INVESTIGATION OF NOISE AND STUDY OF THE RELEVANT ARCHITECTURAL ASPECTS IN SOME SELECTED INDUSTRIES IN BANGLADESH.

BY

NIZAMUDDIN AHMED

MASTER OF ARCHITECTURE

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY

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THESIS

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Nizamuddin ahmed

Approved as to style and content by:

Chairman of the Committee
& Head, Deptt. of Architecture

Member

Member

Member

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THESIS

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by

NIZAMUDDIN AHMED

Department of Architecture
Bangladesh University of Engineering and Technlogy, Dhaka.

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ABSTRACT

The study on the Thesis subject matter was initiated because it was assumed that serious noise problem exists in industries of Bangladesh and that the matter required scientific investigation to be followed up by formulation of architectural measures, among others to tackle the assume problem.

The present study and investigation involved the following areas of concern in connection with the industrial noise scene in Bangladesh:

i Review of the effects of noise on man in general and on industrial workers in particular.

ii Review of the theories and practices of noise control in the industries.

iii Review of the laws, regulations and codes of practices for industrial noise control prevailingin different countries.

iv Case studies of some selected industries in Dhaka involving measurements of dBA levels in a systematic manner covering the work areas in them and comparing these values with internationally recommended levels.

v Recording the noise of a selected industry on a Tape Recorder and subsequently analysing the recorded material in the laboratory with the help of a Frequency Analyzer.

vi Formulations of options for noise control measures from an architectural point of view in the industries of Bangladesh on a broad and general basis with particular emphasis on the use of local materials and construction techniques.

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1:1 NOISE IN THE ENVIRONMENT AND ITS EFFECTS ON MAN

Man is constantly engulfed in the field of sound. From the day of his birth till his death, man is continuously exposed to an array of sound sensations. Many hours of joy, moments of anxiety, periods of annoyance and displeasure are caused by sound. In fact, sound is so common an everyday affair that we take its presence as inevitable, its effect on us as obvious and its performance as guaranteed.

Man in constantly aware of the sonic environment surrounding him. Some of the sounds are useful (Speech, music, etc.) while some are disturbing and still others which are harmful (traffic noise, noise from machinery, etc.).

Exactly what is noise ? Several dictioneries will define noise as "any sound" but we know better. Almost from childhood, a man is able to distinguish between those sounds he readily accepts and others which are irritating, disturbing, annoying. The latter are called noise. Physicists describe noise as a collection of chaotic sound which we perceive through our organ of hearing(ear). Littre defines noise as a "confused mixture of sound". According to Bruel & Kjaer, noise are sounds which are unwanted and unpleasant. Many acousticians like to refer to noise as "meaningless sound". The ILO definition lays emphasis on the health hazards of the noise environment. The ILO Code of Practice for protection of workers against noise in the working environment states that "noise" covers all sound which can result in the hearing impairment or be harmful to health or otherwise dangerous. Noise is also any disagreeable sound. Noise has also been defined as a class of sounds, generally of a random nature, which do not maintain integral mathematical multiple relationship between its frequency components.

Not all noises are harmful to man. The very fact that it is often defined as "unwanted sound" establishes its subjective quality. The desirable high level sound of a "pop" band to a youngster may be intolerable and, therefore, noisy to another whose interests are centred around the softer compositions of the Masters. Creaking of a door is by all means noise but not harmful to the body except the mental annoyance that it creates. High level sounds, desirable or undesirable, are harmful to the body as a number of autonomic functions begin to take effect as sound reaches above 70 dB. Workers in noisy factories are almost always exposed to sound above this level.

Researchers have termed as noise those sounds which are interfering, inappropriate, intermittant, unfamiliar, meaningless and of course, loud. A man reading a newspaper may not find the noise of a train disturbing or annoying but the same noise will definitely interfere with the speech of a person who is trying to converse. The crackling sound of chocolate wrappers in a cinema hall and the whispered coversation in a quiet environment are all very distracting because of their inappropriateness and are termed as noise although the levels of these sounds are very minimal. People are bothered by intermittant sound because they do not know when the sound will strike again and thereby, he can neither adjust to it nor ignore it. The noise of the thunder on a cloudy day is thus bothersome. Sound heard for the first time may appear to be noise-like. There are examples of many musical classics which were rejected and booed by the public during their premier expositions. Thus, one may conclude that people are upset by unfamiliar sounds and they appear to be noises. Songs in a foreign language appear to be noises because of their unfamiliarity. It is only too well known that electronic music often exudes similar response. Meaningless sound can be very irritating and dictioneries often define noise as "a class of sounds which do not exhibit clearly defined frequency components".

Undesired sound such as a singing television commercial appear to be noisy to many although the frequencies in it are well defined. "Sound that does not have a stable and well-defined pattern of frequency or rhythm, and parsists for more than a short period of time, is disturbing to most people because of its apparent senselessness.".

The above examples exhibit the psychological effects of sound on the human mind. Most of their effects depend on the situations under which they are heard. But, there are some sounds which are disturbing in themselves under any circumstances. The scratching of the fingernails on a blackboard falls in this class. High-pitched tones tend to be more irritating as the ear is more sensitive to them.

Loudness of a sound forms the largest singular factor why a particular sound should be termed as noise. Almost anybody will say that sound above a certain level is noisy and thereby disturbing. In a survey of reactions to airoplane noise, only 37% of the subjects interviewed reported annoyance when the sound level was 60 decibels. However, when the intensity of the noise was increased hundredfold to 79 decibels, 88% of the same subjects reported irritation. (1) Undoubtedly, all the subjects would respond positively to being irritated if the aeroplanec noise was increased still further.

Man can be annoyed by sounds of any level depending largely on his preparedness. According to the Conservation Foundation (USA), Man's Threshold of Annoyance is from 50 - 90 dB. It is alarming to note by what amount of annoying noises we are surrounded when we measure the sound levels of a noisy sports car or truck (90 dB), a land power mower (107 dB), a riveter (130 dB), a jet plane on take-off (150 dB), a typewriter (65 dB), an electric kettle (80 dB), etc.(2) However, perception and response are affected not only by the

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(1) Sound and Hearing, LIFE Science Library by Stevens, Warshofsky, Editors of LIFE

(2) Article in Readers Digest, March 1970 by James Steuart Gordon, page 113.

loudness, picth and duration of the sounds, but also by the hearer's own physical and mental condition.

Dr. Gerd Jansen (1) in 1960, then with the Max Planck Institute, Dortmund, West Germany, after testing 665 workers working in the noisiest conditions and 340 in quiet jobs, descovered that the body's autonomic nervous system beings to react at 70 dB (equivalent to the sound of a vacum cleaner or of traffic on a relatively quiet city street). The nervous system regulates such involuntary responses as heartbeat, temperature, digestion and respiration. At around 70 dB level of sound, the diastolic blood pressure is raised and the heart receives a rationed supply of blood because the arteries are constricted. As sound level increases, the situation worsens with more serious effects taking place such as the dilation of the pupils, drying of the mouth and tongue, loss of skin colour, contraction of the muscles of leg, abdomen and chest, sudden excessive production of adrenaline, stoppage of the flow of gastric juices and excitation of the heart. The above-mentioned effects are automatic, unaffected by the subject's health, annoyance or his familiarity with noise on the job.

Dr. Jansen and Dr. Gunther Lehmen,(2) among others, used electrocardiographs and electroencephalographs to demonstrate that bursts of sounds - as low as 55 dB and not loud enough to wake the sleeper - are recorded by the brain. And, to make matters worse, the autonomic nervous system reacts on the sleeper just as it does when the subject is awake. Our body is designed to adapt with time to most environmental changes but it shows no sign of any ability to become used to noise either while the hearer is awake or sleeping.

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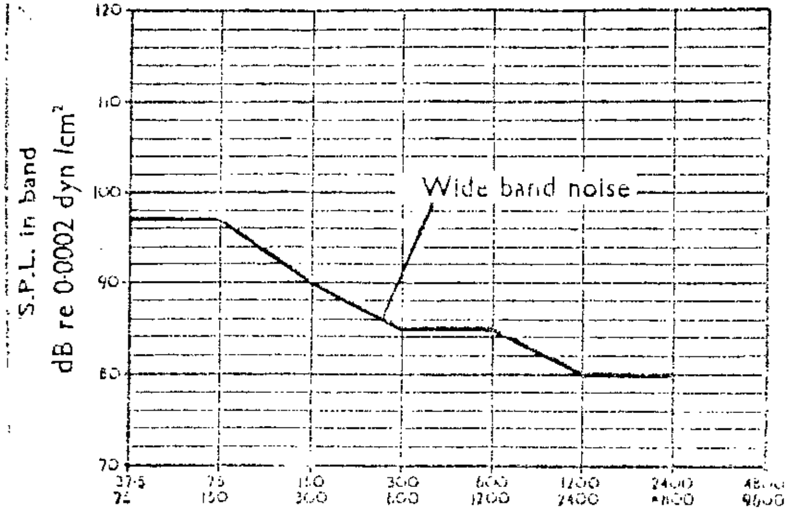
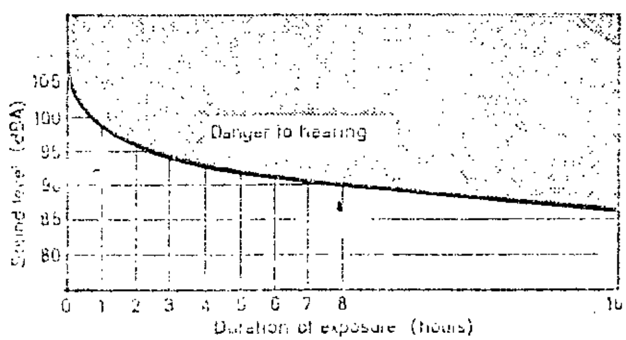
(1) Dr. Gerd Jansen was with the Max Planck Institute, Dortmund, West Germnay

(2) Article in Readers' Digest, March 1970 by James Steward Gordon, page 113



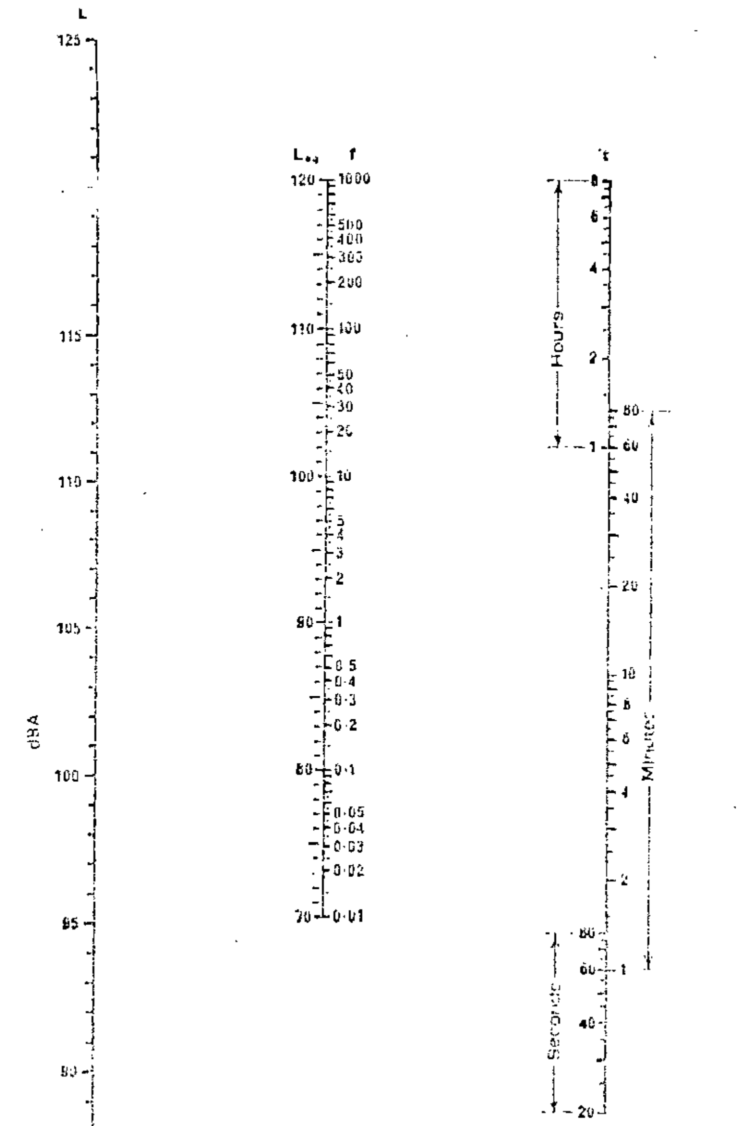
Tentative Deafness Risk Criterion

FIGURE 1



A proposal for noise exposure limits to avoid hearing damage

FIGURE 2



Nomogram for calculation of L_{eq}

For each exposure connect sound level dBA with exposure duration t and read fractional exposure f on centre scale.

Add together values of f received during one day to obtain total value of f. Read L_{eq} opposite total f.

Example. 95 dBA for 1 hour $f = 0.5$
85 dBA for 7 hours $f \simeq 0.3$
Total $f \simeq 0.8$ $\therefore L_{eq} \simeq 89$ dBA

FIGURE 3

Immediate damage to hearing can be caused by a noise of 150 dB. According to Burns, (1) Risk of Deafness in sound pressure level varies with frequency. At lower frequencies, it is possible to withstand louder noises with the same risk of deafness as at higher frequencies with lower sound levels. Burns has given minimum spl values, in specific frequency bands, which should not be exceeded if permanent deafness is to be avoided. The values only apply to broad band, steady noise, to which persons are exposed for the whole working day, five days a week. See figure 01.

The sound pressure level may be exceeded if the exposure duration is reduced. It is also probable that the minimum levels shown in the figure may be reduced further if the noise is not more or less continuous, but instead contains one or more strong discrete frequencies.

According to many, noise loud enough to cause immediate damage to hearing will hardly occur in buildings. However, prolonged exposure to loud noises can cause damage as is the cases in factories, plant rooms and discotheques. It is usually suggested that a worker should be exposed to a maximum of 90dBA (2) for not more than eight hours per working day. If the duration of exposure is reduced, a higher noise level is permissible. For each halving of exposure-time, an additional 3 dB is permissible. See figure 02.

Many of the noises likely to cause damage are not continuous. For example, machinery in a factory may be put on and off several times during the working. To rate this situation, Leq with a target max. of 90 dBA for an eight-hours day can be used. Leq is calculated (from Figure 03) after summing the periods when the machinery is on.

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(1) Accoustics Noise and Buildings by Parkin and Humphreys

(2) According to International Standards Organisation and Occupational Safety & Health Administration.

Leq is the A-weighted energy mean of the noise level averaged over the measurement period. It can be considered as the continuous noise which would have the same total A-weighted acoustical energy as the real fluctuating noise measured over the same period of time.

Leq is given by $10 \log_{10} \frac{1}{T} \left(\frac{P_A(t)}{P_o} \right)^2 dt$

where T = total measurement time

$P_A(t)$ = A-weighted instantaneous acoustic pressure.

P_o = reference acoustic pressure (20 P_a)

Loud sounds, besides being potentialy dangerous as a cause of damage of hearing, have other physical effects. Sounds of 140 decibels (military jet at take-off) produce a number of unpleasant bodily sensations: a feeling of vibration inside the head, sever pain in the middle ear, loss of equilibrium, nausea. Sudden sounds at a much lower level (the sound of a firecracker) produce a startle reaction i.e. the body's complex response to an emergency. The blood pressure and the pulse-rate acoelerate, the muscles contract, perspiration increases, the flow of saliva and gastric juices is drastically reduced, digestion ceases. However, on repeated exposures, these responses tend to wear off.

Noise produces many physical and psychological reactions that have nothing to do with hearing. The most familiar of these is the so-called startle reaction caused by a sudden, unexpected noise. The head jerks forward, the face tightens into a grimace, the heartbest quickens, breath comes in short intervals, gasps, the blood sugar increases and the muscles tense from head to knees in a reaction that lasts less than a second. There is more to it. Continuous exposure to any steady, moderately loud noise containing a broad range of frequencies (such as radio static) tends to constrict the blood vessels of the skin and may effect vision. There are also indications that steady noise upsets the body's metabolism by increasing adrenal-gland activity.

The world is having to pay for the rapid progress it made during the last few decades. No doubt it is a far healthier and happier place to live in than it was a mere 50 years ago but along with the happiness and comfort came pollution of water and the air, the hazards of nuclear explosion and, of course, noise. Un-wanted sound or noise in the everyday life is relatively harmless but deeply disturbing. The noise in the industries are usually of such high levels that not only are they disturbing but they are also harmful to the workers. The situation is so alarming that modern man is bound to do something about this harmful by-product of his technology. Noise everywhere is a growing national health problem. Most of the developing nations including Bangladesh are yet to grasp its reality. Steps taken by developed countries to stop the noise-nuisance include setting up of realistic health standards that are enforceable by laws and codes. This also means redesigning the noisy machinery and equipment, which will mean additional cost. But, "public health is above any economic consideration". (1) The sooner we realise this, hope for the lot of mankind will be that much sooner.

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(1) Law in the industrial city of Dortmund, West Germany.

1:2 NOISE IN THE INDUSTRIES AND ITS EFFECTS ON INDUSTRIAL WORKERS.

Industrial workers in any country perhaps form the largest single group which is exposed to the hazards of high levels of sound or noise. The problem is of grave nature in the developed nations where life is greatly mechanised, industries are many in number, large in size and noisy in character. In a developing country like Bangladesh the nature of the problem may not be as serious as that in the industrially - advanced nations. However, in the handful of industries that we have and for the few thousand workers who toil in them, noise is of sufficient high level to merit attention from architects, engineers and other professionals concerned with Industrial architecture.

In the industrially developed nations, more and more factory owners are becoming aware of the effects of harmful noise and are taking measures to protect their workers with insulated booths, earplugs, ear muffs, etc. This is positively different from the situation in Bangladesh where, most unfortunately, even the workers are not aware about the risk of damage to hearing loss that theytake each day they go to work. The aim of the steps adopted by the factories in the developed nations is to preserve the hearing of workers exposed to high level on-the-job noise. It is alarming to know that 60% of such workers will be hard of hearing by age 65. Protective measures do a whole lot of good. The ear muffs ruduce the noise reaching the ear by as much as 20dB.

The noise problem in the industries is three-fold:

a requirement to ensure reasonable condition for the individual worker who is making the noise either manually or by his machine.

b protection of other workers either within the immediate vicinity of the noise source or at some distance and possibly in some other room.

c protection of the surrounding properly from the noise created in the factory.

Protection of workers from general noise, not necessarily of their own making can be tackled in two ways.

a General introduction of sound-absorbant materials can nearly always bring about small but significant reductions in the overall sound levels.

b Intruduction of partial or complete screening either of the man who needs quiet or of the machine making the noise. The latter is more effective.

Different types of industries are characterized generally by different average noise levels. It is possible to categorize the industries in general in relation to the average noise levels in which their workers carry out work. Such a categorization has been done here as follows :

a Work carried out in noise below 85 dB:(1) Knitting and sewing workshops; paper, biscuit and chocolate factories; printing and ceramic industries; typing offices; urban transport vehicles, etc.

b Work carried out in noise of 85-100 dB: lathes, milling machines and other mechanical workshops; looms in textile factories; workshops using compressed air apparatus; electric drills; mechanical saws,etc.

c Work carried out in noise of 100-115 dB: Servicing large machine tools; in boiler rooms; in tinplate workshops; forges, crushing mills, rolling mills, workshops manufacturing nails; certain types of pneumatic drills, etc.

d Work carried out in noise of 115-130 dB: Heavy pneumatic drills; hydraulic presses; aircraft engines with pistons and small turbo motors; large compressors; large diesel engines; turbines; transatlantic liners" sirens,etc.

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(1) Noise and Vibration in the Working Environment:ILO

e Work carried out close to the source of noise of 130-160 dB: In the vicinity of large aircraft turbo-engines; gun explosions; running jet engines, etc.

During the launching of Saturn V rockets and also during explosions of an atom bomb the noise exceeds 160-174 dB.
It is possible to generalize the problems for at least particular types of industries. For instance, that high levels of sound (exceeding 90 dB(A) for 8-hour exposure) are injurious to one's body and that it induces auditive and extra-auditive diseases is true for any worker in any industry. But, solutions to these problems can hardly be generalized. Each industry has its own set of machinery; the set-up is different; the size, shape and form of the space is different and even materials and methods of construction is different from one another. And, all these play a significant role in the formulation of a noise control procedure. Thus, each industry has to be tackled individually; the analysis of the noise scene being carried out to the necessary details.

Industries will continue to be noisy as it is very much unlikely that the manufacturers will be able to produce "silent" machines. The effect that such noisy industrial environment has on the industrial workers will be universal. The search for noise control possibilities by different means and methods should continue unabated until a "quiet" working environment can be ensured for each worker everywhere.

1:3 INDUSTRIES IN BANGLADESH AND THE PROBLEM OF NOISE

Hardly any humanitarian thought is given towards the improvement of working conditions albeit the lot of the workers. As elsewhere, industrial workers in Bangladesh form the largest single group which is exposed to the hazards of noise. The situation here is doubly alarming because workers in Bangladesh as in most developing countries are totally unaware, unlike their counterparts in developed nations, of the dangers of working continuously in a noisy environment. And so, unknowingly and innocently, workers in Bangladesh continue to be exposed to harmful levels of noise. The owners of industries and the management here cannot be charged of intentionally maltreating their employees by way of exposing them to the harmful noise because they are no more aware about noise and its effects than the humble worker. No government regulations exist; the ILO Code of Practice is not practised anywhere in Bangladesh. The few in the high echelon of power who, from visits abroad or from ILO publications, are in a position to assess that our workers are being exposed to the dangers of harmful noise levels choose to remain silent: quite an irony despite all the noise.

The body's autonomic functions began to react adversely in presence of sound (or noise) levels above 70 dB(A). Most industries in Bangladesh contribute to a background noise of 60-65 dB(A) outside the four walls of the factory proper. The situation inside can well be imagined. Sound, unlike heat and cold or several other sensations, does not get adapted with time and acts on the human body irrespective of race, sex or age. Obviously, aged people are more susceptible to noise-induced diseases. Thus, a Bangladeshi workers would be as much in danger of all the noise-induced physiological and psychological effects on his body as his counterpart anywhere else in the world. If it is noise and its relation to man, the effect would be same everywhere. And so, if the workers in the developed nations need protection from noise, so do our men in Tongi and Khalishpur.

Bangladesh is not an industrially based nation. We have from time immemorial laid more stress on agriculture. However, the number of industries is increasing annually.(1) There are several industrial townships in the country namely Tongi, Khalishpur, Narayanganj, etc. Besides, we have innumerous small-scale workshops in most district towns and a sizeable number of workers in this sector are often exposed to very high levels of impact noise, if not steady level of harmful noise.

A general survey would be enough to convince one that noise levels in amany industries in Bangladesh are above acceptable standards with respect to the laws in force in the developed nations. In Bangladesh, there are no laws, regulations or Codes of practice pertaining to the level of allowable noise in the industries. The present situation is that everything is allowed. But, then none is aware of the havoc that noise is actually playing. It is also with this noble intention that study in this field has been undertaken to open the eyes of the workers, owners, government officials, trade unionists, etc. that our workers need to be protected from the hazards of high-level noise in our industries.

A poor nation like Bangladesh need not shy away from attempting to protect its workers from the bad effects of noise on the pretext of its economic difficulties because such an effort may not be expensive. Low-cost noise control systems are in vogue in many countries and there are some systems which can also reduce operating costs. For example, Job rotation can be practised with several workers sharing the work-load in a noisy area one by one

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(1) Statistical Year Book, Bangladesh Bureau of Statistics.

as the rest keep on working in quieter zones for rest of the day. Reducing air pressure to required level from the unnecessary high level also help to drop noise levels. This would also save energy which means that noise control by this method would also reduce operating costs. Tightening loose parts in machines, replacing ineffective vibration isolation mounts, etc. can also reduce noise and they are not at all expensive. Furthermore in the context of the prevailing situation in our country, the planning, design and construction of the industrial buildings can be improved considerably without extra-ordinary increase of cost. Thus, it is not necessary for us to accept noise in all its might just because of the apprehension that controlling it would mean extra-large expenditures. There is a good possibility that our engineers, architects, industrial managers and even the workers could study the prospects and come up with methods and means that would just suit our purpose.

Lack of awareness in this regard is at its extreme. Industries in Bangladesh do not have any record of the noise level in their workplaces. Workers never attribute any of their physiological or psychological disorders to noise. Medical officers in our industries do not have any record pertaining to the effect of noise on the workers. The total subject matter is in the dark.

Many of our industries exceed the 100 dB(A) mark. And, therefore, there is bound to be all the effects that is inherent in this high-level noise-human being relationship. But, none of us seem to care. Architects and engineers attend to such details as rainwater, sunlight, windflow, etc. but ignore, out of sheer ignorance, the equally important factor of noise while designing industries. Once the industry has gone into operation, the workers without knowing anything about it grow to accept the situation with all its decibels. The management is not bothered because the workers are not bothering them. And, so the bad effects of noise continue to take its toll silently.

