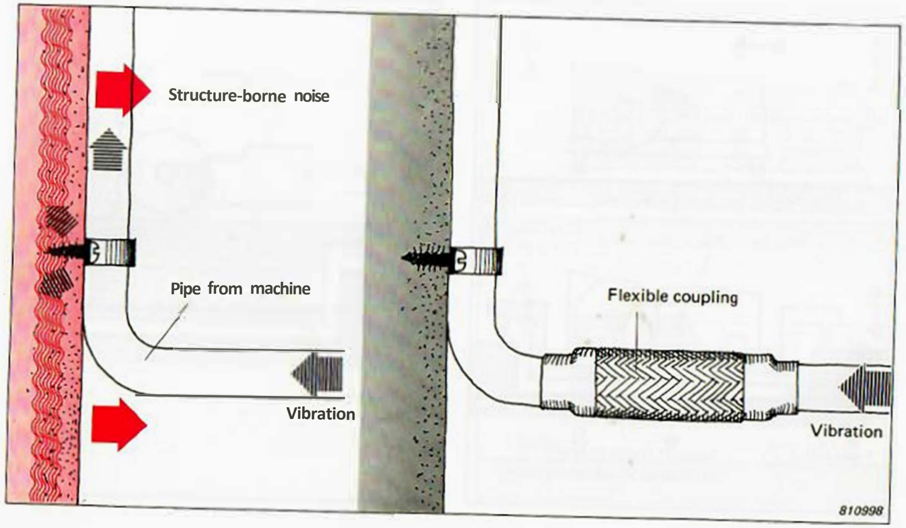
Flexible mounts for vibration isolation can be obtained in a wide variety of types and materials to cope with any load requirement and any practical situation. For mounting heavy machinery, individual springs are used, with or without additional damping; for mounting light structures, pads of cork, expanded polystyrene, foam rubber, or rubber are often employed. Ceilings, ducts, and pipework are normally suspended from spring hangers or artificial rubber straps. Other isolators for special purposes and some individual types are shown in the drawing.



Structure-borne sound via connections must be avoided

The most effective vibration isolation can be made totally ineffective if the vibration is transmitted by connections such as pipes, electrical conduits, supply ducts, etc. These must be flexible or contain flexible sections if vibration transmission is to be avoided.

Principle



I •ample

II, 11i11oration plant can be a serious ,,,1 ., source because of th large ııı.,•,ure changes in the fluid dur- " " ,is passage throu_gh the com- 1111,,,,or unit. Careful v1brat_1on isola- 111111 of the entire plant is nec s- uy and all ingoing and outgoing l"P";..,ork should be iso ated from 11ııı plant by flexible couplings.