BUILDING DIGEST

CENTRAL BUILDING RESEARCH INSTITUTE INDIA

NOISE AND ITS CONTROL

Part II—Industrial noise

Introduction

Noise is produced in almost all industrial operations. A part of the mechanical energy applied in these operations is wasted as heat and a still smaller portion is radiated as noise. Very little power is required to make loud noises and the ear, being a sensitive device, responds to even extremely small sound powers. An aircraft jet engine is a powerful source of noise, yet it produces only a few tens of kilowatts of sound-power compared with the total output of the engine which may be of the order of 100,000 KW. Noise reduction measures in industries should therefore be considered at every stage of manufacture. Sufficient care should be taken in the planning stage, both in the design and installation of noisy machinery, in order to obviate the need for elaborate and expensive corrective measures later on.

Properties of noise

Noise is described as unwanted sound. Sounds produced by machine tools, manufacturing processes and material handling are not intelligible and therefore can be classified as noise. In certain processes, however, the worker follows the job by the ear and times his movements according to the "information-sounds" produced during the process. For him the noise from his machine carries some meaning and is not entirely unwanted. Thus, the distinction between intelligible sound and noise is purely subjective.

For purposes of study of industrial noise the frequency region of interest is generally from 20 to 10,000 c/s. Noises encountered in factories are complex and they are composed of a large number of sounds of different frequencies which often extend over the entire frequency region mentioned above. Such noises are called continuous or wide-band noises.

Measurement of noise

Noise is usually measured and expressed in terms of sound pressure level (SPL). If p is the pressure of a sound wave, then its SPL is expressed in decibels as :

$$\text{SPL}=20 \log_{10} \frac{p}{p_r}\ db$$

where p_r (0.000 2 dyne/sq cm) is the reference pressure and also the lowest sound pressure that an average human ear can perceive. The decibel is a convenient unit to state the SPL and the noise reduction achieved by sound absorbing materials and partitions. Sound pressure level at various frequencies may be represented in the form of a graph between SPL and frequency. This is called a spectrogram. Noise is usually measured in eight octave frequency bands* having widths of 37.5-75, 75-150, 150-300, 300-600, 600-1200, 1200-2400. 2400-4800 and 4800-9600 c/s. The spectrogram gives the distribution of sound energy among the various frequencies comprising the noise. A noise can also be analyzed in half or one-third octave bands in order to obtain greater details of energy distribution. Noise spectra can be obtained with a simple set-up consisting of a sound level meter and an octave band filter set. Alternatively, noise may be recorded on magnetic tape for subsequent analysis in the laboratory.

A sound level meter is employed to measure overall SPL. It is used in environments where noise is steady (i.e. its level does not vary with time), or where the fluctuations in level are not too large. For impact type noise an oscilloscope or an impact noise analyzer is employed to obtain its peak level as well as decay time constant. The latter is the time taken for the peak level of noise to fall 8.7 db from its initial value and is indicative of the damping of the source. Octave band levels of impact noise can be obtained by using a filter set.

Origin and types of Factory noise

Noise produced by machines and processes associated with production and handling of goods are often very intense. In cases where the process itself is quiet, noise from common equipment such as fans, blowers, furnaces, etc., may be quite high. When located close to a residential area, noise due to processes like riveting and forging or from service equipment like compressors and exhaust fans can be a major source of nuisance to the residents. Noise levels in production areas of some major industries are shown in fig. 1. Fig. 2 depicts the noise levels measured at worker's ear during the various operations.

* It is the frequency band between f and 2 f.