The Environment Pollution Control Board formed in April, 1977 (1) "to provide for the control, prevention and abatement of pollution of the environment of Bangladesh" has thus far failed to undertake any study regarding industrial noise and its effect on our workers. The question of promulgation of any law or code of practice does not arise in the context of their inactivity in this field. The Board should by all means be the pioneer in assessing the noise climate in the industries, appraise the workers and all concerned about the bad effects of high level noise, initiate laws and code of practice and see that these are enforced strictly in our factories. The Board should also standardize the maximum level of allowable noise for various working time-periods in concurrence with the ILO. The ignorance of the Environment Pollution Control Board about the matter speaks volumes about the importance meted out to industrial noise in Bangladesh.

Perhaps a detailed survey of the workers would show that many of them in Bangladesh are suffering from the effects of noise. Audiometric tests would reveal that many have incurred noise-induced hearing loss and other associated diseases. But, it can be said with conviction that if the levels of noise exceed 90dB(A) for eight-hour shifts, there are bound to be many ill-effects, the extent of which would be revelead through a detailed survey of the workers and the working conditions in our industries.

The effects of industrial noise and noise in general on man has already been discussed elaborately. The noise from our industries would have the same effects on our workers. It is time for us to take up the matter seriously. The possible bad effects of high-level industrial noise must be explained to the workers and all others

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(1) The Bangladesh Gazette, April 6, 1977.

concerned. Steps must be taken to assess the extent of damage already having taken place. Measures must be taken to reduce the noise-level in our industries. Workers must be provided with adequate protection. Care must be taken during design-stage to consider noise as a factor of design. Workers must be provided with regular medical supervision by professionals. The total awareness must grow.

1:4 AIMS, OBJECTIVES AND SCOPE OF THE PROBLEM UNDER INVESTIGATION

The broad objective of the study is to collect information by noise measurements in a systematic and adequate manner in order to understand the prevailing Industrial Noise scene and formulate measures for Industrial Noise Control and for Hearing Conservation Programms so as to protect workers from permanent hearing loss in the audible frequency range due to exposure to high noise levels.

More specifically, the objectives may be enumerated as follows :

1 Measurement of Environmental Noise Level in dB(A) at work stations throughout the industry.

2 Measurement of Environmental Noise Level in Octave Bands at work stations throughout the Industry.

3 Determining the time-varying noise exposure for workers.

4 Preparation of an objective and useful picture of the prevailing industrial noise scene.

5 Formulation of Noise Control and Hearing Conservation Programmes with emphasis on architectural solutions.

Ordinarily sound pressure level (SPL) is measured and expressed in 'decibels' (dB) i.e. one-tength of a 'bel'. 1dB is such a level at which the sound is barely audible to human ear in a quite surrounding. 'Decibel' is logerithmic rather than a simple arithmatic quantity. Consequently an increase of 3 dB registers doubling of the sound level. The dB-scale, however, does not take into account the varying sensitivity of the ear to sounds of different frequencies. To compensate for this deficiency, quick noise measurements without frequency analysis may employ weighting networks (A,B,C or D) which approximates the frequency response of the human ear. The A-network approximates the frequency response of the ear at low SPLs, the B-network at medium SPL_s and the C-network at high SPL_s. However, now a days, only the A-network is widely used, the measurement being expressed as dBA because the B and C networks do not give good correlation to subjective tests. The D-network has recently been standardized for aircraft noise measurements.

A sound is rarely a pure tone i.e. consisting of a single frequency only. Most common sounds consist of a number of frequencies lying within the audible range. The sensitivity of the human ear to sound is frequency dependent, the ear is more sensitive at the middle frequencies (2 KH_z to 5 KH_z) than it is at the lower and higher frequencies. Also sound absorption by the fabric of the built form is frequency dependent — different materials absorbing different amounts of sound at different frequencies. Therefore, the description of a sound by its sound level (dB) only will be incomplete without a description of its frequency content.

For a complete description of the sound, a frequency spectrum graph would be necessary which would show the sound level (in dB) for every octave band or third octave band measured seperately. The Octave scale is a scale used in music. The interval of an octave — the most perfect consonance in music — is produced when the 'higher' of the two sounds contains double the number of vibrations of the lower sound. Thus an octave difference between two sounds means doubling of the frequency. The range of all frequencies within an octave is referred to as the 'octave band'.

When measuring a sound, a 'band-pass filter' may be used in conjunction with the sound level meter, atmitting only one octave band at a time. With successive measurements the full spectrum can be builtup by plotting the sound level measured in each octave band in a chart called a 'Spectogram'. Third Octave band refers to a frequency band which is one-third of an octave wide. $\frac{1}{3}$ Octave band analysis in noise measurement is meant to correspond well to the way in which the ear itself actually works.

Most workers do not remain at a fixed station of work throughout the work period and many others are exposed to cyclical noise at their work station. This results in a situation whereby the said types of workers experience time-varying noise exposure(1). In other words, these said workers do not experience the same noise level throughout the entire work period.

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(1) Industrial Noise Control and Hearing Testing Bruel & Kjaer.

OSHA (1) limits the maximum exposure time per day. e.g. 8 hours at 90 dB(A). If a worker works for 8 hours a day, a 90 dB(A) environment represents 100% noise dose. According to Noise Codes, the partial exposures that such workers receive through out their work period are summed up. Let us consider the following example: A worker performs half of his work in a 88dB(A) environment and the other half in a 92 dB(A) environment. Since full work periods at 88 and 92 dB(A) represents exposure of 60 and 160% respectively, half periods exposures are 30 and 80% for a total period of 110%.

Sample :

EMPLOYEE NOISE EXPOSURE RECORD
EMPLOYEE NAME :
DATE : SIGNED :

INTERVIEW		COMPUTATION ISO		
WORK LOCATION	% TIME	dB(A)	8Hr DOSE %	PARTIAL DOSE %
1	60	85	30	18
2	5	95	315	15.75
3	10	88	60	6
4	25	91	125	31.25

RECOMMENDATIONS TOTAL DOSE : 71%
WITHIN LIMITS, MAY CONTINUE WORK

PARTIAL DOSE = $\frac{\%\ TIME}{100}$ X 8Hr DOSE

FIGURE 4

ISO Noise Dose (%)	dB(A)	OSHA* Max Time* (Hrs - Min)
10	80	
15	82	
20	83	
25	84	
30	85	16–0
40	86	13–56
50	87	12–8
60	88	10–34
80	89	9–11
100	90	8–0
[illegible]	91	6–56
160	92	[illegible]
200	93	[illegible]
250	94	4–36
315	95	4–0
400	96	3–29
500	97	3–2
630	98	2–50
800	99	2–15
1000	100	2–0
1250	101	1–44
1600	102	1–31
2000	103	1–19
2500	104	1–9
3150	105	1–0
4000	106	0–52
5000	107	0–46
6300	108	0–40
8000	109	0–34
10000	110	0–30
12500	111	0–26
16000	112	0–23
20000	113	0–20
25000	114	0–17
31500	115	0–15
	→	*Pending

Consider the above sample. Noise survey are carried out throughout the factory and noise levels are measured at each work station. Then each employee is interviewed to find out at which station this "mobile" worker works for how long a time. These are noted in the record card and his total dose in the 8-hour period is found out. It is of great importance once we know whether this total dose is within the internationally-accepted limits or not. The

(1) Occupational Safety and Health Administration (USA).

job-interview scheme is a great aid in pointing out which stations are the greatest contributors to the noise problem as far as the workers are concerned and which stations should be given priority during noise control programmes.

A better and more effective method of calculating Noise Dose is the use of Personal Noise Dose Meters which are miniature integrating Sound Level Meters which are worn by the worker in his shirt pocket or belt or on a hard hat, near the ear.

Dose Meters measures noise continuously and read out in percent of maximum allowable exposure after monitoring for eight hours. This method is especially useful where noise levels vary unpredictably. Where representative data can be obtained in less time, the reading can be converted to equivalent of 8-hour exposure.

Hearing Conservation Programmes employ test on workers from time to time to identify those who are susceptible to loss of hearing due to high level noise. Such employees are then provided with protective measures or are assigned to quieter areas of work. This programme has double benefit in the developed countries:

1 It protects the workers from noise-induced hearing loss

2 It protects the employer from having to pay up compensation claims for hearing loss.

The Measurement Survey Report is one of the most important documents in the entire Hearing Conservation Programme. The report may help to initiate costly noise-control investigations, personnel rotations, periodic hearing tests. The measurement survey report should include the following information :

a Sketch of site showing machine location and dimension, worker's position and microphone position.

b Model and serial no. of sound level meter and statement of caliberation verification.

c Weighting network and meter damping used

d Operator's name and number

e Noise level and duration

f Useful description of area, noise characteristics and operator habits

g Time, date and signature

The Report should be neatly filled in and maintained in the worker's personal file.

NOISE SURVEY RECORD	
DATE :	TIME :
INSTRUMENTATION	
LOCATION :	
EMPLOYEES NAME :	
SHIFT	
SOUND LEVEL dB(A)	
DAILY NOISE DOSE % EXPOSURE	
IMPACT NOISE dB :	
OCTAVE ANALYSIS IF STEADY LEVEL :	

Hz	31.5	63	125	250	500	1K	2K	4K	8K	16K	LIN
dB											

REMARKS:
SKETCH
SIGN :

FIGURE 5

Due to scope and time constraints, surveys on industries will be limited to Tongi and Joydebpur areas. Travelling to other parts of the country would have been helpful but the noise scene pertaining to industries in Bangladesh is very much unlikely to vary from one area to another. It is appreciated that a further study is necessary to confirm the above statement. Thus, the study is limited to the industrial areas of Tongi and Joydebpur.

This being a pioneer study of its kind, it is extremely difficult to exude a sense of cooperation from owners of most industries who are usually apprehensive of anything new and unknown. Thus, it has been convenient to choose factories where access was easy. Permission to investigate into matters relating to industries belonging to the government is practically impossible. Industries chosen are large and command a respectful and important position in their own fields. The names of the industries shall be kept anonymous for obvious reasons and because of commitment to this effect to the Owners.

1:5 APPROACH TO INVESTIGATION

The approach to investigation vis-a-vis the problem under study involves three main areas of enquiry — firstly, the effects of noise on industrial workers; secondly, international regulations for noise in the industry and thirdly the prevailing industrial noise environment in Bangladesh.

The enquiry in the first area is aimed at highlighting the effects of industrial noise on the workers in the working environment. The research in this area involved gathering, assessing and interpreting relevant information from published sources.

The second area of enquiry is aimed at reviewing the prevailing international regulations for control and prevention of noise in industries. Sources on the subject were ILO publications, reference material in local libraries and text tooks on acoustics.

In trying to assess the prevailing noise environment in the industries of Bangladesh, a few typical industries, apparently noisy, were surveyed. Measurements with Precision Sound Level Meter were taken at several stations within the noise-space to find the existing noise climate. Tape recordings of the spaces, followed by frequency analysis in the laboratory were also part of the study.

The four industries were chosen on the basis of the following :

1. Location — Tongi and Joydebpur, 12 and 20 miles from Dhaka respeotively.
2. Accessibility — possible because Owners are more concious and co-operative towards the study.
3. Material — Brick, R.C.C., Plaster, Glass and M.S. frames for windows, steel shutter, etc., all of which are typical of most local industries.

4. Method of construction — R.C.C. columns and beams spanning the entire encompassed by 5" or 10" brickwalls, covered by R.C.C roof with sky lighting.

It has been observed by the student that security measures are rather strict in the factories. Most of the workers are keen on anything that concerns their welfare. Hardly any worker departed from his work or work position to inquire about the measurements being taken. No worker speaks to a stranger unless spoken to. However, once they get into talking they are very friendly and extremely cooperative. Some are, of course, critical and make their point rather loudly. On the whole, the atmosphere is highly congenial for any such study.

The only way to be sure if a noise problem exists is to measure the noise and thereby have at hand objective information on which to base any subsequent discussion and decisions. The measured values can be compared with acceptable levels based on the following criterion:

National Standards on Occupational Noise Exposure Limits

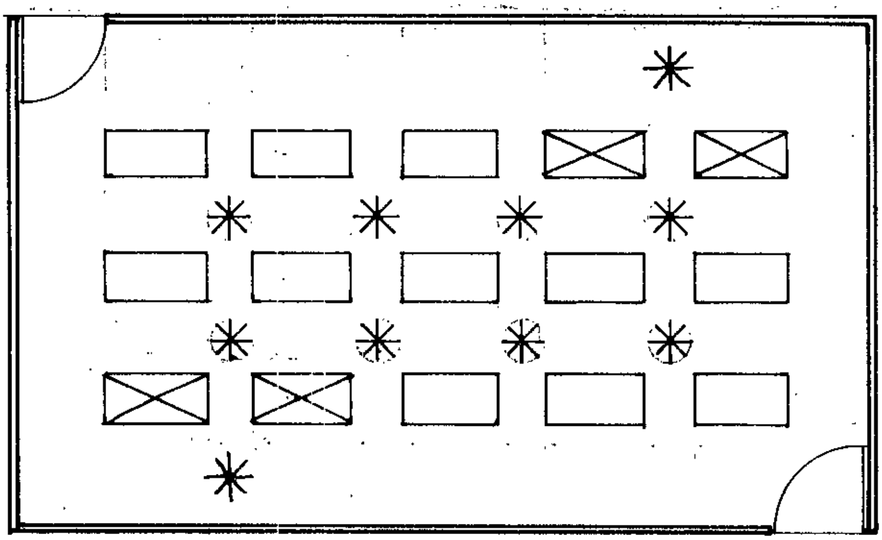
EEC member state	Steady noise level (dB(A))	Time exposure (h)	Halving rate (dB(A))	Over-riding limit (dB(A))	Impulse peak SPL (dB)	Impulses (no./day)
Germany	90	8	–	–	–	–
France	90	40	–	–	–	–
Belgium	90	40	5	110	140	100
Luxembourg	–					
Netherlands	–					
UK	90	8	3	135*	150	–
Irish Rep.	90	–	–	–	–	–
Italy	90	8	5	115	140	–
Denmark	90	40	3	115	–	–
Others						
Sweden	85	40	3	115	–	–
Norway	–					
USA (Fed.)	90	8	5	115	140	100
Canada (Fed.)	90	8	5	115	140	–
Australia	90	8	3	115	–	–

* UK over-riding limit 135 dB (SPL), on 'fast' response

(After Hay)

FIGURE 6

In work spaces with fairly uniform noise levels, the first step should be to determine the average level by making a number of A-weighted measurements with a portable Sound Level Meter at points suitably distributed around the workplace as below :

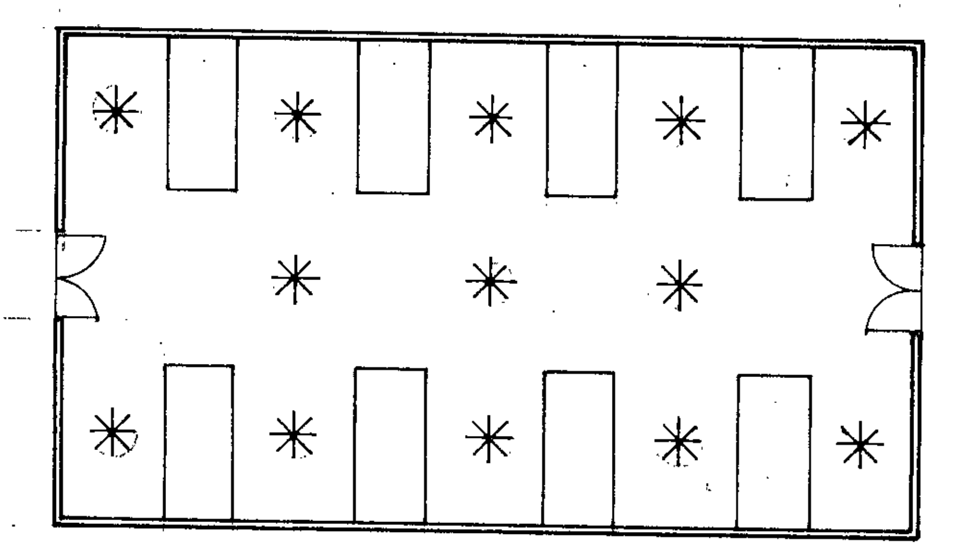


✳ measuring position

▭ machines producing average noise

☒ machines producing high noise

FIGURE 7



▭ MACHINE

✳ MICROPHONE POSITION

FIGURE 8

If the result of these simple measurements indicate a noise climate which is other than clearly acceptable, a further set of measurements should be made to investigate the noise spectrum in detail i.e. in terms of Octave Bands.

The first point to tackle when it is found that the noise level at a particular place is too high, (on comparison with accepted levels), is to locate source/s of the noise. If there is likely to be more than one source, the contribution from the various sources should be determined. The next problem would then be to determine which source/s should be considered the most serious one/s and to study whether this source/s could be removed or quietened. If such a solution is too expensive or too complicated to adopt, it might be more convenient to work on the path of the noise from the source to the listener. When the listener is in the direct radiation field from the source, as is normally the case with a person operating a noisy machine, then either the operator should be supplied with some sort of ear defenders or an enclosure might have to be built around the machine. If the noise is of a low-frequency nature and the source is mounted directly on the floor (wall), considerable noise reduction can be obtained simply by supporting the source on vibration isolators.

While surveying the noise, the following should be remenbered :

Measurement of noise should be made in noisy working areas where

a it is important, for safety reasons, that a worker should be able to hear a message or other signals

b the worker would be subjected to extra strain, and the work would possibly be hindered, by difficulties in oral communication.

Consideration should be given to defining the maximum distance at which speech intelligibility is preserved at normal voice loudness.

When noise is measured in the working environment, adequate data should be collected, especially regarding

a the location, nature, dimensions and other distinctive features of the plhace of work where measurements are made;

b the source/s of the noise, the location of the source in the plant and the type of work being performed;

c the instruments used, its accessories, the result of caliberation tests, and the vanues indicated;

d the locations at which measurements were made, and the direction of the microphone;

e the number of workers exposed to the noise;

f the duration of the workers' exposure;

g the date and time, and the name of the observer.

Noise may

a Damage hearing if consistently of a high level or of an impulsive nature

b Impair safety by making warnings difficult to hear

c Hinder communication between employees who work as a team and where efforts are interactive, or who carry out much of their work by telephone and direct discussion;

d Interfere with efficiency, either as a direct result of communication loss, as above, or by causing fatigue and loss of concentration;

e Be annoying

Procedures to measure and evaluate noise exposure depend on the goal to be attained. This applies in particular to

a assessment of the risk of hearing impairment

b assessment of the degree of interference to communication essential for safety purposes

c assessemnt of the risk of nervous fatigue, with due consideration to the work to be done.

When noise is measured, both normal working conditions and conditions involving the highest noise levels should be taken into consideration.

The following values may be recommended :

a a warning limit value of 85 dB(A) (1)

b a danger limit value of 90 dB(A) (2)

Measured values should be compared with above limits.

While measuring noise, one should be thouroughly familiar with operations of noise measuring instruments through study of operating instructions before attempting to make noise surveys, setting up the equipment and checking its operations before taking it to the workroom area. At intervals during the surveys, batteries should be checked, as well as the over-all instrument caliberation.

Instruments should be protected from vibration and shock, extremes of temperature. Overheating can damage circuit components. Allowing instruments to become very cold will result in condensation of water vapour in the instrument when it is used in a heated space the next time.

When conducting surveys, it is important to be assured that the meter indication is due to noise and not to other influences. Wind blowing across the microphone causes a rushing sound that is registered on the meter. Use of windscreen can minimise this effect. Electric and magnetic fields can also cause needle deflections. These

(1) American Academy of Ophthalmology and Otolaryngology
(2) International Labour Office

electro-magnetic effects can be reduced by reorienting the meter until minimum coupling with electric field is obtained, as indicated by minimum meter reading.

It is important to obtain representative data. The microphone should be moved about to determine that standing waves are not present. If they are, a spatial average should be obtained. When conducting exposure surveys of various kinds, the most important consideration is to measure levels that are typical of those at the workers' location. Noise should be measured at the position of the worker's head. It is not necessary, in fact it is undesirable to measure sound right at the ear, since diffraction around the head can alter the sound field. It is better to measure at some location a few inches or feet away where exploration with the Sound Level Meter indicates levels that are the same as at the workers' location.

FREQUENCY ANALYSIS

It is important to measure the frequency spectrum of the noise environment before selecting ear protectors or absorbing materials as they are all frequency-dependent. The frequency spectrum of the noise from machine must also be known before erecting noise enclosures because of the same reason. Octave Band filters are used for these purposes. If noise control requires more datail, then a Third Octave and Narrow Band Filters are used to identify specific noise sources, to measure the effectiveness of internal machine modifications and to trace vibration-induced noise sources.

When many frequency analyses are performed, it is convenient to use a Graphic Level Recorder to plot frequency analysis spectram. This cuts down probability of error.

PART- II

EXPERIMENTAL SET-UP AND PROCEDURE

2:1 NOISE MEASUREMENT AND ANALYSIS TECHNIQUES ADOPTED

Sound (or noise) is such a common part of our everyday lives that we rarely appreciate all of its functions. Too often in the modern society, sounds annoys us — hence we call them noise. Besides it has numerous adverse effects on human body's autonomic nervous system as has already been discussed. Worst of all sound can damage and destroy the delicate instrument designed to receive it — the human ear.

Why do we need to measure and analyse sounds (or noises) ? Sound measurements permit precise, scientific analysis of annoying sounds. Also, sound measurements give a clear indication of when a sound may cause hearing damage and permit corrective measures to be taken. Furthermore, measurement and analysis of sound is a powerful diagnostic tool in noise reduction programmes. It is a tool that permits the improvement of the quality of our lives. Thus, sound measurements and analysis are vital in noise control and hearing conservation programmes.

The most common noise measurement is expressed in dB(A) level. It is measured with a Sound Level Meter, using the A-weighting filter to simulate the frequency response of the human ear. The sound signal is converted to an identical electrical signal by a high quality microphone. Since the signal is quite small, it must be amplified before it can be read on a meter. After the first amplifier the signal may pass through a weighting network (A,B,C or D). An alternative to the network is an octave or third octave filter which may be attached externally. After additional amplification, the signal will now be of a high enough level to drive the meter — after its RMS value has been determined in the RMS detector. RMS means root mean square' — a special kind of mathematical average value. It is of importance in sound measurements because the RMS value is directly related to the amount of energy in the sound signal. The value read on the meter is the sound level in dB. The sound signal is also available at an output socket so that it may be fed to external instruments such as recorders or noise dose meters.

The basic components of and their sequence of arrangement in a Sound Level Meter are as follows :

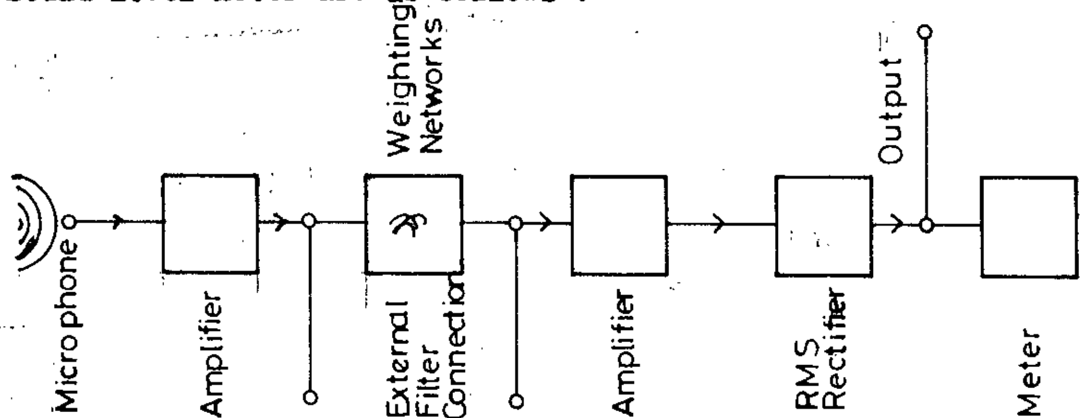


FIGURE 9

All these components are integrated in a compact and portable instrument called the Sound Level Meter (SLM) which responds to sound in approximately the same way as the human ear and which gives objective, reproduceable measurements of sound level.

The built-in read-out consisting of the RMS rectifier and the meter circuit include two different meter damping characteristics, Termed "Fast" and "Slow". The "slow" characteristic is intended for use in situations where the reading obtained with the "Fast" characteristic fluctuates too much (more than some 4dB) to give a reasonably well defined value of the sound level.

The microphone choosen for a particular noise measurement will generally have to fulfil two rather different groups of conditions :

Firstly, it must operate satisfactorily over a range of environmental conditions such as humidity, temperature, air pollution and wind.

Secondly, it must also meet the technical constraints such as frequency response, sensitivity and directivity.

Generally speaking, the condenser type microphone is best able to meet these conditions and has therefore become the most widely used type. B & K makes condenser type microphones with three types of characteristics :

i Free field microphones: They have uniform frequency response for the sound pressure that existed before the microphone was introduced into the sound field. It is important to note that any microphone will disturb the sound field but the free field microphone is designed to compensate for its own disturbing presence.

ii Pressure microphones : They have uniform frequency response to the actual sound pressure present which ofcourse includes the microphone's own disturbing presence.

iii Random incidence microphones: They respond uniformly to signals arriving simultaneously from all angles such as in the case of highly reverberent or diffuse sound field.

With regard to frequency response, sensitivity and directivity, there may not be any unique solution to the microphone problem but certain compromises many need to be made. All these factors are interconnected and related to the physical size of the microphone. Thus, the smaller the physical dimensions of the microphone (dia. varries from $\frac{1}{8}$" to 1"), the wider is the frequency range but the smaller is the sensitivity and the lesser are the effects of directivity.

Before commencement of the experimental measurements, the SLM needs to be calibrated using one of the following two instruments which are small battery driven devices producing a known sound pressure level (dB) at a known frequency to which the measuring system can be adjusted :

i The Pistonphone (B&K, Type 4220): This device operates at 250 Hz and produces a sound level of 124 dB accurate to ± 0.2 dB.

ii The Sound Level Callibrator (B&K, Type 4230): This device operates at 1000 Hz and produces a sound level of 94 dB accurate to ± 0.25 dB.

To obtain the best results, the microphone should be well sealed in the coupler opening. It is a good policy to calibrate the instrument (SLM) before and after each set of measurements.

Although noise measurement with a sound Level Meter is relatively a simple matter, it is none the less advisable that some basic rules for proper use of the SLM be faithfully adhered to. A check-list of these basic rules are enumerated here as below :

i Check that the batteries are OK and take along an extra set of good quality batteries. If the instrument is to be stored for a long time, the batteries should be removed.

ii Make sure that the instrument is properly calibrated. Periodic use of an acoustic calibrator is recommended.

iii Decide which weighting network should be used. Normally this would be the A-network.

iv Make some orientation measurements before noting actual values. Determine the kind of sound field prevailing (i.e. free-field or diffuse field) and find the correct measuring positions.

If measurement is taken too close to the source i.e. in the 'near field' (about twice the greatest dimension of the machine), the SPL may vary significantly with a small change in position.

If the measurement is taken far away from the machine i.e. in the 'reverberent field', correct measurement of the direct sound will not be possible

Between the 'near' and the 'reverberent' fields lies the 'free field' which can be found by noting that the SPL drops about 6 dB for a doubling of the distance from the source. It is here that the measurements should be made. It is quite possible, however, that the conditions are so reverberent or the room is so small that no 'free field' exists.

v When using SLM with a free-field microphone, hold the meter at arms length to avoid reflections and point the microphone at the sound source.

vi If the sound comes from more than one direction, it is important to choose a microphone and mounting (extension rod or an extension cable) which will give the best possible omnidirectional characteristics.

vii Select the correct meter response, 'Fast' or 'Slow' to get an accurate reading. If the sound is impulsive, an impulse sound Level Meter should be used.

viii During the measurement, remember to :

a Keep away from the reflecting surfaces.

b Measure at a suitable distance from the machine (i.e. in the free-field).

c Check the back ground noise level and make appropriate corrections, if necessary.

d Do not measure behind shading objects.

- e Use a wind screen whenever working outdoors.
- f Be careful not to accept readings if the meter is over loaded or over deflected.
- g Keep a well documented measuring report

In our investigation, B&K SLM 2203 with a high sensitivity ½" dia. free-field condenser Microphone (Type 4165) was used giving it a measuring range from 26 to 140 dB(A) and a wide frequency range, both in free and diffuse sound fields due to its excellent omnidirectivity. Measurements were taken at the nodal points of a grid-iron plan superimposed on each of the spaces investigated and the spot values of dB(A) were recorded.

Once the quick and simple dB(A) measurements were done the next step in the experimental work was the frequency analysis of the measured noise in the Octave bands. Octave band frequency analysis is required to analyze a noise and to predict the necessary insulation/absorption characteristics of noise barriers and space enclosures, and to measure noise reduction between common walls of adjacent spaces. Octave analysis is also invaluable when a noise control system must be reworked because it assists in defining the minimum modification that will enable the system to meet the desired specification. Octave analysis is performed with a combination precision sound level meter and octave analyzer which can be a battery operated, compact and portable device for direct measurements in the field.

In case of non-availability of such compact and portable devices as the case was with us, a battery operated portable Tape recorder can be used in conjunction with the SLM for recording and storage of field noise data for later processing (frequency analysis) in the laboratory. In our case B&K Tape

Recorder (Type 7004) was used in conjunction with B&K SLM (Type 2203) and the set-up used is shown below :

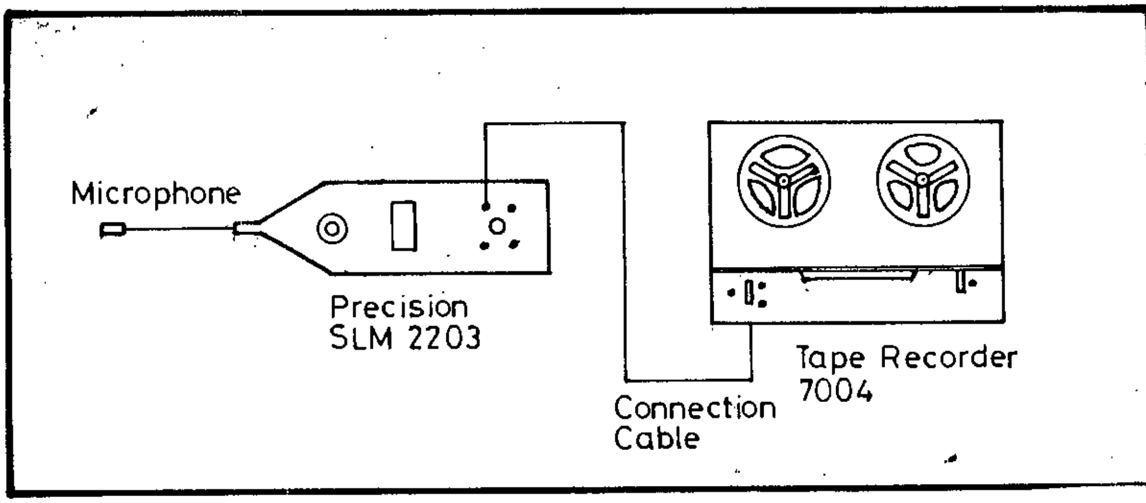
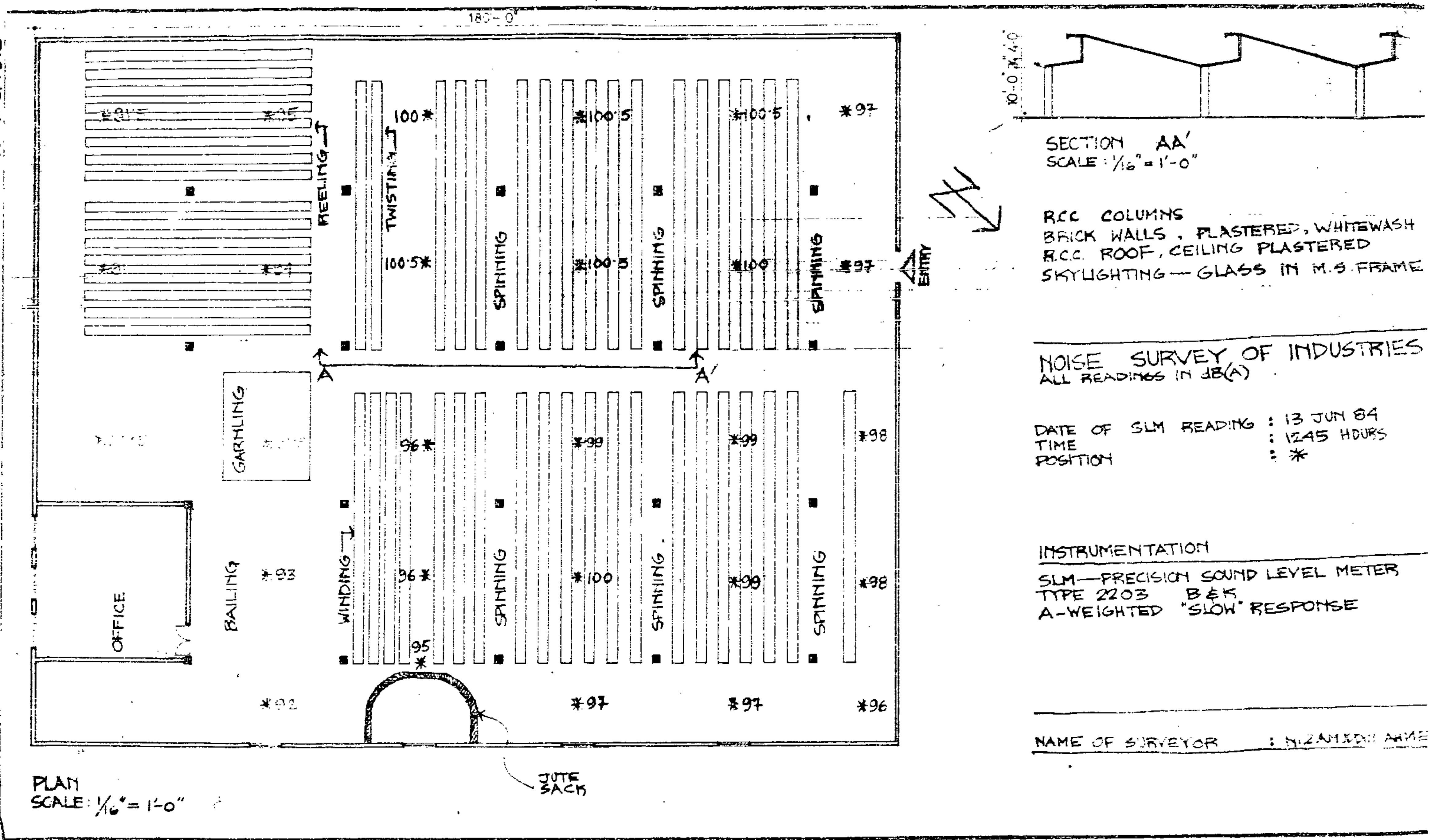


FIGURE 10

7004 Tape Recorder is an equipment used for field recording and storage of acoustic and vibration data. It has two tracks and is intended mainly for acoustic measurements. It uses direct recording Technique and has two Tape speed modes. In one mode, speeds of 15 ips and 1.5 ips are available suitable for 1:10 scale acoustic measurements and applications calling for an extended frequency range. In the second mode, a maximum signal to noise ratio is obtained at speeds of 15 ips and 7.5 ips for recording within the audible frequency range. The measurement setup stated here was used as per the standard operating procedures and continuous reading for a period of approximately 2 minutes was recorded on the Tape Recorder at two stations in Factory P&R.

The following drawings show the four factories and the dBA values at positions spread all over in a grid-iron pattern.



180'-0"
REELING
TWISTING
SPINNING
SPINNING
SPINNING
ENTRY
GARNLING
WINDING
SPINNING
SPINNING
SPINNING
BAILING
OFFICE
JUTE SACK
A
A'
100
100.5
100.5
100.5
100.5
100
97
97
96
99
99
98
96
100
99
98
95
93
97
97
96
10'-0"x4'-0"
SECTION AA'
SCALE : 1/16" = 1'-0"
R.C.C. COLUMNS
BRICK WALLS, PLASTERED, WHITEWASH
R.C.C. ROOF, CEILING PLASTERED
SKYLIGHTING — GLASS IN M.S. FRAME
NOISE SURVEY OF INDUSTRIES
ALL READINGS IN dB(A)
DATE OF SLM READING : 13 JUN 84
TIME : 1245 HOURS
POSITION : *
INSTRUMENTATION
SLM—PRECISION SOUND LEVEL METER
TYPE 2203 B&K
A-WEIGHTED "SLOW" RESPONSE
NAME OF SURVEYOR :
PLAN
SCALE : 1/16" = 1'-0"

FIGURE 11

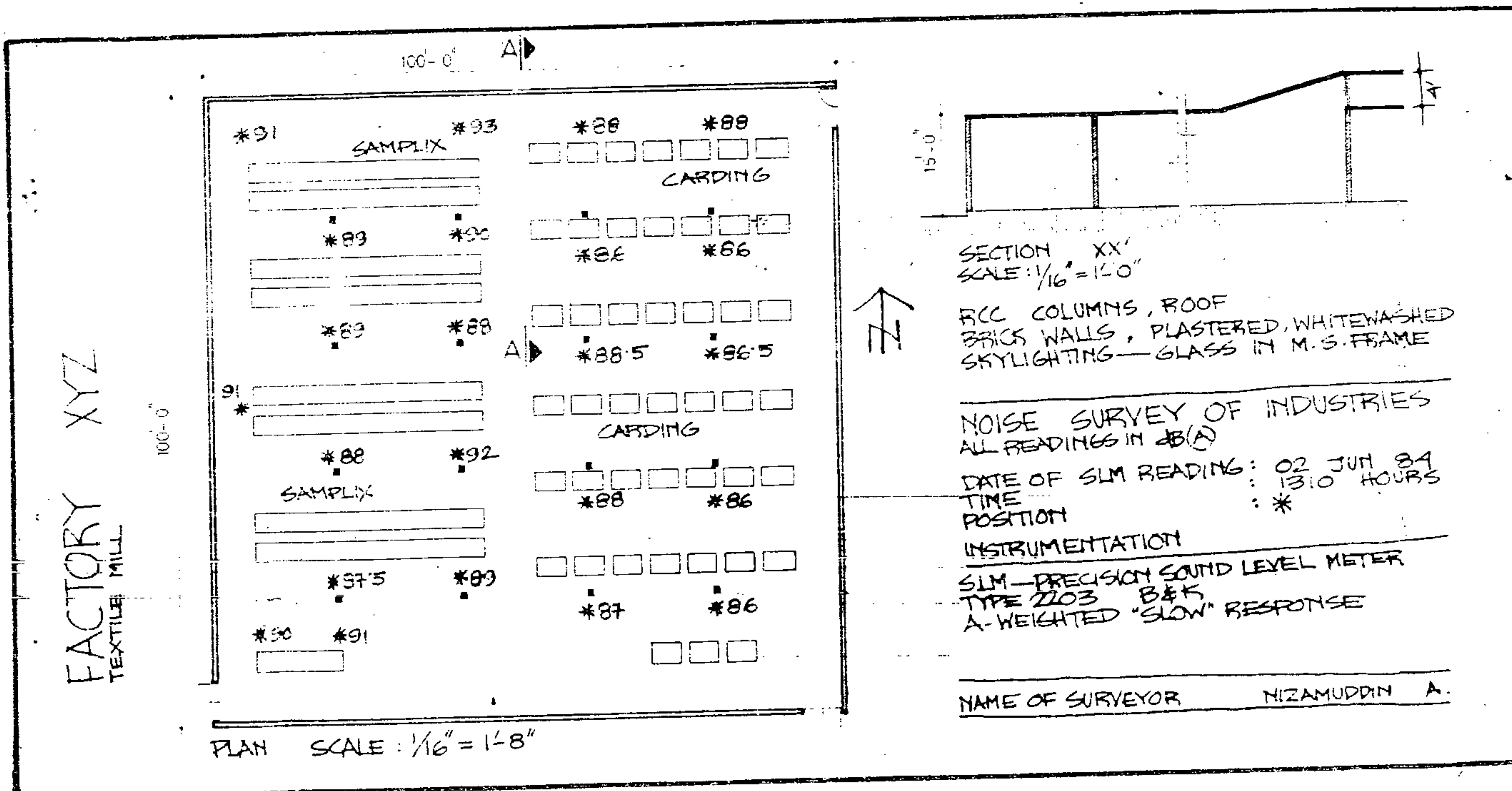
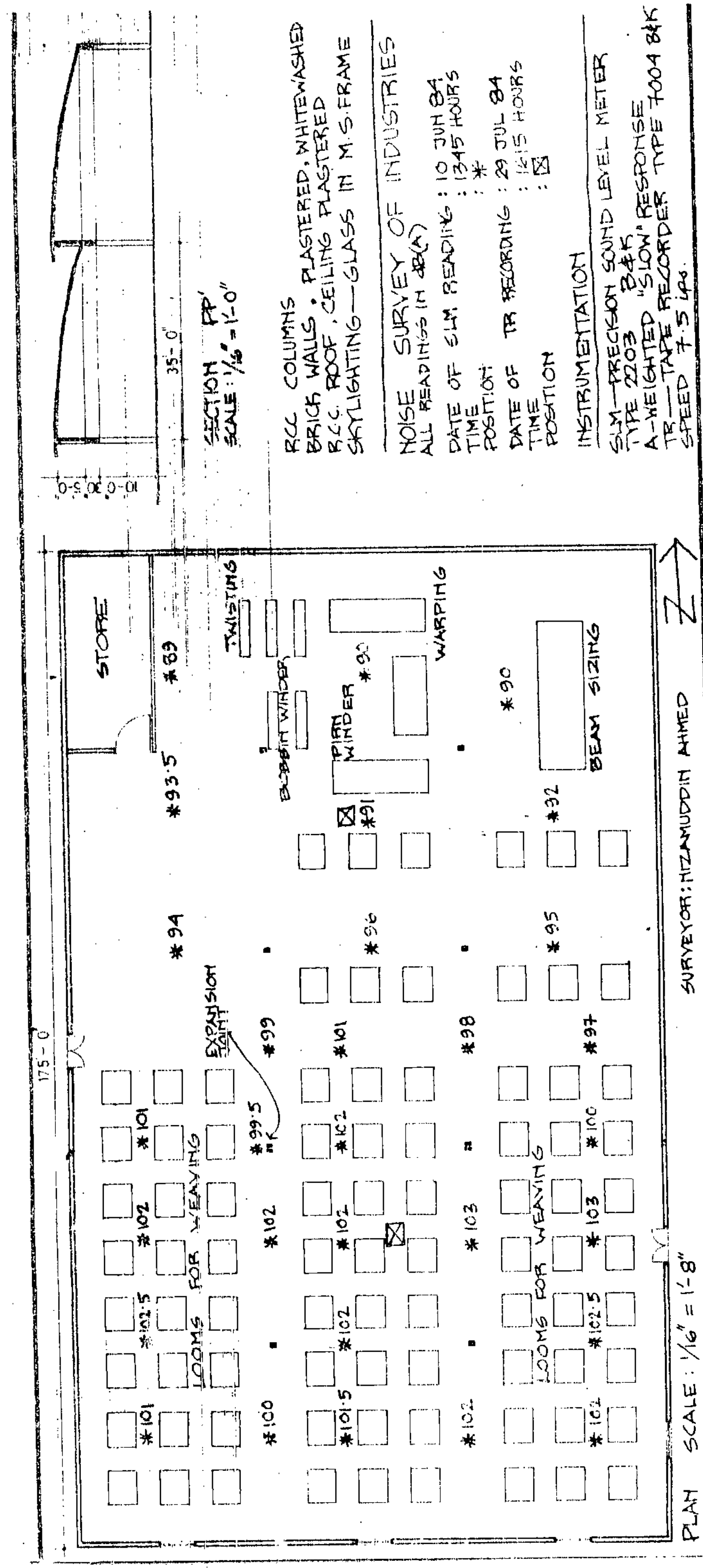

FACTORY XYZ
TEXTILE MILL
100'-0"
A
SAMPLIX
CARDING
*91
*93
*88
*83
*86
*89
*88.5
*86.5
*92
*97.5
*90
*87
PLAN SCALE : 1/16" = 1'-8"
SECTION XX'
SCALE : 1/16" = 1'-0"
15'-0"
4'
RCC COLUMNS, ROOF
BRICK WALLS, PLASTERED, WHITEWASHED
SKYLIGHTING — GLASS IN M.S. FRAME
NOISE SURVEY OF INDUSTRIES
ALL READINGS IN dB(A)
DATE OF SLM READING : 02 JUN 84
TIME : 1310 HOURS
POSITION : *
INSTRUMENTATION
SLM — PRECISION SOUND LEVEL METER
TYPE 2203 B&K
A-WEIGHTED "SLOW" RESPONSE
NAME OF SURVEYOR NIZAMUDDIN A.

FIGURE 12



SECTION PP'
SCALE: 1/16" = 1'-0"
35'-0"
10'-0" 30'5-0"
RCC COLUMNS
BRICK WALLS, PLASTERED, WHITEWASHED
R.C.C. ROOF, CEILING PLASTERED
SKYLIGHTING — GLASS IN M.S. FRAME
NOISE SURVEY OF INDUSTRIES
ALL READINGS IN dB(A)
DATE OF SLM READING : 10 JUN 84
TIME : 1345 HOURS
POSITION : *
DATE OF TR RECORDING : 29 JUL 84
TIME : 1615 HOURS
POSITION : ⊠
INSTRUMENTATION
SLM — PRECISION SOUND LEVEL METER
TYPE 2203 B&K
A-WEIGHTED "SLOW" RESPONSE
TR — TAPE RECORDER TYPE 7004 B&K
SPEED 7.5 ips
STORE
TWISTING
WARPING
BOBBIN WINDER
PIRN WINDER
BEAM SIZING
EXPANSION JOINT
LOOMS FOR WEAVING
LOOMS FOR WEAVING
175'-0
N
*89
*93.5
*90
*90
*91
*92
*94
*96
*95
*99
*101
*98
*97
*99.5
*101
*102
*100
*102
*102
*102
*103
*103
*102.5
*102
*102.5
*101
*100
*101.5
*102
*102
SURVEYOR: NIZAMUDDIN AHMED
PLAN SCALE: 1/16" = 1'-8"

FIGURE 13

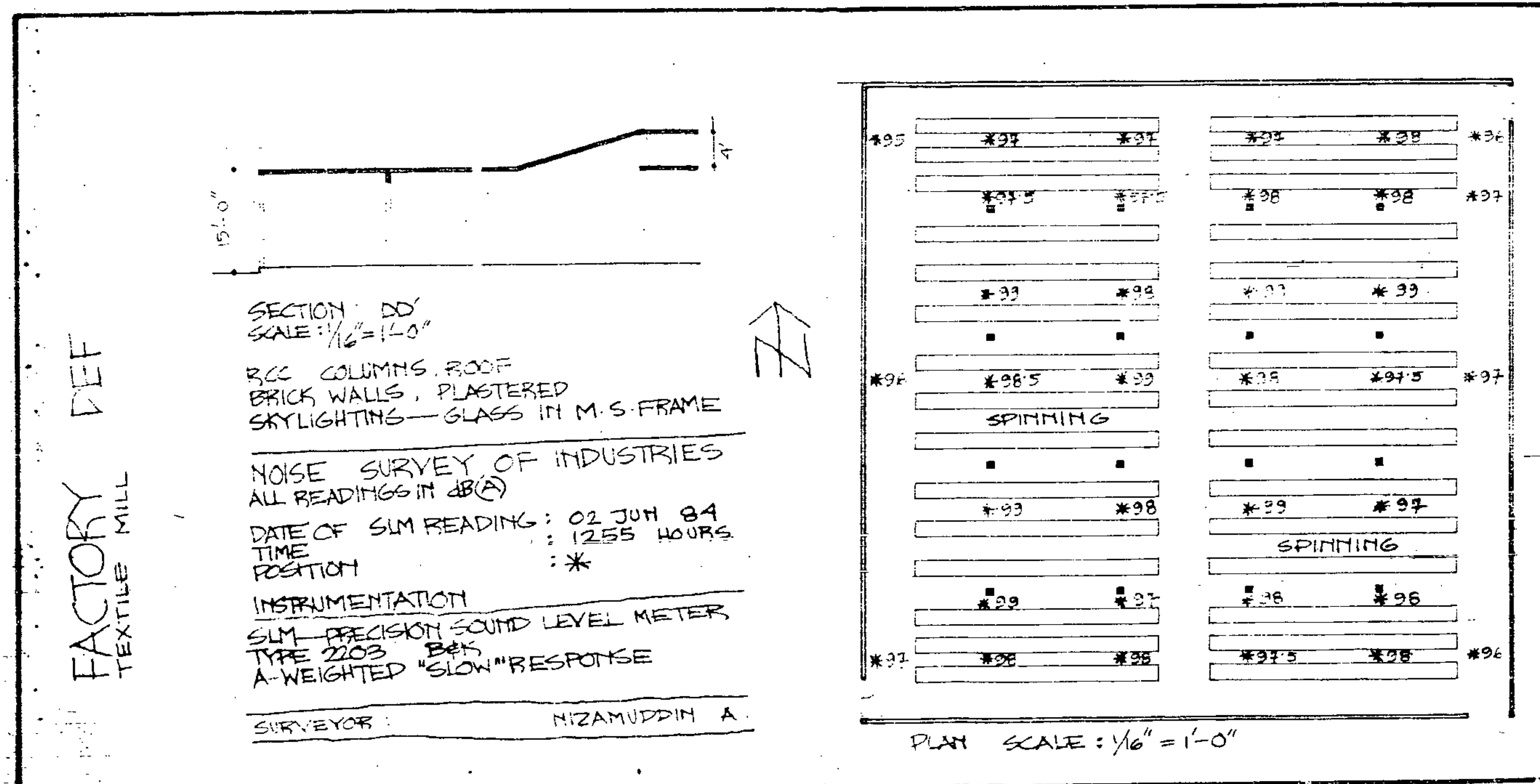
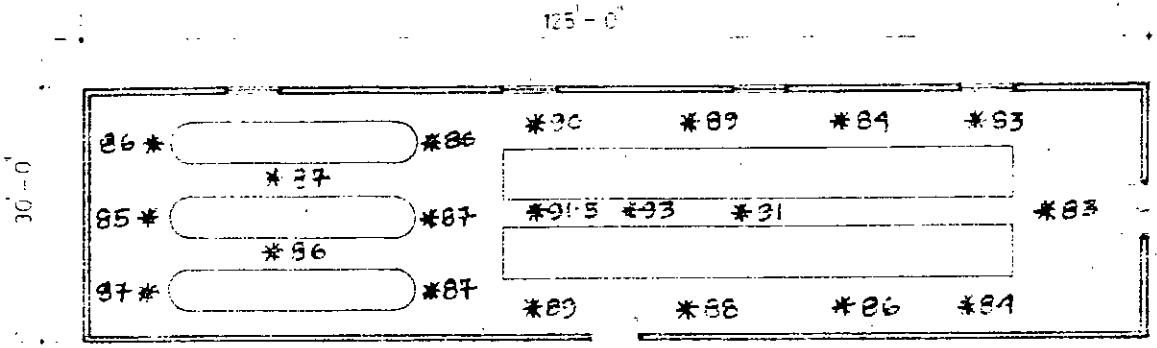
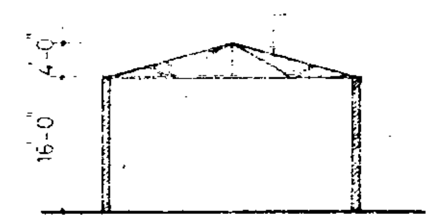

FACTORY DEF
TEXTILE MILL
15'-0"
4'
SECTION DD'
SCALE : 1/16" = 1'-0"
RCC COLUMNS, ROOF
BRICK WALLS, PLASTERED
SKYLIGHTING — GLASS IN M.S. FRAME
NOISE SURVEY OF INDUSTRIES
ALL READINGS IN dB(A)
DATE OF SLM READING : 02 JUN 84
TIME : 1255 HOURS
POSITION : *
INSTRUMENTATION
SLM — PRECISION SOUND LEVEL METER
TYPE 2203 B&K
A-WEIGHTED "SLOW" RESPONSE
SURVEYOR : NIZAMUDDIN A.
N
SPINNING
SPINNING
*95
*96
*97
*97
*96
*98.5
*99
*99
*98
*97.5
*98
*98
*98
PLAN SCALE : 1/16" = 1'-0"

FIGURE 14



PLAN SCALE : 1/16" = 1'-0"



SECTION GG'
SCALE : 1/16" = 1'-0"

FACTORY GHI
PAPER & CARDBOARD MILL

NOISE SURVEY OF INDUSTRIES
ALL READINGS IN dB(A)

DATE OF SLM READING : 02 JUN 84
TIME : 1100 HOURS
POSITION : *

BRICK WALLS
STEEL TRUSS,
C.I. SHEET ROOF

INSTRUMENTATION

SLM—PRECISION SOUND LEVEL METER
TYPE 2203 B & K
A-WEIGHTED 'SLOW' RESPONSE

SURVEYOR : NIZAMUDDIN AHMED

FIGURE 15

Readings were recorded in the noisiest section of each industry and sections with comparatively lower noise levels (below 90dBA) were not taken into consideration for the purpose of the study.