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steady or fluctuat-
transient noise may
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quickly dying off, or
ber of impulsive
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s of time.

tinuous and steady
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roduced by (i) ma-
rotating at constant
like motors, com-
s, etc. (ii) reciprocat-
vibrating machines
ake-outs in foundries
ves in coke batching;
i) escaping gases like
t from pneumatic
r hissing noise from
guns. Machines, fans,
sually produce low
middle frequency noi-
rresponding to their
and harmonics, where-
aust gases give rise to
frequency noise with
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sing rapidly with escape velocity.

ntinuous but fluctuating noise is
only found in machine shops
metal fabrication and material
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nother are heard above the steady
ground noise produced by motors,
ces, etc. Steady noise in these
generally consists of low fre-
cy sounds while the superimposed
s often contain middle and high
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operations with a drop forge ham-
or a manually operated hammer
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noise reaches its peak level within
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noise depends to a large extent
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es of the system. Impacts occurr-
in material handling, especially in
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ries, are of a similar nature.
re impacts are quickly repeated, as
example, in riveting and chipping,
successive noise impulses cannot be
rately judged by the ear and the noise appears
be continuous. Such noise is generally found to

FIG 1 – RANGE OF NOISE LEVELS IN WORK AREAS OF SOME MAJOR INDUSTRIES
JUNCTION OF THE TWO SHADED AREAS INDICATES MEAN LEVEL AND THE FIGURES IN BRACKETS GIVE THE LOUDNESS OF THE NOISE IN SONES

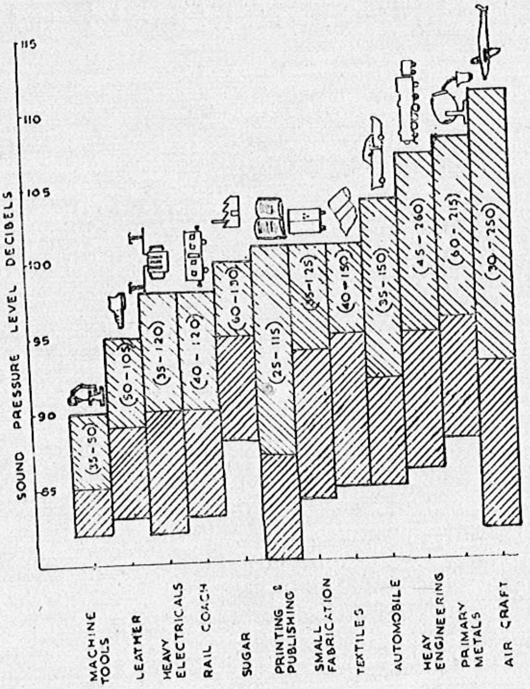
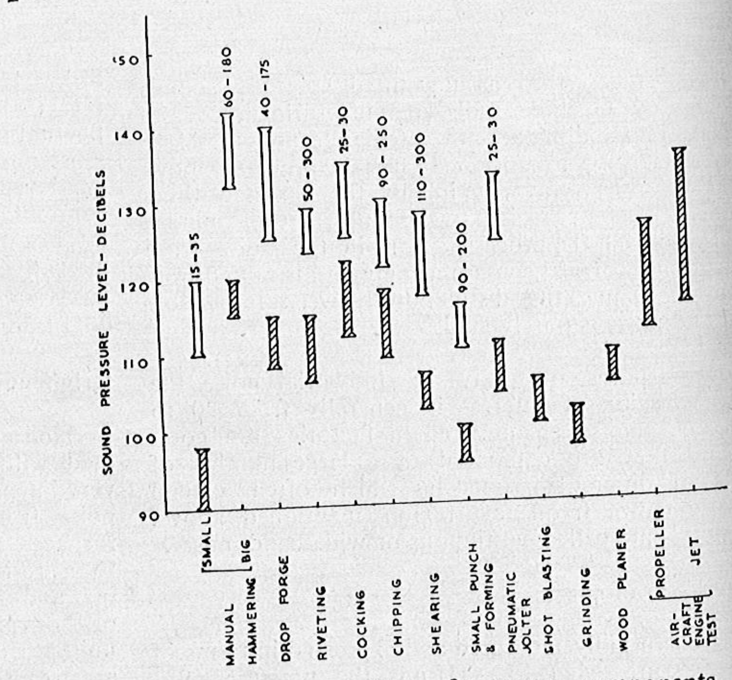


FIG. 2 – NOISE LEVELS IN EXCESSIVELY NOISY INDUSTRIAL PROCESSES

RANGE OF PEAK LEVELS OF IMPACT NOISES WITH THEIR DECAY TIME CONSTANTS (IN MILLISECONDS) INDICATED AT THE TOP.