Having done the field recording of the noise on the magnetic tape of the recorder, the equipments were brought back to the acoustic laboratory for processing through a Frequency Analyzer and recording the levels at various Third Octave bands in a Level Recorder. The instrumentation for this phase of the investigation was as follows:

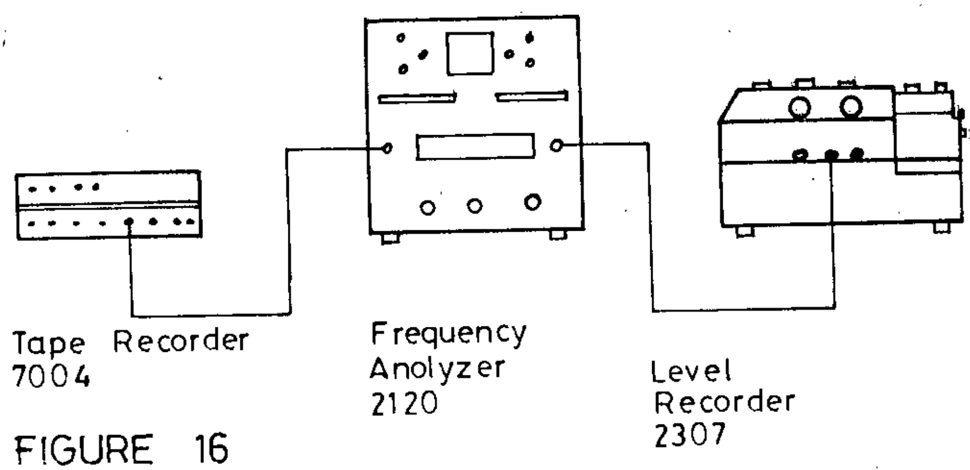


FIGURE 16

The Frequency Analyzer, B & K Type 2120 is a constant percentage bandwidth analyzer for use in the frequency range 2 Hz to 20 K.Hz in conjunction with the internal filters. Used with one of the B & K condenser microphones, the 2120 becomes a precision Sound Level Meter. For our purpose here, however, we utilized the Filter Section of the analyzer only.

The Level Recorder, B&K Type 2307 is basically a recording voltmeter designed to accurately record the RMS, Average or Peak levels of an AC signal in the frequency range from 2 Hz to 200 K.Hz. Recording as a function of time or frequency can be made on pre-printed lined or frequency calibrated strip-chart paper, 50 or 100 mm wide. In our case 100 mm wide recording paper (B&K Type QP 1130) was used and the experimental setup was operated as per standard procedures.

2:2 THE RESULTS

The results of the dB(A) spot values measured in the various spaces under investigation have been presented in section 2:1 in connection with identification of the locations of the noise recording stations (stations 1,2,3,4 and 5) in the different spaces using the Tape Recorder.

The results of the frequency analysis in $\frac{1}{3}$ octave bands were obtained in a series of spectograms which are given below along with other necessary information :

The 1/3 Octave Analysis gives the following results :

OCTAVE BAND(Hz)	STATION ONE(dBA)	STATION TWO(dBA)
20 - 63	72	72
63 - 200	81	81
200 - 630	93	99
630 - 2000	105	108
2000 - 6300	87	90
6300 - 20000	78	78

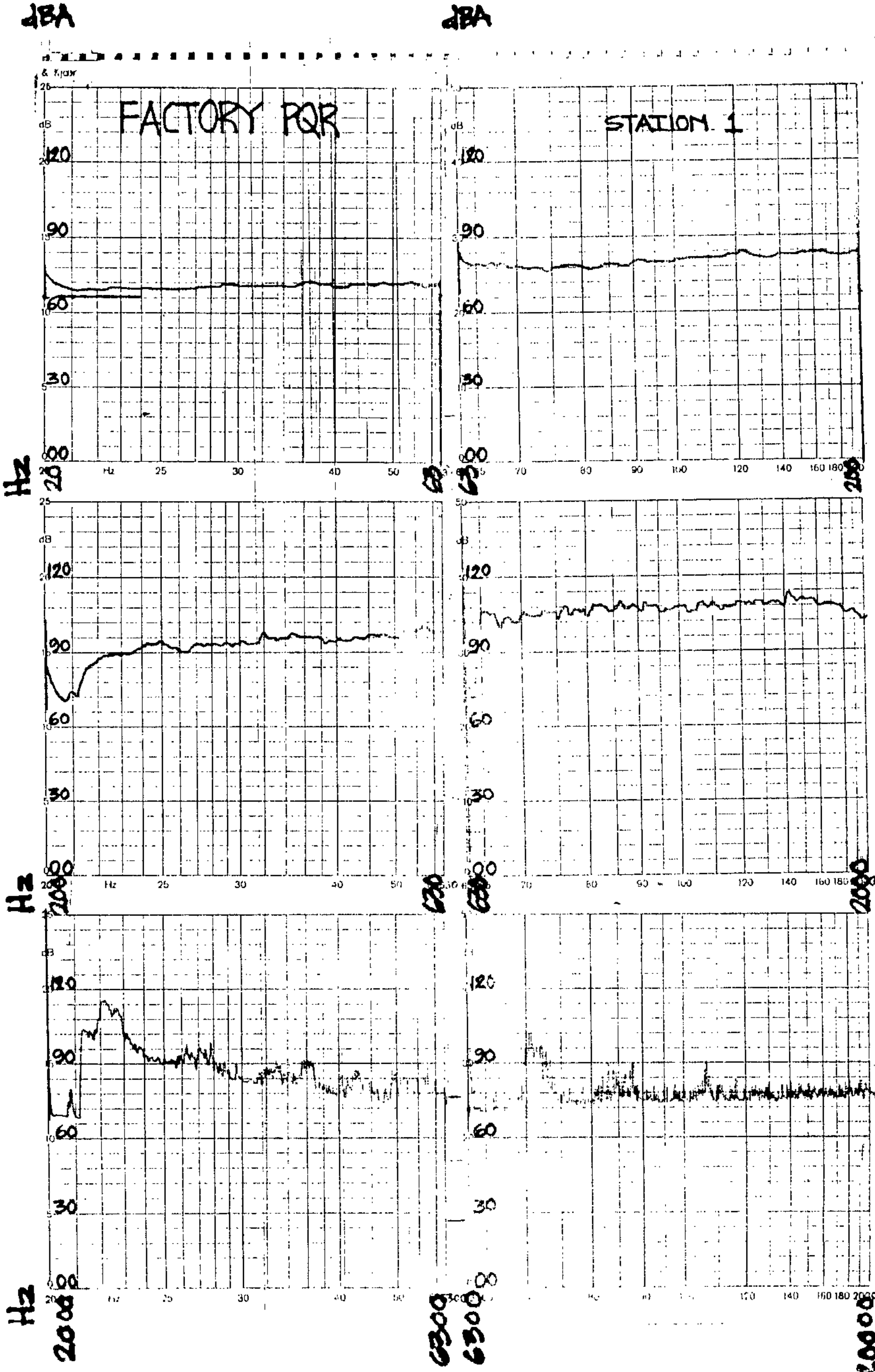

dBA
dBA
FACTORY PQR
STATION 1
120
90
60
30
00
Hz
20
25
30
40
50
630
70
80
90
100
120
140
160 180
2000
6300
20000

FIGURE 17

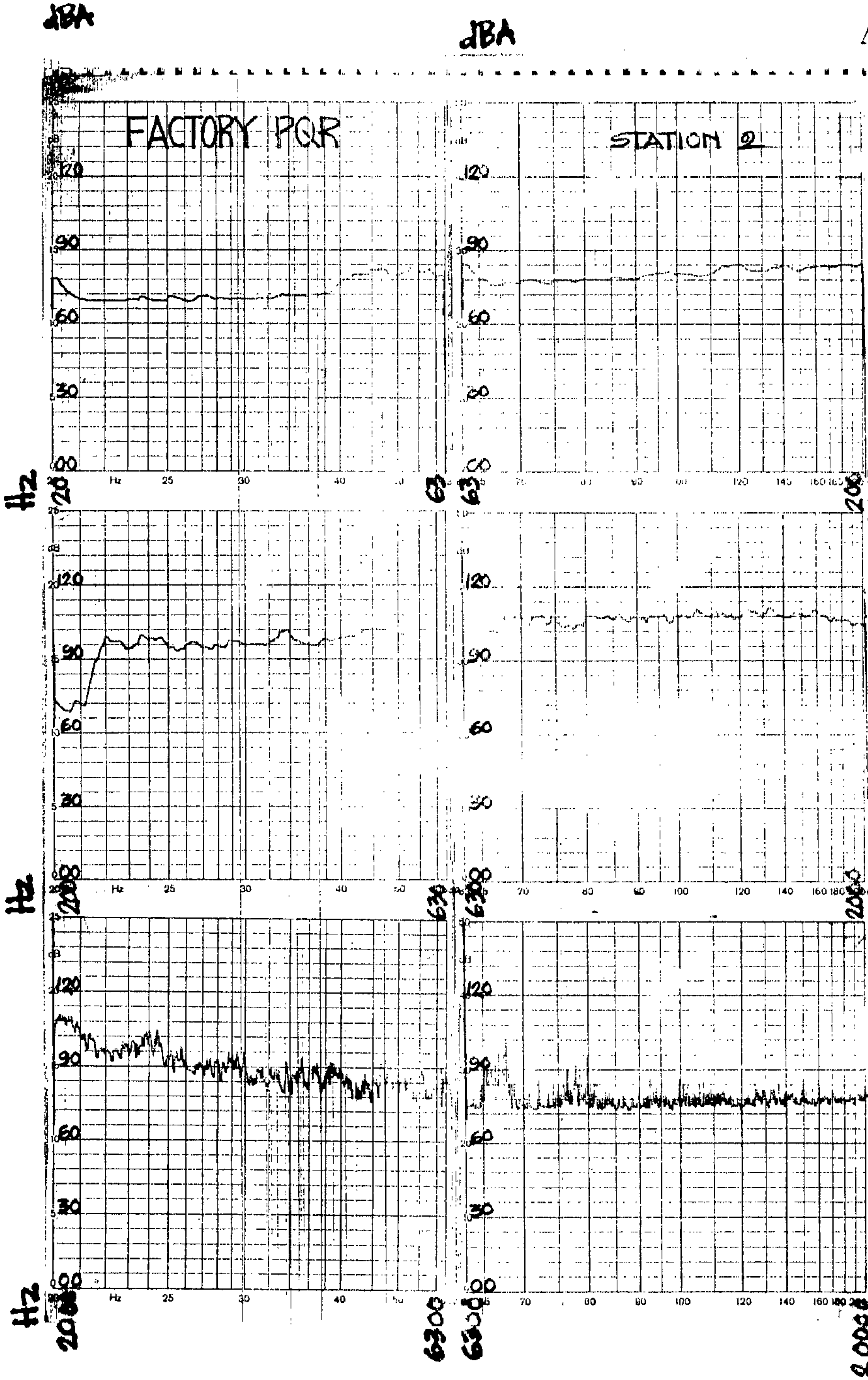

dBA
dBA
FACTORY PQR
STATION 2
120
90
60
30
00
Hz
20
25
30
40
63
70
80
90
100
120
140
160
200
2000
6300
20000

FIGURE 18

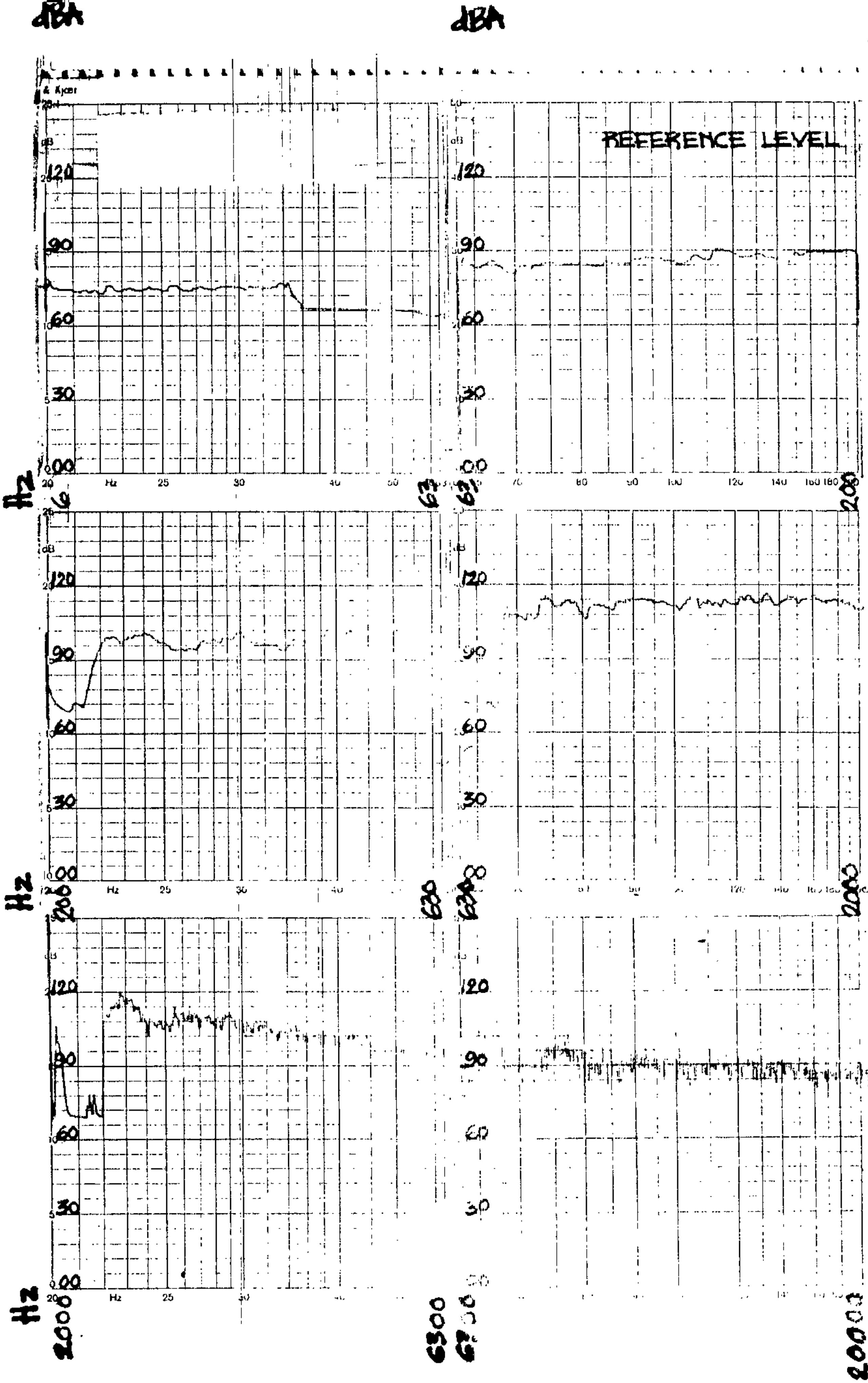

dBA
dBA
REFERENCE LEVEL
120
90
60
30
00
Hz
20
25
30
40
50
63
200
630
2000
6300
20000

FIGURE 19

2:3 DISCUSSION OF THE RESULTS

The 1/3 Octave Analysis of the noise of the industry under study was carried out in order to identify the frequencies where the problem is most serious. It is known that absorption is a function of frequency and that certain materials absorb sound more at certain frequencies than at others. It is possible, following the Octave Analysis, to choose absorptive materials that is most efficient absorption-wise in the frequencies where the noise-problem exists with greater severity.

The general character of the spectograms of the two stations is more or less identical. They show that the dBA level in our Case Study industry is above the recommended level (90 dBA) in the frequencies ranging from 200-6300 Hz. At other frequencies of the spectogram the values are below the recommended level.

In one particular spectral band (630-2000 Hz) the dBA value is found to be higher than the reading of the Sound Level Meters at the station. This can be accounted for by the fact that intermittent or peak values can exceed the over-all sound level depending on the type of noise source. Moreover, spot readings results from an estimation of the average sound pressure level rather than the entire extremity of the deflection shown by the Sound Level Meter.

In view of the spectograms showing an increase in noise level at frequencies 200-6300 Hz. the following locally-available materials have been selected :

- i Perforated partex board
- ii Porous gypsum board with absorptive backing
- iii Porous three-dimensional units of plain sheet(tin) with absorptive materials inside the hollow (so called Functional Absorbers)

It can be surmised from available data that the materials mentioned above shall be efficient in the bands 200-630 Hz, 630-2000 Hz and 2000-6300 Hz. i.e. in the frequencies where the noise level in the particular industry exceeds the recommended level. Relevant specific absorption data on the chosen materials mentioned above are not available as there has not been any investigation regarding absorptive properties of these materials. However, it is possible to estimate their probable absorption co-efficient by assessing the data on absorption co-efficient of similar materials available from published sources. For our purpose such an estimation has been made and the following absorption co-efficient has been assigned to the materials :

i	Perforated partex board	.65
ii	Porous gypsum board with absorptive backing	.80
iii	Functional Absorbers	.80

Our attempt in controlling the noise by introducing absorptive materials in the space may involve maximisation of absorption in the space. This may be effected by the introduction of possible amount of absorption materials in the space without hampering the functional or visual requirements of the space. The absorptive materials may be of the following forms :

i Absorption in the ceiling
ii Absorption in the walls
iii Suspended Functional Absorbers

It shall not be advisable to initiate absorption in the ceiling in our Case Study as it shall nullify the existing skylighting through the roof sections. For our purpose, we may try to absorb the noise by using absorptive materials in the walls and also by suspending these at regular intervals from the ceiling in the form of Functional Absorbers. We shall examine the use of two sets of materials and assess their effectiveness in terms of noise level reduction. The two sets of materials are :

SET I :
- i Absorption in walls: (5'-0" from floor level to ceiling) 3/4" perforated partex board on wooden frame with 1" airspace separating it from the wall.
- ii Functional Absorbers: Three-dimensional cylindrical forms made of porous tin sheet and filled with glass wool.

SET II :
- i Absorption in walls: (5'-0" from floor level to ceiling) Porous gypsum board with glass wool backing.
- ii Functional Absorbers: As in SET I.

PART - III

NOISE CONTROL IN INDUSTRIES: THEORIES AND PRACTICES AND INTERNATIONAL REGULATIONS

The best solution to any noise problem in the industries would be quietening the machines. But, quieter machines also mean more expense in manufacturing the machine. And, hence, the control of noise in the industries get caught in the "laboratory" of trials and errors, tests and experiments for several professional groups, included among which are the architects.

Industrial noise and its effects can be controlled with varying degrees of success by several methods. Chief among these are

- a Planning and designing of industries with acoustic consideration
- b erection of enclosure around the worker exposed to high-level noise
- c erection of enclosure around the source of high-level noise
- d vibration isolation
- e application of acoustic materials to reduce reflections
- f job-rotation
- g audiometric tets under medical supervision: hearing conservation programmes
- h personal protective equipment

a Most acousticians agree that much of the problems associated with industrial noise control would be done away with if tackled during the design stage of the industrial complex. Solutions would then be more appropriate, economic and convenient. This is where the architect plays a vital role in institutionalizing the necessity and importance of the architectural solutions to acoustic problems. Here the problems of noise are solved by planning and designing. Right from the conceptual stage of the design process, the architect bears in mind the noise-problem. Size, shape and form of the spaces, use of materials; methods of construction are all guided tox a great extent by their possible effect on the expected noise. The architect uses his skill to make these effects positive towards noise-reduction.

It is the role of the architect to create a comfortable, workable and meaningful environment in harmony with the functional, socio-economical, traditional, environmental and institutional demands and requirements of the space and the users. In achieving this goal of creating the right environment for the right purpose, right site and at the right cost, the architect attacks the problem in two separate stages :

A Accumulation of information pertaining to the project

B Incorporating the information in design implementation.

Information may be collected by various means as suits the situation. It may be in the form of case studies, interviews, surveys, measurements, etc. One information may evoke search and in-depth study to gather further information. Often the search may be narrowed to finding the right material, the right method of construction, the right size, height, etc. In beginning to hunt for information, a goal is always set. The architect knows what he is looking for but he has the faintest idea of what his findings will be. Will they be positive or negative towards his approach to design ? If negative, how bad is the situation ?

In tackling the design problem in the industries, the architect in addition to thoughts on such broad areas as siting, finances, foundation, infra-structure, finish, materials, ventillation, ventillation, lighting, etc has to consider to a great extent the noise-scene. Noise is an inherent factor of most industries. But not doing anything about it is akin to allowing a well-planned systematic crime to take place despite having prior knowledge of it and having known means of preventing it. Being aware of the effects of noise on the human body (the workers to be precise), the architect is bound by ethics and integrity to keep his creation free from the hazards of noise. As all problems are best taken care of if nipped in the bud, the noise problem should be in the architect's list of priorities right from the conceptual stage of his design. Not that noise cannot be abated in an existing industry but control methods are most effective and economically beneficial if considered in the preliminary design stage. Each industry being different in view of product-output, size, location, machinery, etc., each has its own peculiarities regarding the sources of noise, persistence and levels of noise, frequency-content, etc. and, therefore, has to be dealt with as an individual case. The only generalisation may be as regards the maximum allowable noise level, the exposure-periods and the humanatarian awareness that workers have to be given the necessary protection.

In the case of a proposed industry, it shall be within the purview of the architect's basic services to gather all the information he can regarding the noise scene envisaged. Manufacturers of machinery supply information regarding the noise-level of each unit of machine. Where not provided (a very unlikely case), the same can be had from the manufacturer on request or the information-gap can be quite adequately filled up by case studies.

It is always economical and convenient to consider noise as a design factor. If the architect envisages a noise problem that will have an adverse effect on the users of his designed environment, he can readily go about designing his structures to minimise this. Zoning of spaces (noisy and non-noisy), noise tolerant and noise sensitive, selection of the appropriate materials and methods of construction, etc. can all be directed to solving the imminent problem. For instance, he may make use of cavity-walls to separate noisy areas from quieter zones; a proposition which would be expensive and often impossible in an existing structure.

It is always more difficult and less effective to control noise in an existing building or industry. The first step would be to find out if in the particular industry a noise problem exists or not. In searching for an answer to this query, the architect would have to measure the noise levels in the existing industry. This is done by means of a Sound Level Meter. Readings are taken at several points spread over the area in consideration in a systematic pattern.

Whether designing a new industry or trying to curb the effect of noise in an existing industry, the envisaged or existing noise levels would have to be compared with a standard to judge whether the proposed situation or the existing scene is harmful or harmless. Such comparisons are done with government codes, national standards, etc. In Bangladesh (July, 1984), there are no such government code, regulation, standard or practice limiting the level of noise upto which a worker may be exposed to.

It is only possible under the present situation to compare our findings with the standard allowable noise levels of other (most developed and industrialised) countries. Most national standards allow the workers in the working environment to be exposed to a maximum level of 90 dB for each eight-hour shift per day. According to most national standards, halving-time means allowing the worker an additional load of 5 dB. The very fact that different countries have their own code of practice, similar and dissimilar in many ways, show the diversity of the industrial situation in each country. Needless to say, we would be better off with a 'Bangladesh Code of Practice' pertaining to our own needs and demands. Noise control measures would only be effective if proclaimed by our government.