NOISE LEVELS AS INDICATED BY A SOUND LEVEL METER.



contain strong high frequency components. Also, impact noises, whether single or multiple, occurring in industry are usually of very high levels.

In addition to the primary sources of noise discussed above there can be secondary sources not directly related to the work processes. For example, vibrations of a motor compressor might be carried along cooling water pipes to other parts of the system causing them to emit sound, or the impact from a drop forge hammer may be transmitted without much attenuation along the factory floor to distant parts of the building throwing windows or a loosely fitted tin roof into vibration.

Subjective and harmful effects of noise

Excessive noise is harmful to the factory workers in four ways. It may cause, directly or indirectly, (a) annoyance; (b) lowering of efficiency; (c) interference with speech communication; (d) permanent damage to hearing.

Annoyance is purely subjective and is related to loudness which cannot be measured directly with any instrument. Loudness of a noise is a function of level and frequency composition. The degree of annoyance depends on the nature of the noise, whether steady, fluctuating or intermittent. High frequency noise from a wood planer is more annoying than the same level of low frequency noise from a large air compressor. Similarly, impulsive noise produced by a rotary shear cutting rails is much more irritating than equally loud continous noise in the spinning section of a textile mill. The unit of loudness is the sone (one sone being defined as the loudness of a 1,000 c/s pure tone having a SPL of 40 db). The loudness scale is linear, that is, a noise having a loudness of 60 sones will sound twice as loud as another of 30 sones.

Excessive noise (of the order of 90 db and above) is generally found to undermine the efficiency of the worker resulting in a decrease in his work output. This is especially so in jobs that call for mental concentration or constant vigilance. Although no definite relationship has yet been established between the level of a noise and the resultant fall in efficiency, it is believed that the level should be kept below 90 db to minimize this effect.

High frequency noise will cause interference with speech communication. The Speech Interference Level (SIL) barely permitting intelligible communication at a distance of 3 feet is 55 db (see Building Digest No. 32 "The problem of community noise"). It is very rarely that such low SILs are found in industrial work areas. In fact, in some production areas (as weaving in textile mills) speech communication is virtually impossible at any distance or at any voice level. In environments where the SIL exceeds 70 db, reliable conversation is barely possible in raised voice even at 1 ft. and noise reduction measures are necessary to bring down the SIL. Where instructions to workers are given through a public address system, column loudspeakers instead of single speakers should be used because of their better directivity and clarity of reinforced speech.

Prolonged exposure to very high noise levels may result in permanent and incurable hearing loss and lead to what is known as industrial deafness. Even brief exposure to noise levels of 90 to 95 db is known to cause temporary loss of hearing which may persist from a few minutes to even weeks. For example, working close to a pneumatic drill often has this effect. It is now generally agreed that where an octave band level of continuous steady noise between frequencies 150-9600 c/s exceeds 85 db, the risk of damage to hearing exists. Slightly higher levels are permissible for frequencies lower than 150 c/s. This applies to workers exposed to continuous noise for 8 hours a day. However, the International Standards Organisation has recently proposed a criterion designated by Noise Rating Numbers-85. This rating allows the following octave band levels for a five hour, five day week :

Octave-band midfrequency (c/s)	63	125	250	500	1000	2000	4000	8000
Sound Pressure Level (db)	102.6	95.9	91.0	87.0	85.0	82.8	80.6	79.5

For every 3 db increase in the band levels above these values, the exposure of the worker to noise should be halved. Also, if the noise contains a prominent pure tone (such as the whine from a circular saw), the critical levels are reduced by 10 db.