Through comparison with a "selected" standard, it is possible to identify the trouble spots and also to what extent the situation in consideration deviates from the allowable limits.

In controlling noise, it is not enough to find only the noise levels in dB(A). The frequency-content of the troublesome noise would have to be analysed in order to propose effective means of control, be it in the form of absorptive materials, erection of enclosures around the source or providing the workers with personal protective equipment. This is done be tape recording the noise at selected stations and then analyzing the taped material with a Frequency Analyzer in the laboratory.

Erection of enclosure around workers exposed to high-level noise:

This is usually done when the overall noise level results from many machines and when the worker is playing a supervisory role or operating (monitoring) one or more automatic machines. The enclosures must allow visual contact to be maintained with the machinery. Such enclosures are available readymade in many models and sizes in the developed countries. The enclosures as shown in the picture (APPENDIX - B) reduce noise by about 30 dB(A). This is very effective method and often provide more personnel protection than any other means.

Erection of enclosure around the source of high-level noise:

Blocking the sound transmission path is an effective means of controlling noise. The noise, in this case, is not allowed to reach the listener. This is usually done by placing an enclosure or acoustic screen around the machine. The inner walls of the enclosure are made absorptive.

Sometimes the machine, if dominant as a noise source amongst other machines, is isolated in a small area enclosure of fibreglass cloth and lead or lead-impregnated plastic. Such enclosure provide a "limp, dense sound barrier. The curtains, as they are called, can be opened to allow free movement of materials. Enclosing the noisy machinery with this curtain provide lower sound levels in adjacent areas. Only the operator of the noisy machine within the screen need to wear ear-protectors.

Vibration isolation:

This is of great importance when radiation of noise takes place through a building structure. Also, a remote part of the building may be a more efficient radiator of sound than the primary source. To be effective, the vibrating element will have dimensions that are equal to or greater than the wavelength of the frequency of noise. In order to minimize this transfer of energy between the sound source and a secondary radiator, it is necessary to provide some means of vibration isolation. It has been shown that only by vibration isolation a noise reduction of 5 to 10 dB(A) is possible. Generally, the impedences of the sound source and the secondary radiator are made different to effect vibration isolation. Low impedence material is an efficient means for controlling noise. Rubber and cork are effective vibration mounts because of their low impedences.

Acoustical Impedence pC :	Soft rubber	:	100
	Cork	:	165
	Concrete	:	14000
	Glass	:	20000
	Steel	:	59500
	Cast iron	:	39000

Noisy machinery on the ground floor can be isolated by mounting these on its own separate foundation.

Application of acoustic materials to reduce reflections:

Industrial plants often have unusually large reverberation time (3 sec or greater) because of large volumes and the highly reflective qualities of the walls, ceilings and floors. The result is that the entire plant is filled with reverberant sound with reflections being followed by more reflections. It is, therefore, necessary to stop these reflections if we want to reduce to noise level. Today, acousticians are able to reduce the reverberation time and the noise level by using

- i Sprayed-on materials
- ii Acoustic tile
- iii Resonant absorbers
- iv Diaphragmatic absorbers
- v Space absorbers

i Sprayed on materials are applied directly to the concrete walls and roof upto a thickness of 1-in. They are fire-resistant and can be applied easily over service lines and conduits. Reduction is effected by about 8 to 12 dB(A).

ii Acoustic tiles have excellent sound-absorbing qualities at high frequencies. Application of tiles to the ceiling alone will usually provide a reduction coefficient of 0.60 for ceiling area. For building spaces with heights of 9 to 15 ft, such ceiling treatment will bring the overall room absorption coefficient to 0.20, well above the recommended lower limit.

iii Resonant absorbers: These are specially designed units which appear like building blocks. They are efficient in absorbing low frequency sound of high intensity and are called Helmholtz resonators. They derive their sound- absorption qualities from being a "tuned" or resonant element. They can be used as a structural material for both indoor and exterior walls.

iv Diaphragmatic Absorbers: Effective for low frequency absorption of sound. They are usually in the form of large area panels. Light and flexible panels set into vibration with the advent of sound energy and thereby absorb sound. The rate of sound absorption by such a panel is proportional to the product of the amplitude and frequency of vibration, to its internal coefficient of damping, and to the frictional losses at the edges of its mounting. They are effective over a broad frequency range. Commercial fibreboards mounted to wood strips so that they can undergo vibration have absorption coefficient of 0.2 to 0.3 in the range of 1 to 2 K Hz. Effectively used in sound-recording studies and auditoria.

v Space absorbers: These are suspended members made of acoustical materials in the shape of hollow pyramids, spheres, cones, cubes, etc. They can be suspended at very low heights, thereby preventing sound from traversing to remote parts of the space. Space absorbers are ten times more efficient compared to other treatments for sound absorption using the same amount of acoustic material. Since sound is incident from many directions, the spheres, cones, pyramids, etc, are in a position to absorb more sound thereby increasing the total effective area of absorption as compared with a covered-ceiling. Location of such absorbers is also easy and they can be reused.

vi Job rotation: A worker need not work at a noisy station throughout his shift if the management can help. Workers can rotate from noisy to non-noisy or less noisy jobs during a shift through effective management system in order to reduce their exposure time.

vii Hearing conservation programmes: Limit of noise levels in the industries cannot protect everyone as there is a wide variation of response to noise. However, limits protect the majority and the hearing conservation programmes are employed to protect all the workers. Functions under the programme include plant noise surveys, pre-employment and periodic hearing tests and official record-keeping of noise exposure and hearing tests (audiometric tests). Workers who are susceptible to noise-induced hearing loss are identified through tests and given protection or quieter job stations to protect them before their damage renders them permanently deaf.

viii Personal protective measures: This should be the final resort in the endevour to control noise in the industries. Many national standards limit the use of ear protectors to interim control until other means of control are being accompolished and to areas where other means are not feasible or possible. Personal protective measures may be in the form of ear-muffs, ear-plugs or helmets. Their effectiveness depend on how well they fit and how carefully they are worn. Ear protectors should be selected by matching their attenuation characterstics to the Octave Band Analysis of the sound field.

3:2 INTERNATIONAL REGULATIONS FOR NOISE CONTROL IN INDUSTRIES(1)

It is not only in these days of motors, electric trains and jumbo jets that people are concerned about noise. For centuries attempts have been made to find ways and means of reducing its impact or do away with it totally. As far back as 720 B.C., the city of Sybaris, an outpost of Greek civilization in Italy, legislated a zoning system designed to isolate the industrial and residential sections of the town from each other. Julius Caeser, in the First century B.C., issued an ordinance banning chariots from the streets of Rome at night; obviously to protect the citizens from the noise they produced. Today, in Berlin, metal garbage cans are shielded with leather buffers to muffle their clatter. Even unwanted music has been dealth with. The university town of Tubingen in Germany has enacted regulations to protect its citizens from noise created by overenthusiastic music lovers.

The states of New Yourk, Wisconsin, Missouri and California have safety regulations designed to protect citizen against the hazard of job-connected hearing loss. In California, 322 workers sought compensation for hearing impairments in a single year and this prompted the California Regulations which set 95 dB as the maximum noise level to which industrial workers can be exposed. In cases where the sound level cannot be kept this low (as in aircraft plants) workers must be supplied with ear - plugs or helmets.

The American Academy of Opthalmology and Otolaryngology recommends that no worker can be exposed to continuous should level of 85 dB for more than five hours a day without protective gears.

Regulations are not enough. In New York city the Police issue each year an average 300,000 warnings and summonses to violators of noise regulations and yet the city is still noisy.

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(1) Occupational Safety & Health Series:
Noise & Vibration in the Working Environment (ILP)
Protection of Workers Against Noise & Vibration in the Working Environment: Code of practice (ILO)

The city of Memphis, Tennessee the anti-noise ordinance works because it is strictly enforced: as policeman with a noise meter is a common sight on Memphis streets. It works, too, because the ordinance is backed by severe panalties for violators: the maximum fine for violators in Memphis is $50/-, twice as much as a maximum fine in New York City.

Loudspeakers mounted on moving vehicles used in our country as a form of publicity system is a nuisance. The sounds emitting from these loudspeakers are mostly not intelligible to the ear and very often the voice of the announcers are perceived as gurgles. The sound level of these speakers are rather high and they are irritating to the people. This public address system is a common source of noise in our country. The system is practised both during day and night. Amplified music is part of most celeberations including marriages, picnic, etc. in Bangladesh.

Noise Exposure Standards:

Noise can be of varied nature (steady, impulse, etc.), industries vary in type, workers definitely respond differently from each other and most situations can be unique in terms of location, power, mounting of machinery, time of operation, etc. In view of these variations and numerout possible circumstances, fixing Noise Exposure Standards for industries have been the subject of much controversy.

Most of the Noise Exposure Standards proposed base their recommendations on the concept of protecting the employee from them loss of ability to understand speech. In most cases Impairment has been defined as an average hearing loss in excess of 25 dB at 500, 1000 and 2000 Hz. However, the ear being most susceptible at 4000 Hz, the Environmental Protection Agency, USA considers a loss in excess of 5 dB at this frequency as impairment. The British Occupational Hygiene Society propose a standard based on the concept of providing protection from loss in excess of that level at which the worker recognises he has a problem and is actively seeking medical assistance. These three concepts provide limits of exposure which vary widely.

Since 100 percent protection is neither technologically nor economically feasible, it is strongly believed that 95 to 98 percent of protection should be provided for the prevention of noise-induced hearing loss.

Permissible Noise Exposure: Continuous or intermittent

The American Conference of Governmental Industrial Hygienists(ACGIH) has recommended that for each halving of exposure time the limit of sound level be increased by 5 dB(A). The proposed limits of the ACGIH are as follows: these threshold limit values refer to sound pressure levels that represent conditions under which it is believed that nearly all workers may be repeatedly exposed without adverse effect on their ability to hear and understand normal speech. The ACGIH do not mention the distance between the speaker and the worker.

Duration per day (hours)	Sound level (dB(A)*
8	90
6	92
4	95
3	97
2	100
1½	102
1	105
¾	107
½	110
¼	115**

* Sound Level in decibels as measured on a standard level meter operating on the A- weighting network with slow meter response.

** No exposure in excess of 115 dB(A).

Impulse or impact noise:

It is recommended that exposure to impulsive or impact noise should not exceed 140 dB peak sound pressure level.

The US Environmental Protection Agency has recommended a limit of 75 dB at 4000 Hz for 96 percent of the exposed population.

Recommended Exposure Limits for Peak Sound Pressure Levels

Number of Impulses	Permissible limit (dB(A))
1	160
10	150
100	140
1000	130
10000	120

In formulating regulations and recommendations for the prevention of risks due to noise (and vibrations), particular attention should be paid :

a to the substantial reduction of noise (and vibrations) caused by machinery and sound-producing equipment and devices;

b to the enclosure orisolation of sources of noise (or vibrations) which cannot be reduced;

c to the reduction of intensity and duration of sound emissions, including musical emissions; and

d to the provision of sound-insulating equipment, where appropriate, to keep the noise of workshops lifts, conveyors or the street away from offices.

Should such action not be enough to aliminate harmful effects adequately, then :

a workers should be supplied with suitable ear protectors when they are exposed to sound emissions likely to produce harmful effects;

b workers exposed to sound emissions (and vibrations) likely to produce harmful effects should be granted regular breaks included in the working hours in premises free of such sound emissions (and vibrations)

c systems of works distribution or rotation of jobs should be applied where necessary.

NATIONAL STANDARDS

Most of the industrialised countries have rules concerning noise. The number, and the subjects dealt with, vary a good deal from one country to another.

In some countries standard setting and enactment of legislation are two virtually independent activities, for while, in general, standard setting makes for increased safety and better working conditions, its objectives are different. In some countries, the regulations are based on, or refered to, standards laid down by specialised bodies (ACGIH, ANSI in the USA, for instance). Some of these regulations refer to international standards (ISO and IEC, for instance) or even to the national standards in force in other countries (for instance, in Argentina).

In some countries - the USSR, Romania, Poland, Bulgaria, and Czechoslovakia for instance, the standards themselves are drafted by official bodies and are binding.

Hearing impairmant or occupational deafness are defined as follows according to various organisations:

a when the average permanent loss of hearing loss reaches 40 dB in the six bands from 500 to 6000 Hz after 30 years of exposure (British Occupational Hygiene Society)

b when the average permanent loss of hearing reaches 40 dB on the frequencies 1000, 2000 and 3000 Hz in the better ear (British Association of Ear, Nose and Throat Specialists and Department of Health and Social Security October 1973).

c when the pure tone or vocal audiometry, carried out after a period of 6-12 months without exposure to harmful noise, shows at least in the better ear an average hearing loss of 35 dB on the frequencies 500, 1000 and 2000 Hz;

(France 1963)

d when the average definitive loss of hearing on the frequencies 500, 1000 and 2000 Hz exceeds 25 dB (ISO and ANSI).

In many countries, loss of hearing due to noise is specifically recognised as an occupational disease. This is the case in Austria, Bolivia, Bulgaria, Colombia, Costa Rica, Czechoslovakia, Denmark, Ecuador, Finland, France, Federal Republic of Germany, Italy, Japan, Mexico, Morocco, Norway, Spain, Sweeden, United States, USSr, Yogoslavia and other countries. In the United Kingdom and India, deafness or loss of hearing of occupational origin are being actively considered for classification as occupational diseases for which compensation must be paid.

In Switzerland, a major loss of hearing caused by noise, according to Federal Council Ordinance of 17.12.1973, is an occupational disease. The Swiss regulations provide mandatory on the part of the employers to informed insured persons of any particular risk to which they are exposed by reasons of their work, and of the precautions required. Medical supervision is often called for.

In the USA, regulations provide that protection against the effects of noise must be provided if noise exceeds the figures given in the table and is measured on the scale of normal slow-response sould level meter. When workers are exposed to noise exceeding the figures in the table, all possible administrative and technical precautions are to be taken, and if even then the noise is not reduced below figures indicated, personal protective equipment must be provided and used to keep the exposure within the prescribed limits. Nobody must be exposed to impulse noise exceeding 140 dB.

In 1960, the Association of German Engineers in the Federal Republic of Germany published standards regarding the maximum permissible noise in places of work and residential areas; much of which was embodied in the circular of the FRG Ministry of Labour dated 22 March, 1961. The maximum permissible noise in workplaces is defined by a curve, passing through the following points 90 dB at 100 Hz, 80 dB at 1000 Hz and 70 dB at 10000 Hz.

In Poland, a decree enacted in 1959 lays down limits for noise in places of work :

a 40 dB(A) for work demanding a high degree of concentration;

b 50 dB(A) for workshops and other places where high precision work is required;

c 90 dB(A) elsewhere.

When speech has to be possible noise must not exceed 70 dB(A). Furthermore, the Polish Regulations recommend that attempt must be made to keep noise 5 dB below the permissible level.

Yugoslavia's regulations dates to July, 1971. It lays down the following codes :

a to protect hearing: 90 dB(A) is the maximum permissible for 8 hours' work per day.

b not to hampre speech:

Maximum permissible noise levels: speech interference

Noise in dB(A)	Distance in meters	
	Ordinary Voces	Loud Voce
45	7	14
50	4	8
55	2.2	4.5
60	1.3	2.5
65	0.7	1.4
70	0.4	0.8
75	0.22	0.45
80	0.13	0.25
85	0.07	0.14
90	-	0.08

c different levels are laid down for certain places of work as, frinstance, those in which it is important to be able to distinguish noises and those in which the work done is largely mental.

In Bulgaria, rules are laid down for vibration but for noise.

Maximum permissible exposure to noise in a place of work in dB(A)

COUNTRY	EXPOSURE TIME IN HOURS										
	16	8	6	4	3	2	1½	1	¾	½	¼
U S A	-	90	92	95	97	100	102	105	107	110	115
ACGIH-USA (proposed)	80	85	-	90	-	95	-	100	-	105	110
Canada	-	90	92	95	97	100	102	105	-	110	115
Alberta (Canada)	80	85	-	90	-	95	-	100	-	105	110
Argentina	-	-	95	100	-	105	-	110	-	115	-
Yogoslavia	-	90									
Poland		90									
		50 for high-precision work									
		40 for high-degree concentration work									
FR Germany		90 at 100 Hz									
		80 at 1000 Hz									
		70 at 10000 Hz									

Medical Prevention

In Belgium, provision is made for medical supervision for all industrial and other workers exposed to

a stable noise of at least 90 dB(A) for 40 hours a week
95 dB(A) for 20 hours a week
100 dB(A) for 5 hours a week
110 dB(A) for any period.

For pure sounds, the figures should be reduced by 5 dB(A);

b intermitent noise, when total exposure amounts to one of the above exposure times, for a particular noise level;

c 140 dB impact noise repeated 100 times a day.

The Medical Supervision prescribed comprises a preemployment and periodical examination. Pure tone audimetry is undertaken.

Laws in Spain passed in 1971 provides mandatory medical examination on recruitment. There is a second examination two months after the pre-employment examination and then a check-up every year.

In Switzerland, a mobile unit measures hearing of persons at risk under the supervision of the Industrial Hygiene Department of the National Accident Insurance Fund. The Department also colloborates with ear, nose and throat specialists and with hearing research and measurement centres in hospitals.

In Finland, hearing tests has to be taken every three years on workers exposed to continuous noise for 40 hours a week in excess of 85 dB(A). Annual examinations are provided for is levels exceeds 100 dB(A).

In the USSR, according to a Decree passed in 1969 by the Ministry of Public Health, workers have to undergo a pre-employment test and thereafter periodical medical examination to make sure they are not suffering from the effects of noise or vibration. Secpail attention is given to tests of hearing and of the central and peripheric nervous systems.

In Czecholovakia, according to regulations issued by the Ministry of Health, workers employed in noisy environments will have to undergo a pre-employment test and subsequent check-up once a year.

In Yugoslavia, persons working in areas where the noise level exceeds 90 dB(A) must be examined before employment and afterwords from time to time. Hearing tests are done by specialists.

Technical Prevention

In Belgium, the General Labour Protection Regulations proclaims: "All possible action must be taken to reduce at source exceesive noise and vibration caused by work or present in the working environment. Should it be impossible by technical means to obtain satisfactory reduction, workers shall wear suitable personal protective equipment supplied by the employer. The employer may in certain circumstances be obliged to reduce exposure time or to organise work breaks".

In Switzerland, government regulations (1969) stipulete the following :

a noise must be avoided, or reduced to the greatest possible extent;

b for the workers' protection, buildings must be properly designed, sources of noise must be accoustically insulated or isolated, work must be suitable organised and workers must be provided with ear protection.

In Norway, act dated 7.12.56 on labour protection requires the employer to ensure that, as far as possible, noise and vibration are eliminated.

Laws in France state that employers must ensure that noise is maintained at levels compatible with their workers' health by reduction at source, the isolation of noise workshops, the sound-profing of premises or the use of appropriate techniques or any other suitable means. Should action to ensure collective protection prove impossible or inadequate the workers must be provided with individual protective devices.

In Italy, the occupational health standards dated 16.3.56 state that whenever work produces tremors, vibration or noise harmful to health, technical action must be taken to reduce the phenomena.

In Spain, the Ministry of Health passed in March 1971 the Occupational Health and Safety Decree which states that noise and vibration must be avoided or reduced at source as far as possible. When noise exceeds 80 dB, and whenever noise cannot be reduced in any other way, personal ear-protectors must be worn by the workers. For noise above 110 dB and above, protection must be carefully designed.

In Austria, the competent authority can, if need arises, demand that special noise control measures be taken. The 1951 legislation demands that workers employed on certain kinds of work be provided with ear-protectors.

A Labour Code in Canada dated 02.11.1971 provides that when, in a place of work, the noise reaches 90 dB(A) or more, or percussive noise exceeds 140 dB at the peak sound pressure, the employer must put up notice at the entrances to such places warning people who enter of the presence of dangerous noise.

Personal Protective Equipment and Other Preventive Measures:

In Canada, regulations on Noise Control provide that the employer may allow his employees to go on working in work-places where noise exceeds 90 dB(A) provided each of them has been issued with, and wears, ear-protectors.

In Yugoslavia, the regulations state that if for technical reasons it is impossible to abide by the limits prescribed, the workers at risk must be issued with suitable individual protective equipment. (1969)

In Spain, when level exceeds 80 dB(A), protective devices must be used (plugs made of rubber, plastics, malleable wax, cotton or glass fibre). When noise is very loud, the staff must wear ear-muffs, anti-noise helmets of similar equipment.

In Argentina, Japan and Belgium among other countries, national regulations prescribe that individual hearing protection devices must be issued by the employer to workers employed in noisy surroundings.

In the USA, the regulations lay down that ear-plugs must be adopted and fitted, or individually chosen by some competent persons. Cotton wool alone is not enough.

In the USSR, the health standards provide that ear-muffs weighing between 200 and 500 gs. and exerting a pressure of 0.4 to 0.8 kg. on the ears must give a minimum attentuation of 5 dB in the low frequencies and of 25 to 35 dB at high ones. The USSR regulates that if preventive action proves ineffective in reducing noise bwlow the maximum permissable levels, workers' exposure time must be reduced by periodical job rotation, etc.

THE EEC DIRECTIVE:

The EEC has proposed a directive for implementation in the Member States in order to protect workers from risks to their health due to exposure to excessive noise. The terms of the directive are stringent in that the specified maximum noise level is below that of many current machine rooms. The EEC calls for regular checks of the noise to which the workers are exposed to as well as health checks on the workers.

The EEC directive seeks to impose two limiting levels of maximum permitted noise generation:

i a maximum level of 85 dB(A) to which a worker may be exposed continuously during a normal working day;

ii a maximum instantaneous level of 140 dBA.

To those unfamiliar with noise measurements, the logarithmic nature of the customary unit is misleading. An improvement from 85 dB to 80 dB or from 9 to 85 may appear to be a marginal change, but in fact, they represent reductions to half or third of the original noise levels.

The EEC proposes that use of ear-defenders must be regarded as an "exceptional temporary measure" to be employed only until the need for them has been eliminated Ear-defenders may worn if that represents the only means of complying with the requirement of prolonged exposure to a maximum of 85 dBA.

In addition to the employer's principal duty to maintain the noise level below the specified level, the employer in his own responsibility must measure and record relevant noise levels, arrange for annual examinations of workers who may be at risk and maintain individual records of such examinations. Employers will be required to employ qualified personnel to cope with these various requirements of noise measurements, noise reduction and medical examinations.

The EEC, as an introductory concession, suggests that for a maximum of five-year period, the upper limit for normal exposure may be increased to 90 dBA, although the application of this relaxation to the installation of newly-commissioned plants will be subject to scrutiny.

ACTS OF BRITISH PARLIAMENT:

The Health and Safety at Work Act of 1974 provides for the protection of workers against risks to their safety and health, including the risk of hearing damage.

The Control of Pollution Act, 1974 gives local authorities powers to protect the communcity against noise. Under Part III of this Act, a local authority may specify its own requirements to limit noise on construction and demolition sites by serving a notice that may in particular:

a specify the plant and machinery which is, or is not, to be used;

b specify the hours during which the work may be carried out;

c specify the level of noise which may be emitted from the premises in question or at any specified point on those premises or which may be so emitted during specified hours and

d provided for any change of circumstances.

CODES OF PRACTICE for reducing the exposure of employed persons to noise give recommendations for the maximum safe daily dosages of noise for the unprotected human ear. The accepted limit for an 8-hour exposure to a steady sound is 90 dBA. If daily dosage exceeds the safe limits, ear protectors should be provided.

Protection may be in the form of

a Ear plugs

b Ear muffs

c Box for employee

UK CODE OF PRACTICE :

Attempts to formulate a UK Code of Practice have been continuing for several years, but have yet to reach finality. The two principal pointsof difference between the draft code and the EEC proposals are that the maximum continual exposure lewel proposed in the former is 90 dBA, and this would be a recommended maximum and not a mandatory maximum.

Although the Code of practice would not itself have statuary backing, there is a provision in the Health and Safety at Work Act, 1974 which places duty on all employers to ensure the health and safety at work of their employees.

PART - IV

FORMULATION OF OPTIONS FOR NOISE CONTROL IN THE INDUSTRIES OF BANGLADESH

4:1 SCOPE OF NOISE CONTROL IN THE INDUSTRIES OF BANGLADESH

There is no scope to argue any further that the noise problem in the industries of Bangladesh constitute a serious human, social and economic problem. Noise exposure in our industries, as can be broadly inferred from the few case studies undertaken as part of this research, are of dangerously high levels. (90-103dBA). It would be presently unthinkable and unperceivable in the developed nations and in several developing nations that such a large number of workers (over 5,00,000 in major industries(1) are exposed unprotected by any means whatsoever to all the hazards and ill consequences of noise. The levels of noise in our industries are high enough to merit serious attention from all quarters. Since till date nothing notable has been done in Bangladesh as regards

- a recognizing the problem
- b assessing the extent of the problem
- c formulating means of controlling the problem,

It can be said with sufficient conviction that the scope of noise control in the industries of Bangladesh is tremendous.

The pertinent question may be: If the problem is so serious and the effects so harmful why have our workers not brought the matter up with the management ? The answer may lie in the fact that it is not possible for any layman to connect industrial noise (for that matter, any noise) with the pathological and psychological disturbances such as ulcer, palpitation, fatigue, etc. Moreover, in the economic context of this land, the working class constitute the minimal-income group(2) who are content with the work that earns them their daily bread and are hardly concerned with the working conditions pertaining to light, heat, sound, ventilation, etc.