The above criteria are applicable for continuous and steady noise. No criteria for intermittent and impact noise have yet been laid down. In any case, no worker should be exposed to very high impact sounds without suitable hearing protection as it may result in permanent injury to the ear. Exposure to sounds of 135 db and above even for a few seconds has been known to cause instantaneous rupture of the ear drum.

Methods of noise reduction

The level of ambient noise in a factory area can be reduced by any one or a combination of the following procedures :

(i) Reduction of noise at source
(ii) Enclosing the source of noise
(iii) Use of sound absorbing material

Reducing noise at or near the source is obviously the most effective and often the least expensive method of noise control. Where a job may be done by a number of different processes, the choice should be on the least noisy one. For example, riveting can be replaced by welding, while shaping can be done by pressing instead of hammering. From among the available machine tools of similar performance but different manufacture, only the least noisy should be used. Since the level of noise produced by a source is directly proportional to its amplitude of vibration, sizeable reduction in noise can be effected by using the minimum power necessary to drive the source. Noise from machinery with rotating parts can be reduced by dynamic balancing and, if permissible, a reduction of speed. In work processes involving vibrating or reciprocating movement, the amplitude of vibration should be kept to the minimum practicable.

Frictional noise from rotating machinery and mobile units like trollies and overhead cranes can be minimized by proper lubrication. Noise in cutting operations is reduced by keeping the tools sharp.

Noise due to turbulence from air and steam exhausts can be minimized by providing mufflers immediately after the exhaust or by leading the exhaust gases through pipes or ducts to a distant silencer. Pipes carrying gases at high pressure should have as few bends and internal protrusions as possible. Any acoustical meterial used for lining ducts to cut down noise must be able to withstand the high temperatures and gas velocities involved. Where a jet of air is used for cleaning or other purposes, its pressure should be kept at the minimum necessary.

Reduction of structure-borne noise and vibration can be achieved by interrupting the rigid path between the source and other parts of the structure by resilient materials like felt, glass wool or rubber or shock absorbing devices like steel springs or other proprietary mountings. The higher the ratio of the driving frequency of the source to the natural frequency of the resiliently supported system, the greater will be the reduction of transmitted vibration. A ratio of 3:1 has been found to be satisfactory in most cases.

Low frequency noise and its transmission to other areas in multistoreyed factories can be reduced by anti-vibration devices. The machine may also be mounted on a heavy concrete base floating on resilient mounts and isolated from the rest of the floor by a cork-or loose sand-filled gap around the perimeter. It is important that the resilient material used is not loaded beyond its elastic limit. Service equipment can also be vibration-isolated in a similar way by providing loose flexible connections or bends in pipes and conduits as near the source as possible.

In most cases the best way to control noise is to completely enclose the source by a highly insulating (50 db or more) structure. The dimensions of the enclosure will depend on the size of the source, work process involved and material handling requirements, etc. An ordinary masonry partition, e.g., a 9-inch brick or 4-inch dense concrete wall (Appendix A. Building Digest 32) will suffice in most cases. In choosing a partition for an enclosure its average sound transmission loss, which is the average insulation in the frequency range 125-4000 c/s, should be taken as the guide (Building Digest No. 32). For special noise problems, where there is a prominent pure tone, as in the noise from a power transformer, or where it is confined to a narrow band of frequencies only, specifications of the enclosure will be governed largely by the frequency to be suppressed. A double-wall enclosure with a cavity of 2 to 3 inches is often found to be more effective, especially for high frequency noise, as compared to a single partition of same total surface weight. Acoustical absorbers are poor sound insulators and hence should be used only for lining the inside of the enclosure to increase its efficiency. All joints should be carefully sealed to avoid direct air leakage paths. Ventilation and service ducts should also be acoustically treated to prevent transmission of noise. Instead of enclosing the whole machine, sometimes covering its noisy part only with steel plate has been found to be sufficient. Fig. 3 illustrates a typical example of noise reduction using the various measures described above.

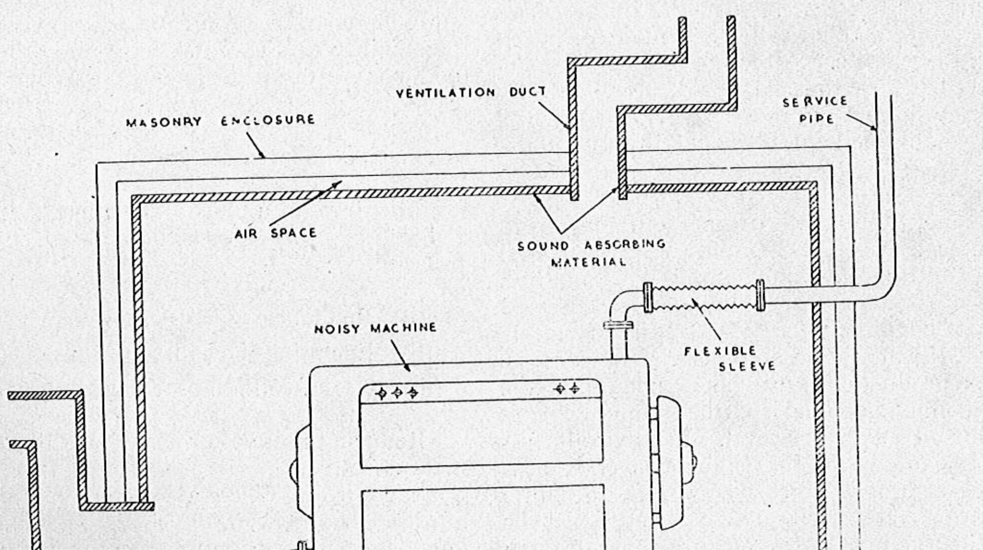


FIG. 3. TYPICAL MEASURES ADOPTED FOR REDUCING AIR-BORNE AND STRUCTURE-BORNE NOISE FORM A SOURCE

Where it is not possible to completely enclose a machine, partial enclosures and non-porous barriers lined with sound insulating material on the noisy side can be used. Such enclosures are usually in the form of tunnels, composite screens, boxes open on one side or more, depending on the noise source. Average noise reduction obtained in this manner is about 20 db, and more at high frequencies. Openings in such barriers should face acoustically treated walls, ceilings or screens.

Noise in highly reverberent areas (e.g. weaving or steel rolling) can be controlled by the use of absorbing material applied to the walls and ceiling of the building (Building Digest No. 32) or by employing functional absorbers. Porous materials can be used for absorption of middle and high frequency sounds. For low frequency noise better absorption is provided by panels of thin sheet material mounted over an airspace. Use of absorbers, however, will not affect the direct sound radiated from the source. Functional absorbers are most effective in shops where machines are closely spaced. The above treatment may also be used for impact noises to cut down the general clangour in the area.

Protective devices

The above measures may not provide the required safety to the worker exposed to high direct noise levels, as in the case of riveting and forging. There it becomes necessary to protect his ears with ear-plugs (insert type) or ear-muffs which can provide average attenuation of the order of 40-50 db. For extremely intense noise (120 db or above), a combination of both is recommended.

Office areas in industrial workshops

Small industrial units generally have offices located in the same building as the factory, which results in noise from the production area reaching the offices through common walls and floor. Offices should be located in a separate building and as far away from the noisy areas as possible. Where it cannot be avoided, the common wall should be heavy and impervious, and should have no doors, ventilators or permanent openings.

Rooms and cabins used by supervisory staff adjacent to work areas should also have highly insulating walls and doors. Double glazed windows with leaves of heavy glass should be employed (see Appendix B. B.D. 32).

There is a demand for short notes summarising available information on selected building topics for the use of Engineers and Architects in India. To meet the need this Institute is bringing out a series of Building Digests from time to time and the present one is the 33rd in the series.

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