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(1) Statistical Year Book, Bangladesh Bureau of Statistics

(2) The minimum wage of a factory worker is Tk.460/-

The prevention of noise is relatively costly[1]. But, a developing nation like Bangladesh may try to achieve sufficiently satisfactory results in noise control practices by employing local materials and contruction methods. Experts at a meeting held in 1974 at the International Centre for Advanced Technical and Vocational Training, Turin stressed that "measures taken at the design stage of new buildings, installations or processes, as well as when new machines, equipment or processes are introduced" should be (among other considerations) the basis of any noise prevention programme. Presently, industrial machinery is 100% import-dependent and, hence, there is nothing we can do to reduce the noise from the machinery itself. Our field of concern would be to control noise after the foreign-made machines have emitted the same. In this regard we can attempt to manipulate the following in our favour:

- a Volume of the space
- b Shape of the space
- c Foundation and mountings for the machinery
- d Application of absorbent materials on wall,ceiling,etc.
- e Judicious use of locally available materials

It must be noted here that it would be highly taxing on owners of industries to effect noise control in the industries solely by importing foreign materials and technology use of which is a costly proposal even in most developed nations.

The manipulation of the above factors would normally precede such other noise control measures as

- a the reduction of the number of jobs involving exposure to noise hazards
- b the reduction of exposure time
- c the use of personal protective equipment and
- d provision of appropriate information and training for exposed workers

(1) Noise and Vibration in the Working Environment: ILO

The buildup of sound levels in a room is due to repeated reflections of sound from the enclosing surfaces.(1) Reduction in the volume will result in reduced reverberation time and an improved situation. The shape of a space has a great deal to do with reflected sound from wall surfaces, etc. Careful handling of these during design stage can considerably negate reflections that aid in the creation of noise. In order to prevent noise travelling through the structure, it is essential to make the foundation of the machinery discontinuous with the main structure. Flexible mountings are often employed to isolate the machinery from the building structure. Otherwise the machine vibration may generate noise at a remote part of the building, where an element occurs with a corresponding resonant frequency. Locally available partex boards, gypsum boards, etc. are already being used successfully because of their absorbent qualities to reduce noise in other enterprises. The use of these materials with variations and combinations in methods of mounting can be effective in reducing noise level in our industries. The obvious building materials such as brick, concrete, mild steel frame, etc could be used to the advantage of noise control if their acoustic properties were studied and their usage guided by ensuing findings.

4:2 NOISE CONTROL BY PLANNING, DESIGN AND CONSTRUCTION METHODS

Noise generated in an industrial space will have two components :

i Direct sound emitted by the machines

ii Indirect or reverberant sound affected by the volume of the space and the nature and character of the materials and construction of the envelope of the space.

In attempting to control noise in a space, it shall be necessary to take into consideration both these components. The control of noise emitted by the machines is fundamentally the responsibility of designers and manufacturers of the machines and perhaps to some extent that of structural engineers who are responsible for designing the foundations for these machines. As a rule, machines in use in Bangladesh industries tend to be noisy because our industrialists, motivated by the cost factor rather than machine performance, opt in favour of importing the least expensive machinery. Quieter machines now being produced abroad are necessarily expensive. However, we may certainly formulate some measures to excercise reasonable control over the direct noise from machines. The architect's responsibility in this respect is generally confined to the following :

i Planning of the machine layout considering functional requirements and limiting the total machine noise in a space by isolating groups of machines in acoustically protective compartments or spaces.

ii Designing the envelope of the compartments with suitable sound insulation characterstics.

iii Erection of enclosures around the machines

As regards the reverberant component of the noise in the space, the architect's responsibility is greater, more direct and of utmost importance. It involves the following :

i Determining the geometry and volume of the space in consideration of the functional requirements and also in relation to the general acoustic requirements such as avoiding concentration of reflected sound in any work area and minimising the reverberation time by keeping the volume of the space to the necessary minimum.

ii Choosing materials and construction methods for the envelope of the space in relation to the functional, visual and acoustic/noise control requirements. Maximising sound absorption in the space without adversely affecting other requirements will reduce the reverberant noise; thereby reducing the total noise in the space. However, noise reduction in a space by absorption alone is not at all an efficient means as can be seen from the following chart:(1)

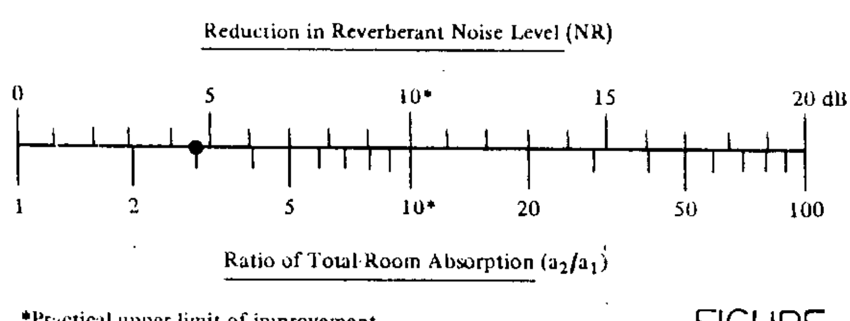


FIGURE 20

(1) Concepts in Architectural Acoustics by M. David Egan

The chart indicates that the reverberant noise level can be reduced by a margin of 10 dB if the amount of absorption is increased by more than ten times the initial value before treatment. Also this is practically the upper limit for most remedial situations.

Having outlined the general responsibilities and scope of work of the architect with respect to noise control in industries through planning, design and construction methods and having already reviewed the noise control theories and practices, we may now attempt to formulate a set of options for noise control measures in the industries of Bangladesh. These options will be necessarily of a general nature and by no means should they be expected to provide all the answers pertaining to the noise problem in any specific industry which will have particular characterstics. Nevertheless the options formulated will provide useful guidelines for local designers of industrial spaces. Furthermore, since the options are formulated with particular consideration to local materials and construction techniques, these will be found practically useful in the context of the situation prevailing in Bangladesh.

In order to proceed with the formulation of the appropriate options for noise control in industries in Bangladesh, we may examine the possibilities in the areas of planning, design and construction methods, in that order. For this phase of our study we shall use data and information collected from only one of the Case Studies because it is considered that this will not only be enough to establish the basis of our formulation but also the formulated options will generally be applicable to a large number of industries in Bangladesh for noise control purposes. The Case Study selected for study here is described as follows :

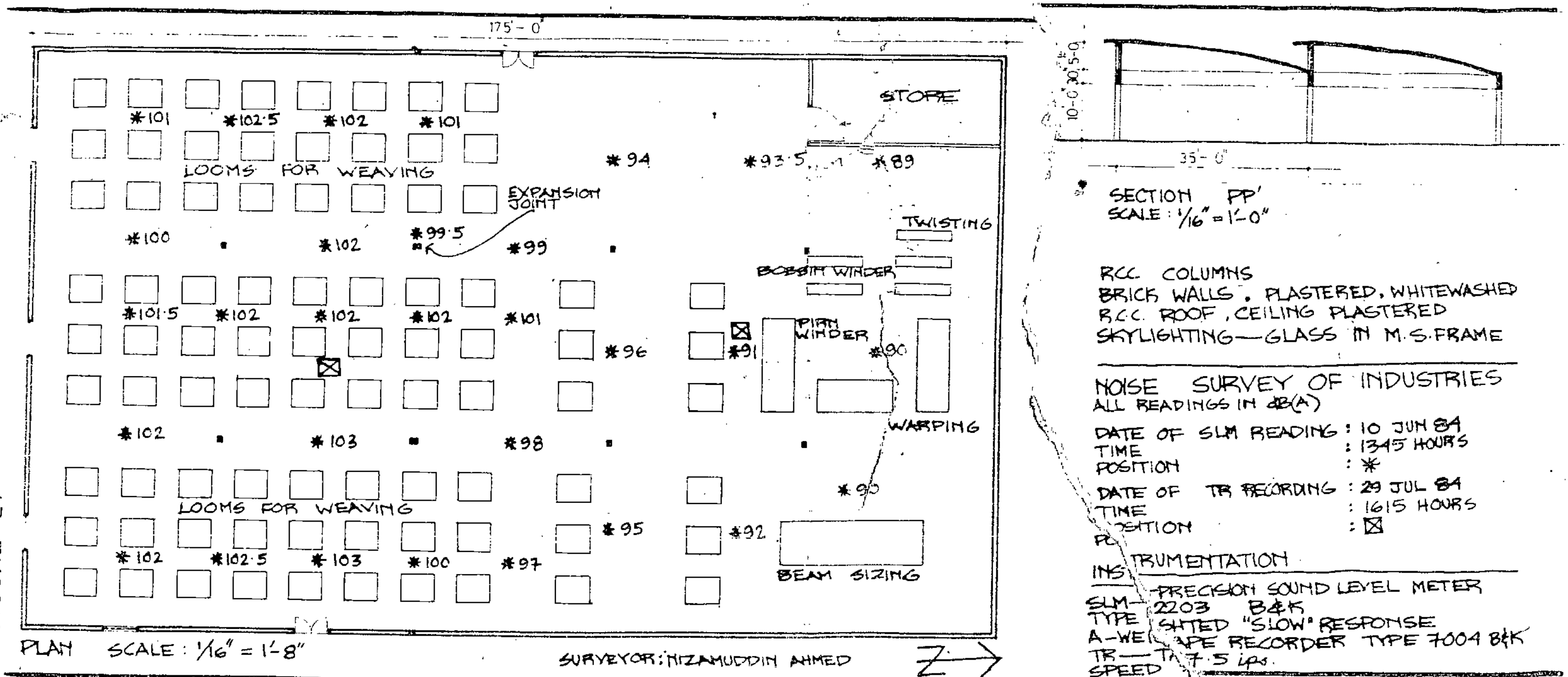


FIGURE 21

The machines are looms of a textile factory. There are also other ancilliary machinery and equipment in the space. The general pattern of activity is that each worker is stationed for the entire part of his 8-hour shift at his machine. Many workers sit and work. Except for the supervisors and the few labourers who move beams, etc. from one place to another, there is hardly any movement of workers. During summer many workers attend to their machine wearing sleeveless vests. Lungi is a common apparel.

Formulated Planning Options

Not all groups of machines in an industry are noisy to the same deafening level. In our Case Study it has been seen that the looms occupying 50% of the area generate levels of noise in the environment ranging from 97 dBA to 103 dBA. The other half of the space occupied by such functions as twisting, pirn-winding, beaming etc. have a much lower level of noise. (89 dBA to 96 dBA). It may not be very difficult to identify similar zones of high and low noises in most industries. Effective noise reduction/isolation may demand zoning of the industry into high, medium and low noise areas on the basis of the degree of noise generation and each such zone may be located in separate building structures, if permissible functionally. This may entail the following benefits :

i Restricting contribution of noise from high noise level zone to zones comprising of medium and low level noises.

ii Further noise control measures shall have to be applied only to the high noise level area, whose size has been considerably reduced on account of the separation and this will result in economic benefit.

iii Each zone will derive its architectural and functional identity from the separation.

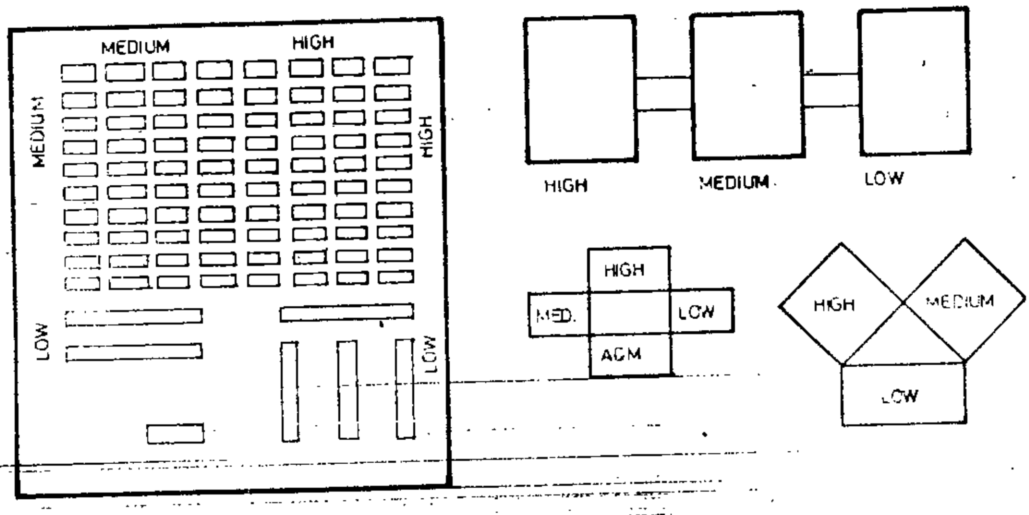


FIGURE 22

In our Case Study, the total area could have been separated into two zones — a high and a low level noise zone. The two zones could have been housed into two separated buildings to the obvious advantage of the low level noise zone.

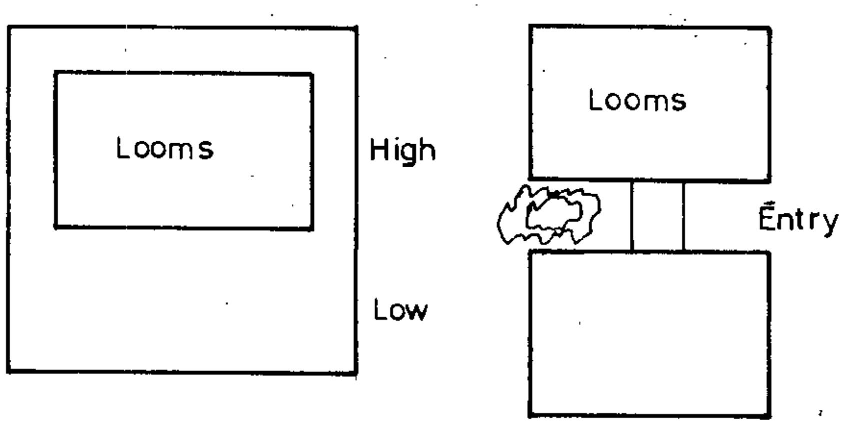


FIGURE 23

When a single building structure is unavoidable due to other demanding factors, isolation of groups of machines by noise protective enclosures on the basis of degree of noise emission and/or optimum number of machines in a space may prove beneficial towards noise reduction procedures. The architect may by careful planning and design reduce the number of machines in a space that contribute to the direct noise acting on the worker. It is simple mathematics that the noise effect of (say) ten numbers of machines emitting near-equal level of noise will be far less than the effect from (say) a hundred such machines.

If a number of equal decibel values are to be combined, 10 log n is added to the decibel value, where n is the number of equal decibel values.[1] Hence, supposing that a machine emits 100 dB of sound. From the formula and considering for the two cases n equal to 10 respectively, we get

for n = 10	10 log 10 = 10 x 1.0000 = 10	
	total noise : 100+ 10	= 110dB
Again for n = 100	10 log 100 = 10 x 2.0000 = 20	
	total noise : 100 + 20	= 120dB

Thus, it is evident that less number of machines would generate considerably less 'dB' levels.

The total number of machines may be isolated into smaller units/ groups which would be acoustically isolated from each other. Again, all the units together would be the entire factory. The snag in this system of "small units" is less efficient supervision because of lack of visual contact; a defect which can be overcome by utilising a composite construction, barrier wall made of brick and glass as shown below. Such an arrangement would provide

(1) CONCEPTS IN ARCHITECTURAL ACOUSTICS BY M. DAVID EGAN

sufficient transmission loss between the spaces and simultaneously provide for the much-required visual contact. Under special cases, the management may require to increase the number of supervisors but compared to the benefit accorded to the workers viz. improved working condition such added expenditure is worth the cost involved. A time may soon come as is already existing in the developed countries when the management of our industries will find the additional expenditure incurred on account of increased number of supervisors much more economical than meeting the claims of workers suffering from noise- induced hearing loss. Breaking up the factory into smaller units without affecting the work-pattern will increase efficiency as the workers will perform within a quieter environment. The isolation of units will mean that less number of machines will be effective noise-wise on the workers and, therefore, the indirect or reverberant noise will also be reduced. Less absorption will be required as compared with the larger factory space because of reduced indirect noise.

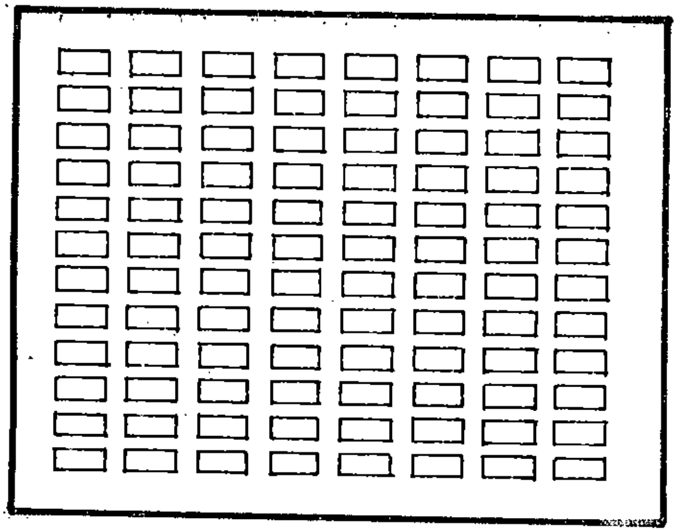
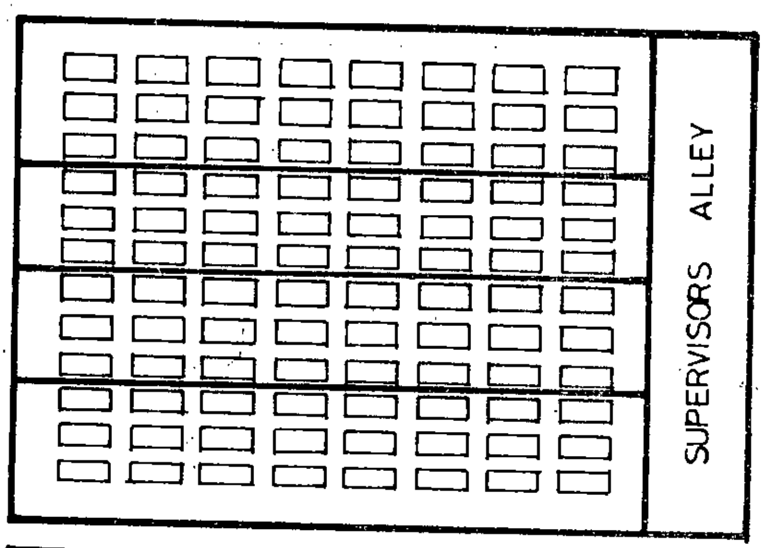
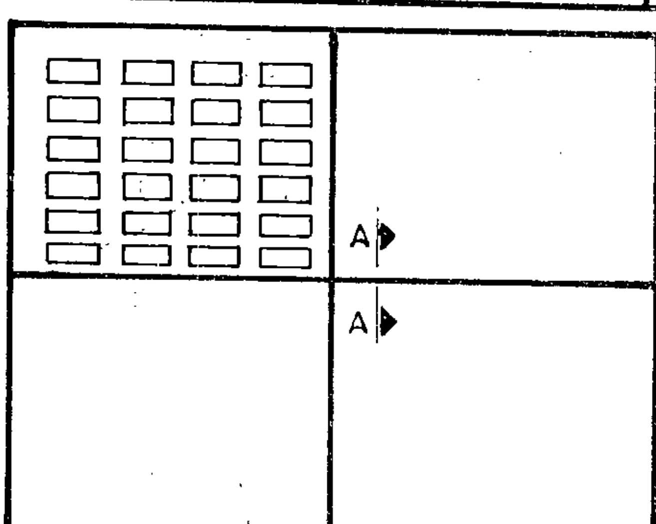


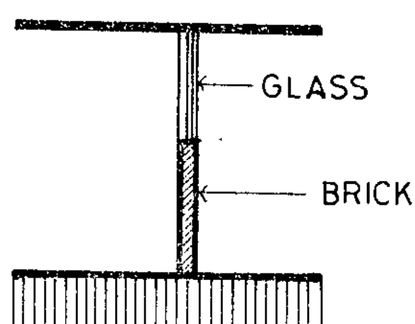
FIGURE 24

ALL THE MACHINES CONTRIBUTE TO DIRECT NOISE. LARGE AREAS OF ABSORPTION REQUIRED





1/4 OF MACHINES CONTRIBUTE DIRECT NOISE. LESS AREAS OF ABSORPTION REQUIRED



SECTION-AA

The advantages and disadvantages of planning into zones and isolation units for noise control is enumerated below :

Advantages

1 Less noise.

2 Unit supervisors will be more effective as he would be dealing with less number of workers.

3 Less area of absorption will be required as noise level would be reduced.

4 Creation of intimate courts and outdoor spaces because of the possibilities of variation in massing by smaller building blocks/units.

5 Worker will find his identity in a small group

6 Movement of beam, etc. regimented.

7 Sense of favourable competition amongst small groups of workers.

8 Day-lighting can be made easily available in small units with shorter spans/bays.

Disadvantages

1 Difficulty in supervision.

2 Additional cost.

3 Possible functional inconveniences.

Formulated Design Options

i Geometrical possibilities of the plan of industrial spaces:

The square plan will provide for dispersion of sound uniformly throughout the space. As a result, at any spot the 'dB'-value will be close to the average dB-value in the space.

Dispersion of sound may not be uniform particularly when the machines are in operation sectionally, in a rectangular plan. There may be several locals of relatively high level of sound, considerably higher than the average dB-level in the space.

The L-shaped plan will be advantageous from the point of view of zoning of machines of different noise levels.

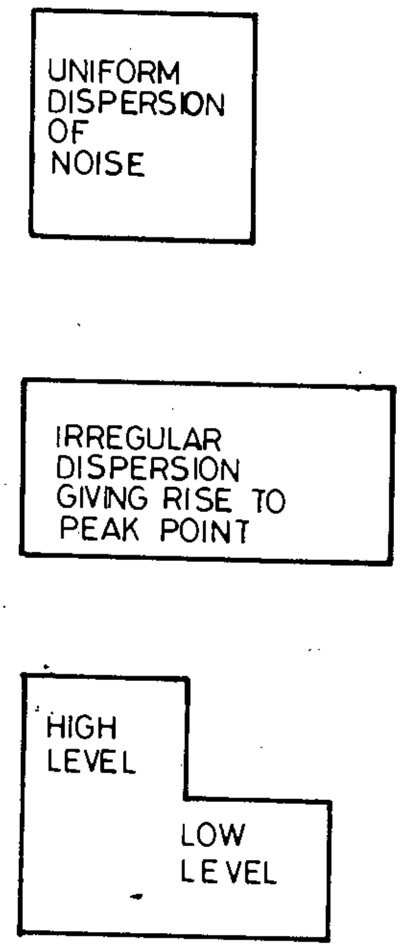


FIGURE 25

ii Possibilities of variation in height of the industrial spaces :

We know from Sabine's equation that R.T. = .05 V/A where,

R.T. = reverberation time in sec.

V = volume of the space in cu.ft.

A = absorption in sabines.

It is evident that reduced volume will mean less reverberation time. The case studies indicate that it is possible to lessen the height of the ceiling to reduce volume in many industries in Bangladesh. Shorter R.T. will result in reduction of indirect or reverberant sound, which in itself could be a noise control measure.

iii Possibilities of maximising the absorption in the space:

Absorption in a space has its consequences on the Reverberation time. The more the absorption the lesser the R.T.(from Sabine's equation). The soft materials used in looms and the clothed bodies of the workers in our Case Study will provide for significant absorption. Again, the hard plastered ceiling and walls will be reflective and will counter absorption. The industrial buildings in Bangladesh have, in most cases, the same hard and sound reflecting materials both indoors and outdoors. There is tremendous scope of introducing large amount of absorptive materials specially by way of using false ceiling to increase absorption. Low and absorptive false ceiling will be effective in two ways: (a) reducing the volume of the room and (b) increasing absorption in the space.

The following is an illustration using the data and information relating to one specific case study and proving the validity and also assessing the degree of noise reduction that can be achieved by manipulation in volume and quantity of absorption, generally speaking :

Calculations done for factory PQR.

Case - I : Plastered wall and ceiling, no absorptive materials.

Case -II : (i) Absorption in walls: (5'-0" from floor level to ceiling) 3/4" perforated partex board on wooden frame with 1" airspace separating it from the wall.

(ii) Functional Absorbers: Three-dimensional cylindrical forms made of porous tin sheet and filled with glass wool.

Case-III :(i) Absorption in walls: (5'-0" from floor level to ceiling) Porous gypsum board with glass wool backing.

(ii) Functional Absorbers: As in SET I. -

<u>Co-efficient of absorption</u>

Man and Machine	6
Plastered Wall/Ceiling	.02
Perforated Partex Board	.65
Porous Gypsum Board with absorptive backing	.80
Functional Absorbers	.80
Glass	.10

(Case under consideration is Factory PQR)

Number of Workers in the factory	100	
Wall Area Total	7100	sft.
Wall Area Above 5'-0" from floor to ceiling	4210	sft.
Glass Area	2625	sft.
Floor/ceiling Area	18375	sft.
Volume	213750	sft.

$$R.T. = \frac{.05\,V}{A} \quad \text{(Sabine's Equation)}$$

where R.T = Reverberation Time in sec.
V = Volume in cft.
A = Absorption in Sabines.

Case I

$$R.T = \frac{.05 \times 213750}{\underset{\text{Man}}{600} + \underset{\text{Wall}}{142} + \underset{\text{Glass}}{262.5} + \underset{\text{Ceiling}}{367.5}} = \frac{10687.5}{1372} = 7.79 \text{ sec.}$$

Case II

$$R.T = \frac{10687.5}{\underset{\text{Man}}{600} + \underset{\text{Wall}}{2794} + \underset{\text{glass}}{262.5} + \underset{\text{ceiling}}{367.5} + \underset{\text{Functional Absorbers.}}{5600}} = \frac{10687.5}{5623.3} = 1.11 \text{ sec.}$$

Case III

$$R.T = \frac{10687.5}{\underset{\text{Man}}{600} + \underset{\text{wall}}{3425} + \underset{\text{glass}}{262.5} + \underset{\text{ceiling}}{367.5} + \underset{\text{Functional Absorbers}}{5600}} = \frac{10687.5}{10255} = 1.04 \text{ sec.}$$

SOUND ABSORPTION: Reverberant Sound Pressure Levels from Sound Power Levels

EXAMPLE – Use of Graph:

Given: 50 hp pump with a PWL of 90 dB (re: 10^{-12} watt) at 500 Hz. Room volume of 5,000 ft^3 and reverberation time (T) of 1 sec at 500 Hz.

Procedure to find SPL: 1. Enter graph at volume of 5,000 ft^3 and read opposite T = 1.0 sec curve to $\simeq -7$ dB (see dashed lines on graph).

2. Therefore, SPL − PWL = −7 and SPL = 90 − 7 = 83 dB at 500 Hz.

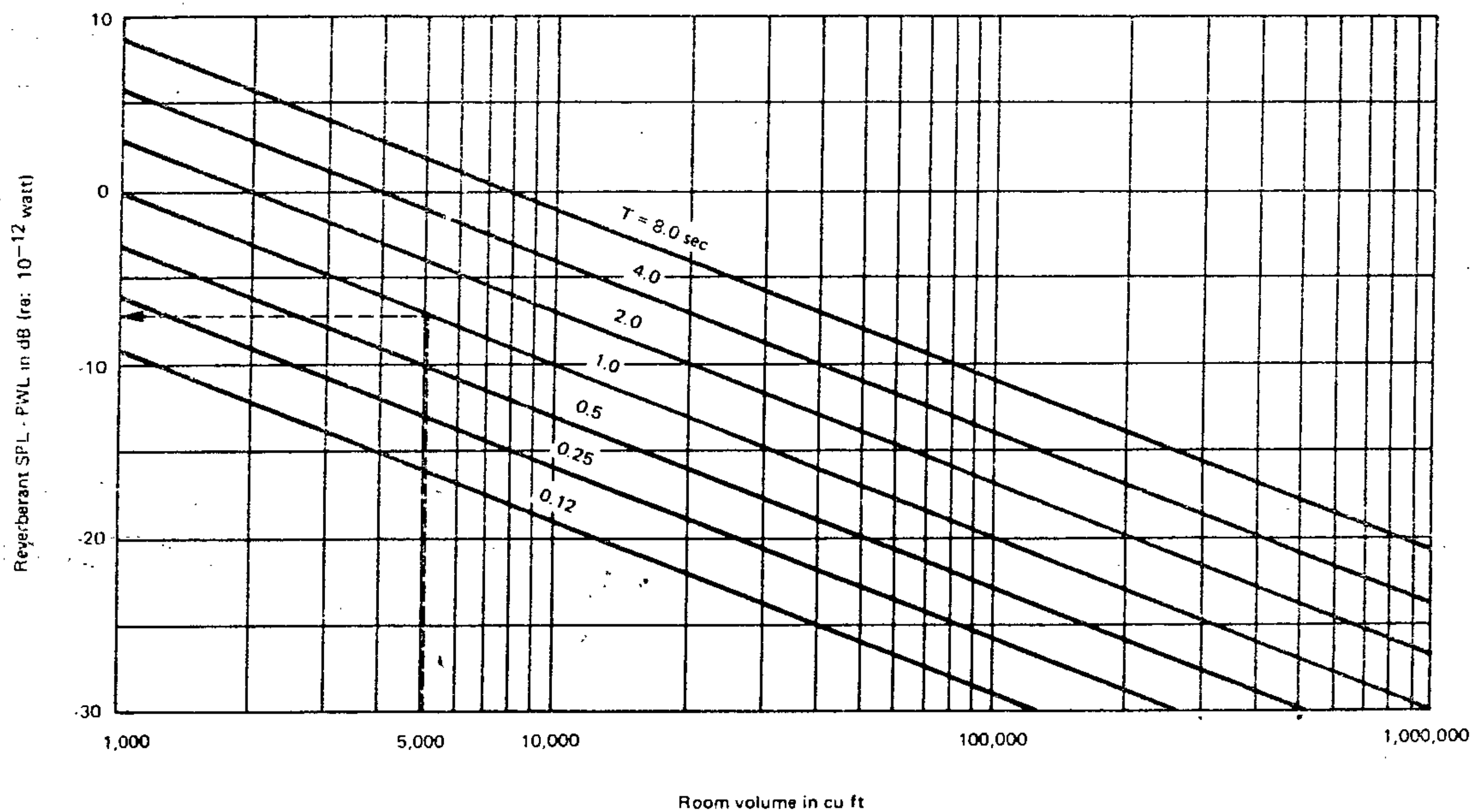


Fig. 26

(Using the Chart shown on previous page)

Case I : Prior to treatment

Volume = 2,13,750 cft.
R. T = 7.78 sec.

from chart, (SPL - PWL) = -14 dB.
SPL = 100 dB.
∴ PWL = (100+14) dB = 114 dB

Case II : With treatment (Wall-perforated Partex Board ceiling - Functional Absorbers)

Volume = 2,13,750 cft.
R. T = 1.11 sec.

from chart; (SPL - PWL) = -22
or SPL - 114 = -22
∴ SPL = 114 - 22 = 92 dB.

Case III : with treatment (wall- Porous gypsum board with absorptive backing ceiling- Functional Absorbers)

Volume = 2,13,750 cft.
R. T = 1.04
from chart, (SPL - PWL) = -23
(SPL - 114) = -23
∴ SPL = (114 - 23) dB.
= 91 dB.

Therefore, we may conclude that a noise reduction of 8 and 9 dBA respectively is effected by use of the two different types of absorptive treatment. Further reduction i.e. possible if we isolate the machines into zones of High & Low level noises.

Formulated Construction Options:

The method and type of construction employed in a building can to a great extent determine the noise level within. Generally, it can be said that massive and solid structure will resist noise transimission from one space to another while soft, resilient and vibrating objects in a space will absorb noise. Hard surface of solid and massive constructions, essential for effecting Transmission Loss(1), give rise to reverberant sound inside a space. Thereby contributing to enhancement of the net noise level in the space. It is therefore often necessary to introduce soft materials in a space along with the noise insulative treatments.

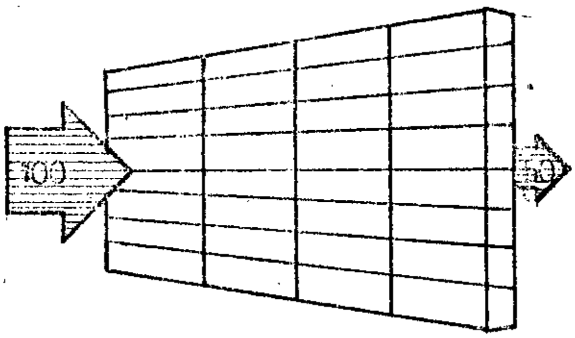
The architect may adopt the following methods of construction in attempting to reduce noise in the industry :

a Erection of walls and screens between noisy spaces to prevent transmission of noise from one space to another. The walls may be of all brick, combination of brick and glass (for visual contact) and combination of brick and absorbents. Situations in which construction of all-brick wall will negate efficient supervision of workers and thereby hamper production, it is essential to make use of the wall-glass combination.

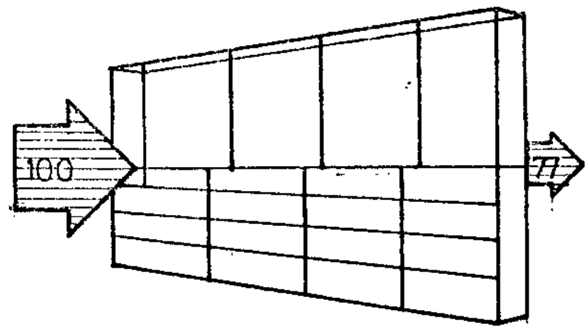
---

(1) Transmission Loss(TL) is the amount is decibels by which sound is reduced by passing from one side of the structure to the other.

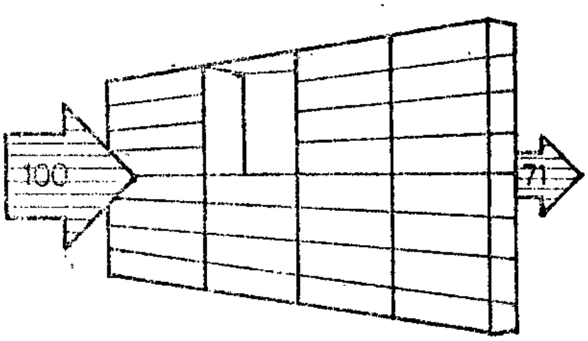
The following are some examples of walls and screens constructed for sound isolation along with their effective TL (b) :[1]



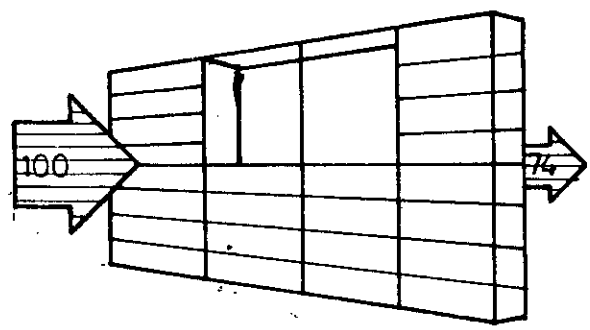
220 MM. ALL BRICK
TL= 50 dB



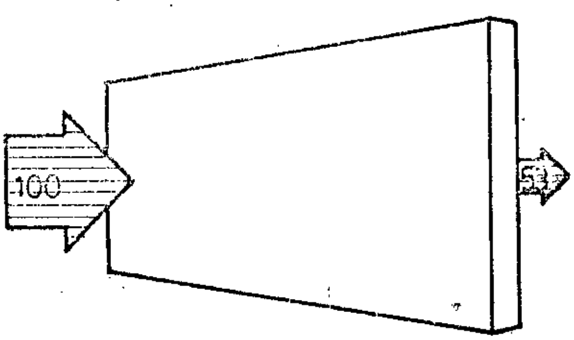
220 M.M. 1/2 BRICK 1/2 GLASS
TL= 23 dB



1/8 GLAS 7/8 BRICK (220 MM.)
TL= 29 dB



1/4 GLASS 3/4 BRICK (220 MM)
TL= 26 dB



150 MM. CONCRET
TL= 47 dB

FIGURE 27

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(1) CONCEPTS IN ARCHITECTURAL ACOUSTICS: M. DAVID EGAN

In the practical situation as exists in our Case Study, a construction of the combination of 50% brick and 50% glass may be the ideal solution in view of the constant supervision necessary. The entire factory space may be isolated into smaller units by using the above-mentioned wall-glass construction. This will effect a TL of approximately 23 dB between two spaces. We know that the average noise level in the whole loom area is appromimately 100 dBA. (see readings). This would mean by back calculation that each of the four smaller units would have a noise level of 94 dBA, approximately.

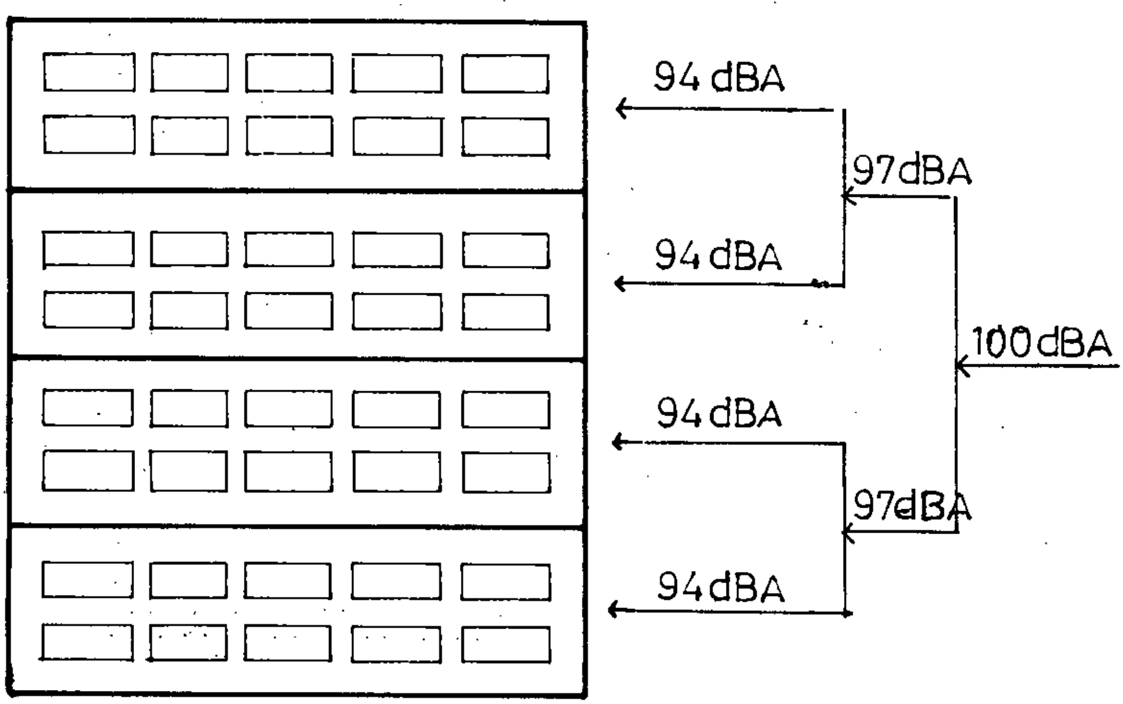

FIGURE 28

This would be the situation if the dividing walls were absolutely sound proof and there was no transmission of sound. However, with the construction of the wall-glass structure a level of noise amounting to 94-23 i.e. 71 dBA would be allowed to filter between the dividers. This would have to be added to the individual level of 94 dBA existing in each unit to find the total noise level in each unit. Addition of 94 and 71 dBA would result in 94 dB since the difference is more than 9 dBA.(1) A further reduction of noise level can be approximated by using acoustic ceiling and the task left to be tackled with absorbents now becomes less difficult.

(1) According to the rules of addition of noises.

Screens are very useful for absorbing directional noise from the source.(1) The screen is absorbent on the inside facing the source. The sound falling on this face will largely be absorbed and will thus be obstructed from contributing to the reverberant sound. Persons behind the screen will be protected from the direct sound, provided the dimensions of the screen are large compared to the wavelength of the sound.

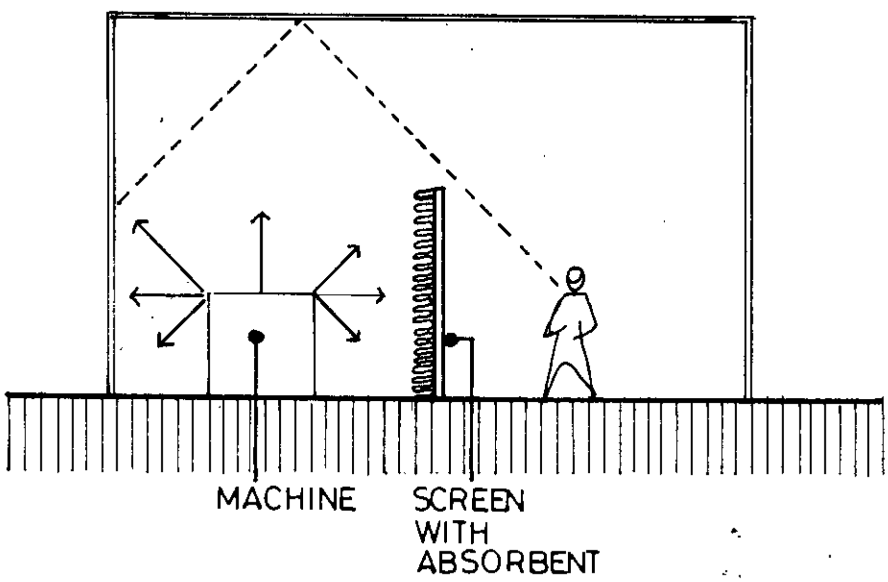

FIGURE 29

It is common sight in industries to see offices within provided only with screen walls (often glazed) and no ceiling. This type of construction is ineffective in providing insulation whereas the lightest type of ceiling would possibly have ensured noise reduction by approximately 20 dB[2]. Obviously, heavier ceiling and walls will provide greater reduction in noise level.

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(1) Acoustics, Noise and Buildings by Parkin and Humphreys

(2) Ibid

When it is necessary to absorb sound on both faces of a screen, absorbents should be used on the faces. For example, the the absorbent faces may consist of perforated hardboard over a layer of mineral wool on both faces. A single sheet of unperforated hardboard in the centre dividing the two layers of mineral wool provide an adequate barrier to sound.

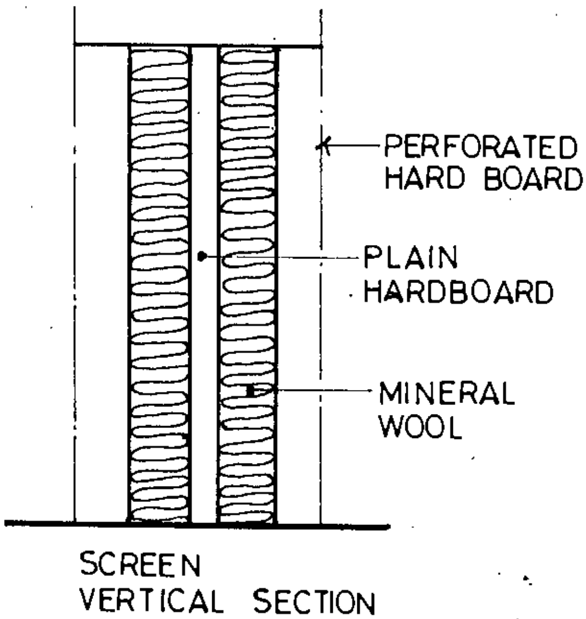


FIGURE 30

In the Case Study, using the two-way absorbent screen between the looms would prove to be very effective. The amount of noise reduced in this manner will depend on the type of absorbents applied to the screen face.

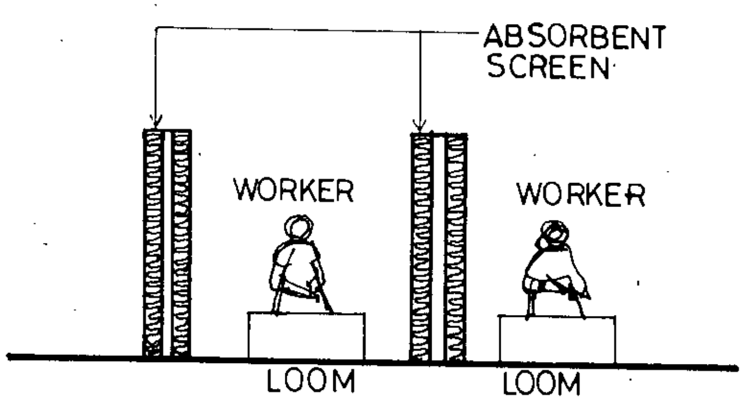


FIGURE 31

PART - V

DISCUSSION AND CONCLUSION

5:1 DISCUSSION AND CONCLUSION

The present study and investigation involved the following areas of concern in connection with the industrial noise scene in Bangladesh:

i Review of the effects of noise on man in general and on industrial workers in particular.

ii Review of the theories and practices of noise control in the industries.

iii Review of the laws, regulations and codes of practices for industrial noise control prevailing in different countries.

iv Case studies of some selected industries in Dhaka involving measurements of dBA levels in a systematic manner covering the work areas in them and comparing these values with internationally recommended levels.

v Recording the noise of a selected industry on a Tape Recorder and subsequently analysing the recorded material in the laboratory with the help of a Frequency Analyzer.

vi Formulations of options for noise control measures from an architectural point of view in the industries of Bangladesh on a broad and general basis with particular emphasis on the use of local materials and construction techniques.

Sound is an everyday phenomenon that we mistakenly tend to ignore. People living in noisy environments grow to accept noise as an obvious companion of their daily life, ignorant of the fact that notwithstanding their ability to tolerate noise, they are being physiologically and psychologically affected by it. The autonomic nervous system - that network of nerve fibres and ductless glands which regulates such involuntary functions as heartbeat, temperature, digestion and respiration - begins to react 70 dB, equivalent to the sound of traffic on most of our city streets.

Industrial workers are particularly susceptible to noise-induced diseases, auditive and extra-auditive, on account of the noisy character of their working environment. Industrial workers perhaps form the largest single group which is exposed to the hazards of high level noise. Noise in the industries and in other environments must be recognized as a growing national health problem and steps must be taken to stop it.

Noise in the industries may be controlled in a number of widely-varying ways. Several noise control theories and practices are in vogue in the developed countries and the present study has attempted to examine these mainly from a viewpoint of the architect's role. Methods of noise control include the following :

i Planning and Designing of industries with acoustical consideration.

ii Erection of enclosure around worker and around machine.

iii Vibration isolation

iv Use of sound-absorptive materials

v Job-rotation of workers to minimise exposure to noise

vi Regular tests under medical supervision to identify workers who are more susceptible to noise-induced diseases.

vii Use of personal protective equipment such as ear-plug, ear-muff, etc.

Laws and regulations pertaining to maximum allowable noise level in industries and exposure-time for workers is in force in most developed and several developing countries. Generally, the maximum allowable noise-level varies between 85-90dBA. while the exposure time is almost universally accepted to be eight hours. Each country has to promulgate regulations that best suits its purpose. This will depend to a great extent on the type of industries and the nature of machinery being used. In Bangladesh, there are no laws limiting the noise level in the industries. There is no mechanism either to measure the noise level in our industries. It may be concluded from the studies carried out that serious noise problem, well above the international recommended levels, exist in many of our industries. Considering that in Bangladesh, in keeping with employment conditions elsewhere, each worker works for an eight-hours shift each day, the maximum allowable time-exposure may be fixed at eight hours without hampering the existing system of practice and habit. However, in deciding to pin-point the maximum allowable noise-level in the industries of Bangladesh, a detailed survey of the actual position is required in terms of general types of industries and nature of machinery. Such a survey may be carried out by the Environmental Pollution Control Bureau. Being aware of the fact that reduction of noise in our industries will incur large sum of money, it may be advisable to adopt the higher noise-level allowed in other countries, namely 90 dBA, as the limiting noise level for our industries. A law or regulation would mean measuring the noise level of each industry and taking effective measures to bring down the level to allowable limits. It would be an economic proposition to enforce a law asking industrialists to bring down the noise level of their industries to 90 dBA rather than 85dBA. Generally speaking, it seems logical from the preliminary studies to allow a maximum noise level of 90 dBA for an eight-hour shift in Bangladesh industries.

Four industries in the Tongi-Joydebpur Industrial Area were selected with such varied functions as weaving by mechanical looms; manufacture of paper and hardboard; carding, samplix, twisting and spinning in cotton mills. The general character of the buildings are R.C.C. columns and beams with peripherial brick walls and either R.C.C. or C.I. Sheet roofs. Measurements were taken with a Precision Sound Level Meter (B&K Type 2203) with A-weighted "slow" response on a grid-iron pattern over the entire working area of each industry. Spot readings showed levels ranging from generally 85-100 dBA with certain areas recording levels as high as 103 dBA. The existing seriousness of the situation in our industries merits urgent attention of all those concerned with industries and the well-being of the workers housed within. The noise-level in our industries with reference to our Case Studies is well-above the 85-90dBA limit set in most international regulations.

Recognizing the fact that the noise level in all our Case Studies exceeded the allowable limits of international standards and that the selected industries had typical construction materials and methods, only one Case Study (Factory PQR) was chosen to carry out Frequency Analysis of its noise. This was done by recording the noise with the help of a Tape Recorder (B&K Type 7004). at two stations in the space. Third-octave analysis was carried out by the help of a Frequency Analyzer (B&K Type   ) and the results were recorded on a Level Recorder (B&K Type 2307).

The noise level on the following Octave bands were recorded :

20-63 Hz, 63-200 Hz, 200-630 Hz, 630-2000 Hz, 2000-6300 Hz and 6300-20,000 Hz. The analysis is necessary to identify the frequency bands where the noise-problem is most serious such that absorptive materials and forms may be recommended in view of their optimum performances in those troubled frequency bands.

The analysis shows that in the Case Study the maximum noise is emitted in the bands 200-630 Hz, 630-2000 Hz and 2000-6300 Hz. Locally available materials such as Perforated Partex Board, Porous Gypsum Board and manufactured suspended cylindrical forms made of porous tin sheet filled with absorptive materials are good absorbers of sound at the frequency bands that offer greater noise problem in our Case Study. It has been illustrated that noise reduction of upto 9 dBA is possible my maximum use of such absorptive treatment with mixed use of these locally - available materials.

Attempt has been made to formulate options for noise control measures in which the architect plays the predominant role. Such measures include

i Planning of the machine layout considering functional requirements and limiting the total machine noise in a space by isolating groups of machines in acoustically protective compartments or spaces.

ii Designing the envelope of the compartments with suitable sound insulation characterstics.

iii Erection of enclosures around the machine and the workers, separating man from machine in both cases.

The following options were discussed in this paper :

i Planning Options

ii Design Options

iii Construction Options.

In formulating the options, emphasis was given on locally-available materials and such methods of construction which are generally practicable in this country.

This Thesis Paper has succeeded in establishing that the noise problem exists in our industries in rather sever magnitudes. The problem recognized and analysed - the paper goes to certain lengths to suggest means of tackling the problem effectively with local materials and local construction techniques. The suggestions may be used as general design guide-lines by persons concerned with acoustical design of industrial spaces. This paper has also highlights the role of the architect in noise control practices. Sufficient published matter has been part of the study of this paper and the facts brought to light may evoke several professionals, especially those belonging to medicine and engineering, to embark upon serious research work pertaining to noise problem, its prevention and control; and the well-being of the workers.

It has been one of the purposes of this paper to stir awareness among Bangladeshi workers, industrialists, architects and engineers, medical doctors, government agencies and all concerned with the growth of industries and the well-being of the workers that noise in our industries exist at damaging levels, that it affects the workers, that there is tremendous scope of improving upon the situation and not necessarily by incurring heavy financial expenditures. If even a segment of the persons concerned have been made a little more aware than before, the purpose of the paper has been largely successful.

PART - VI

APPENDICES AND BIBLIOGRAPHY

NOISE-INDUCED DISEASES: AUDITIVE & EXTRA-AUDITIVE

It is important for persons concerned with the hearing loss of factory workers to know about audiometry and about the more common types of hearing defects. However, a reliable assessment of a person's hearing can be got by a proper clinical examination.

It has always been of interest to acousticians to know how loud a noise will cause serious damage to the ear i.e. damage the eardrum beyond cure or destroy the delicate ossicles. Experiments on animals and investigations of persons damaged by such accidents of exposure to loud noises, it appears that a sound as high as high as 150 dB will cause immediate damage permanently.

However, it is of greater importance to know of hearing loss caused by exposures over periods of time to the noise levels that occur in everyday life. Exposures to these noises cause more deafness; such as damage to the sensory cells of the inner ear, damage to the auditory nerve whence no surgical remedy is possible. Nerve deafness tend to affect at first the higher frequencies but will often, if severe enough, extend over the whole frequency range.

Temporary losses due to noise of low levels will soon be recovered. The period of recovery may be anything between a few seconds to months depending on the nature of the noise exposure and the person concerned.

Permanent hearing loss due to exposure to sound depend on many variables and hence it has been difficult to establish a safe sound level that people may be exposed to without risking damage to hearing. The variables are (a) loudness and nature of the noise (b) whether exposure is intermittent, (c) previous exposure of the person to noise (d) different physical reactions of different persons to the same noise.

Perforation of the eardrum caused by explosion, etc. will result in some loss of hearing. Most often, the eardrum will hear and hearing will return to normal. In extreme cases, it is possible to replace the damaged eardrum by an artificial one.

If the sensory cells in the inner ear loose their sensitivity or there is some defect in the auditory nerve, the resulting loss of hearing is termed as nerve deafness or sensory-neural deafness. This type of hearing loss is different for different frequencies and nearly always is greater at the higher frequencies (above 1000 Hz) than at lower frequencies. This type of hearing losses occur to people working under noisy conditions.

Sensory - neural deafness may be caused by very loud noise which can disrupt the corti and break down the sensory cells Blast or explosion - in war or in industrial accidents - can cause produce sudden and total deafness.

Boilermaker's Deafness is the damage to hearing due to sustained noise. It is an occupational disease among the riveters and others who work in extremely noisy environments over long periods of time Boilermakers Deafness does not destroy hearing completely but it makes the ear non-sensitive to many frequencies.

Occupational Deafness:

The physio-pathological process which takes place on the inner ear or cochlear apparatus rather progressively modifying hearing as a result of the effect of loud noise is termed as Occupational Deafness. The disease originates with the degenerative impairment of the neuro-sensorial cell of the Corti organ and the impairment of hearing progresses. It culminates in a complete exhaustion of the metabolites of the neuro-sensorial cells and their total wasting away from lack of nourishment. The disease can only be detected by the inability of the listener to perceive sounds, initially whispers, door bell and telephone bell and, as the disease progresses gradually and increasingly, conversation. The results of laboratory and x-ray tests are not characterstic at any stage of the disease.

A histological examination, the results of which would characterstically show the atrophy of the neuro-sensorial cells of the Corti organ, is possible only after death.

AUDIOMETRY

The measurement of hearing loss is termed as audiometry and the instrument used to measure this is known as an audiometer. This instrument produces pure tones at various frequencies and at pressure levels which can be adjusted over a wide range, but often only in 5 dB steps. The subject wears earphones and the level of the tone is set below the threshold of hearing. The level of the one of the pure tones is raised and the person is asked when he can just detect it. The test is usually done seperately for each ear. If the person has no hearing defects then the pressures indicated by the audiometer will be on the region of the bottom curve of figure below (fig.5). A person who has some defect in hearing will not be able to hear these tones at these pressures and the tones must be made louder before the deaf person can hear them. The amount by which the levels must be raised above the normal threshold is defined as "hearing loss". For example, an affect person may only just be able to hear at 1000 Hz a level of, say, 34 dB compared with the normal 4 dB i.e. he has a hearing lost of 30 dB at this frequency. A graph showing a person's hearing loss as a function of frequency is called audiogram (see fig.) pg.29.

It is advisable to use special rooms during such tests as noise level in the room will "masl" the test tones and the hearing loss measured inder noisy conditions may be higher than the true hearing loss.

Functional test of the hearing organs are carried out by :

Liminal pure tone audiometry by which routine tests are carried out within the frequencies 125 to 8000 Hz. This is the auxiliary method for diagnosing impairment of hearing and locating such damages.

Supraliminal tonal audiometry based on special tests used for a topographic diagnosis of perceptive deafness.

Vocal audiometry which helps in the rehabilitation of hearing and the selection of hearing aid.

Testing hearing by means of human voice which would be useful in Bangladesh in the absence of essential equipment, sound-proof room, etc. According to the test, in the initial stage of hearing impairment, the listener does not hear whispering or conversation at a distance of 0.5 to 1 m. The progressive characterstic of the disease in its final stage deprives the patient to hear loud conversation at a distance of 0.5 m.

The accumetric test which is widely used and the disease is diagnised by means of Weber-Rinne-Schebach test, also known as classical tests.

Objective audiometry is based on the examination of the cortical potential which appear after sound stimuli and is especially successful in cases of aggravation, retarded children, etc.

Cochleography which is complex but accurate method of diagnosing hearing impairment.

To carry out audiometric hearing tests the following are essential :

a Apparatus for pure tone audiometric tests (Liminal and supraliminal audiometry) :

The appliances would be able to produce all tones below 250 Hz at a level' not less than 5 dB. The frequencies essential for the audiometer are from 64 Hz to 11 584 Hz, in prectice from 128 Hz to 8 184 Hz, or in the case of decimal graduation, from 125 to 8 000 Hz. The intensity of production of pure tones should range between 0 and 100 (110) dB. The audiometers should have a built-in system for muffling noise.

b Apparatus for vocal audiometry: audiometer, test generator (magnatic tapes with standard phonetic tests) and an appliance to measure intensity to be used for phonetic tests.

c Objective audiometry requires built-in apparatus for audiometry, electroencephalography, and a computer for data analysis.

d Apparatus for cochleography are very specialised and are available at a very few scientific laboratories. These are not mass produced.

Sound proof room:

The construction of this room is based on the principle of acoustical and vibratory isolation. The walls of this chamber have to separated from the walls of the rest of the building by a space of at least 10 cm and the floor must rest on anti-vibratory supports. The resonance frequency of this room must be less than 10 Hz, the R.T. should be practically zero, the walls shall have to be accustically corrected with a substance (mineral wool, glass fibre, cotton, etc) whose absorption coefficient on the average is 0.99 (99%) at the lowest frequencies (125 Hz) during an audiometric test.

A quick test to detect hearing loss is based on apure tone audiometry for examining the stage of hearing at the frequency of 4 000 Hz only, at which according to recommended to carry out tests at frequencies of 2000 and 4000 Hz.

The behavorial pattern of a worker suffering from occupational deafness is reflected on the mental stage of the patient who/ moody and withdrawn from social contact among other negative signs.

Occupational deafness is a progressive disease is which can only be stopped by shifting the affected worker to jobs away from noisy environment. Spontaneous improvement is unknown in this disease as it involves an irreversible degenerative process provoking an atrophy of the neuro-sensorial cells of the organ of the Corti.

Evaluation of the impairment of hearing is carried out in order to establish the degree and pinpoint the localisation of defective hearing. Assessment of scope of loss of hearing is carried out with the help of established tables. The workers must also be assessed regarding their capacity to work in order to find out whether they should be allowed to continue or prevented from continuing to work in a noisy environment. The assessment requires :

a a complete set of data on the state of the ear for the case history;

b a case history of the work involved;

c physical noise measurements;

d audiograms obtained at the time of first examination (on employment preferably) and subsequent tests;

e an evaluation of the rapidity with which is pairment progressed during the period in question;

f data concerning the average loss of hearing of other workers engaged in same work.

It is of utmost importance to watch the rate at which deterioration in the impairment of hearing develops. The degree of impairment reached is not as much a factor as the speed. Therefore:

a all workers suffering from a rapid deterioration of hearing must be removed from noisy jobs. This is particularly important for young woekers with a relatively short period (less than ten years). Whenever a sudden and rapid progression of impairment is noticed in any age group (for any number of years of exposure), the concerned workers should be immediately removed from their noisy environment.

b workers with more than 15 years service in the noise area and who respond to show slight imapirment may be allowed to continue to work provided they undergo audiometric tests regularly.

c workers with very long period of work and suffering from medium impairment of hearing have to undergo audiometric tests every six months in addition being treated by audiologists.

d workers with long periods of service and suffering from serious impairment must be treated systematically by audiologists. For these group of workers audiometric tests are compulsory every 3-4 months. If the progression of impairment is obvious, it would be necessary to change jobs.

Workers whose individual sensibility to the effect of noise is particularly pronounced and persists throughout life are termed as Handicapped Workers by the ILO. Such persons may return to their noisy jobs provided that impairment has immproved during the period of non-exposure or abaence from noisy job. But, reassignment should only be allowed, according to ILO, only if the management of the factory (or working environment) has improved the working conditions (decrease in noise, etc.) so that they should not once more be exposed to the same hazards

In the evaluation of hearing impairment where auditive defects are determined by pure tone audiometry and according to the degree to which conversational area (512-4092 Hz) is affected. Thus, impairment is evaluated as follows:

- upto 30 dB : slight impairment
- upto 60 dB : medium impairment
- upto 80 dB : serious impairment
- above 91 dB: hearing is practically lost.

The hearing tests must be carried out by a team of qualified specialists such as :

- a physician-audiologist (or a specialist in ear, noise and throat specialised in audiology) or an occupational physician specialised in audilogy.
- a technician or audiometrician who will be in charge of all technical processes.

AUDITIVE EFFECTS OF NOISE

a Masking - The masked noises of low intensity (in presence of the higher intensity masking noise) would be less audible or totally inaudible creating a dangerous situation where the workers would fail to hear a warning of imminent danger against which he should seek protection. The situation would have been safer had the noises containing the warning signals not been masked. It would be increasingly difficult to locate a sound source in space in presence intense sound causing serious consequences as the closeness of danger may no longer be correctly parceived.

b Pain - High level sounds initially are annoying, then intolerable and later cause pain. At higher levels (130 dB), auditory sensation is replaced by pain.

c Auditory sensation - This is a predetermined motor response which takes place 100 to 400 ms (reaction time) after the source has emmitee sound. The time varies according to circumstances and on sound intensity and the physical and metal condition of the subject. The longer the reaction time the greater the risk of accident.

d Auditory fatigue - The threshold of perception is increase of sound level. That is the auditory sensivity is decreased and this is known as auditory fatigue. This depends on the duration as well as the intensity of the sound. Intensive noise of short duration may cause fatigue similar to that caused by less intensive noise but of longer duration. For auditory fatigue to occur sound level must be at least 60-70 dB. Below this level prolonged noise may not cause auditory fatigue.

e Pathological effect on hearing - Injury to the ear caused by very intense noise is called acoustic trauma. This is irreversible hearing loss. In damages due to industrial noise, the frequency band affected is centered around 4000 Hz. It is important to note that noise-induced hearing loss does not progress after exposure to the noisy environment is terminated. Moving a worker whose hearing has been damaged by exposure to high level noise to a quieter zone will be enough to stop further aggravation of the injury.

Effects on other organs of perception:

Exposure to very high noise levels may often disturb the sense of balance and give the impression of "walking in space". Higher noises may cause vertigo and nausea.

Psychological effects of noise:

It has already been said that noise by defination is undesirable, uncomfortable, annoying, etc. and such feeling being greatly subjective they can be termed as psychological effects of noise. Such initial feelings on exposure to noise may extend cause neurological disorders. Intellectual and psychomotore performances requiring concentration are affected by noise. Noise is discomforting as it most often makes speech (and sound signal) communication difficult. The cause-and-effect relationship between noise and observed mental disorders is not always easy to establish. The malaise may be a feeling of distress, discomfort, annoyance or surprise.

As soon as the noise appears, the listener may be startled or alarmed. Gradually as the noise prolongs a different type of physiological reaction takes place. The listener exposed to long periods of intense noise suffers from fatigue, lassitude sometimes accompanied by general debility. This may be followed by the development of various disorders such as giddiness, fainting, headaches, migraine, loss of appetite, loss of weight and anaemia by much of the reactions are subjective.

EXTRA-AUDITIVE EFFECTS OF NOISE

There are many extra-auditive effects of noise which, fortunately, are more or less reversible. Some of these are:

Among the extra-auditive effects of noise the following shouldbbe mentioned :

Effect of noise on the central nervous system

effect on cerebral cells:	Modifications of the cerebral bio-electric currents have been noted;
effect on cerebral micro-circulation:	there are noticeable changes in vascular tone, the special blood vessels having a tendency to spasms and the peripheral vessels a tendency to dilate;
effect of noise on the psychomotor area:	a disturbance of the psychomotor reactions; insufficiently precise gestures;
effect on the psychological area:	the effect of noise frequently results in disturbed behaviour, apathy, moodiness, fear, insomnia, etc.

Effect of noise on the balance organ

Extremely intense noise gives rise to giddiness, a-loss of balance, a hesitant gait, nausea.

Effect of noise on endocrinous glands

Under the effect of noise there is a temporary increase in the activity of the adrenal cortex (and of the medulla); there is an increase in the growth hormones of the phpophysis.

Effect of noise on the organ of sight

Coloured vision is weakened, there is slower receptivity of visual impressions, adaptation to darkness is slower.

Effect of noise on the Cardio-vascular system

effect on the eart :	accelerated pulsations in the "alarm phase";
effect on blood pressure	increased pressure at the beginning of stress only. Later no changes or a slight increase in distolic pressure; spasms in the peripheral blood vessels, the intensity and duration of which depend on the intensity and duration of the noise.

Effect of noise on the digestive system

Gastric pains may appear (intense spasms of the pylorus).

Effect of noise on electrolytes

A certain amount of retention of sodium (decreased diuresis) and loss of potassium.

Effect of noise on the quality of work and on productivity

Disturbances in the psychomotor area lead to mistakes in delicate work. Total productivity (in heavy work) is not decreased.

Effect of noise on blood

Noise has been observed to affect protein synthesis, an increase in transaminases and in phosphateses, and an increase in eosinophils.

The above examples refer to persons who are in good health (mentally and psychologically).

Preventive measure is noise control

It is obvious that prevention is better than cure. Preventive measures against hearing impairment requires a combination of medical and general protection measures and careful use of personal protection equipment.

Medical protection measures include:

- an audiometric test before recruitment ("audiometrical pedigree"). The maximum hearing deficiency in the conversational area must not exceed 20 dB.
- indicative post-stimulus tests during the first (examination;
- the periodical audiometrical tests. These must be carried out after one, two, three and four months of employment, and subsequently at regular intervals;
- the periodical test may in some cases consist of a rapid detection test, i.e. one carried out on a frequency of 4 000 Hz (or 4 000 Hz and 2 000 Hz).

General medical examinations could already at the recruitment stage detect a state of health which makes work in a noisy environment contra-indicated, such as: epilepsy and other organic disturbances of the central nervous system; purulent diseases of the ear and otosclerosis; cases of vestibulopathy: manifest disturbances of the vagal and endocrinous system; serious hypertension; coronary disease; stomach or duodenum ulcer; a manifest asthenia.

General measures and technical protection include: general measures, and individual measures.

General measures and technical protection are applied according to the following principles :

- planning of industrial sectors
- technological improvement in the work process and noisy machinery;
- prevention of noise at the source;
- prevention of noise transmission through floors or other areas; prevention of resonance;
- isolation of workshops and machines, or possibly enclosing them;
- soundproofing workshops (correcting the acoustics by means of absorbent substances).

It these measures are not sufficient to diminish the noise effectively, personal protective equipment is used.

Personal protective equipment for the protection of hearing

Means of hearing protection must satisfy the following must satisfy the following essential condition:

- they must prevent sufficiently the propagation of noise;
- they must not provoke skin irritation in the outer hearing canal;
- they must allow the transmission of signals for verbal communication;
- they must be easy to wear and clean;
- they must not be expensive.

Evaluation of the efficiency of personal protective equipment is based on a determination of the binaural hearing threshold in the free acoustical fields of persons with normal hearing, with or without the equipment.

Personal protective equipment may be helmet, earmuff or earplugs

The helmet is worn in workplaces where noise intensity is great.

It decreases noise by an average of 40-50 dB.

Advantages: it prevents the propagation of sound waves through the bone of the cranium. It protects the skull and may be fitted with a microphone to allow social contacts.

Faults: expensive, large and heavy.

The **earmuff** is also used in workplaces with intensely loud noise.

This decreases noise by 25-40 dB, and gives batter protection against high-pitched sound.

Advantages: it clings to the ear (Provided it is supplied with a layer of liquid which clings even to the folds of spectacle frames). It supplied with a microphone it makes conversation possible.

Faults: unpleasant to wear in hot premises or in summer.

Earplugs. are made of various substances and must correspond to the form of the outer duct. They come in five sizes. Another type consists of balls of cotton or cottonwool mixed with wax. Earplugs should be ware only on medical advice.

This decreases noise by 8-30 dB and gives better protection against higher pitched sound.

Advantages: very cheap, simple to distribute, easy to wear in workshops with a high temperature.

Faults: possible local disturbance, weak protection. with the ball variety jaw movements bring about cracks which allow noise to be transmitted.

In the case of persons with normal hearing the use of such equipment diminishes hearing fatigue and increases the perception of words (R.C. Coles). It noise above 100 dB is present words cannot be distinguished either with or without personal protective equipment. In this case conversation requires specially encased microphones or special signals emitted by machines.

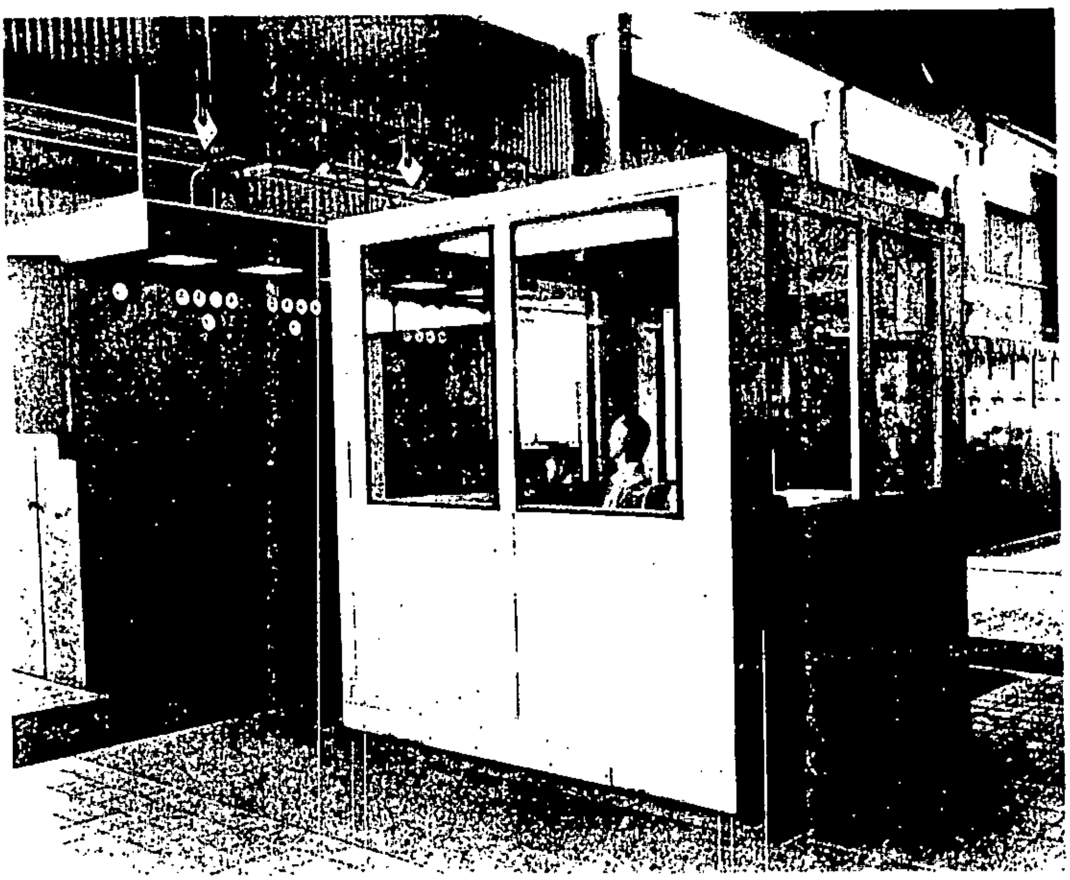
In cases of manifest deafness the persons concerned have to be tested (both with and without personal protective equipment) to evaluate their capacity to understand words in specific working conditions in order not to make it even more difficult for them to understand words and sound signals when they are wearing the protective equipment.

While providing the workers with personal protective equipment, it must be borne in mind that these can not be regarded as substitutes for technical prevention, Such protections are mere temporary means until such time as there has been made sufficient technical improvements. Workers must be induced and advised to use the personal protective equipment that is provided. However, workers must not be forced to use any particular type and they must be free to choose between different types and kinds of personal protective equipment. All such equipment must be tested for efficiency according to methods approved by competent authority. Care must be taken that such devices do not cause any undersirable effect and are comfortable to the user. The device should be appropriately suited individually to each worker's personal need and requirement.

It is not withing the scope of this study to take into consideration the effects of infrasonic (frequencies below 20 Hz) and ultrasonic (above 20000 Hz) waves on the body mainly because such conditions hardly ever occur in the types of industries generally found in Bangladesh.

Infrasonic sounds are present during the running of petrol-run lorry engines (10-20 Hz, 90 dB); diesel-run lorry engines (5-10 Hz, 102-103 dB); jet engines (1-20 Hz, 143 dB) and in compressor rooms with vibrating stands, turbines, etc.

Ultrasonic sounds are more rare as they are found when working with telescripters (24000 Hz, 40 dB); during mechanical welding of ships (38000 Hz, 58 dB); in aeroplane system engine (24000 Hz, 90 dB); in jet plane engine (18000 and 27000 Hz, 115 dB).



Prefabricated acoustic enclosure for personnel protection. (Courtesy of Industrial Acoustics Co., Inc.)

GLOSSARY OF TERMS

ABSORPTION
The conversion of sound energy into another form of energy, usually heat, when passing through an acoustical medium.

ABSORPTION COEFFICIENT
Ratio of sound absorbing effectiveness, at a specific frequency, of a unit area of acoustical absorbent to a unit area of perfectly absorptive material.

ACOUSTICS
The science of the production,control,transmission,reception and effects of sound and of the phenomenon of hearing.

ACGIH
American Conference of Governmental Industrial Hygienists

AUDIOMETER
Apparatus for determining a person's sensivity to pure tones as a function of frequency.

AUDIOMETRIC TESTS
Measurements of prson's threshold of hearing at selected frequencies.

AUDIOMETRY
The science of determining a person's sensivity to pure tones as a function of frequency.

BACKGROUND NOISE
The total noise in a given environment(Ambient Noise) above which signals must be presented or noise sources measured.

BANDWIDTH(EFFECTIVE NOISE)
The badnwidth of an ideal filter that would pass the same amount of power from a white noise source as the filter described. Used to define bandwidth of a thrid-octave and octave filters.

BRUEL AND KJAER(B&K)
Manufacturers of Acoustic Instruments and Equipment for laboratory and field tests. Based in Denmark.

CONSTANT BANDWIDTH FILTER
A filter which has a fixed frequency bandwidth, regardless of centre frequency.

CONSTANT PERCENTAGE FILTER
A filter whose bandwidth is a fixed percentage of centre frequency.

DECIBEL SCALE
A linear numbering scale used to define a logarithmic amplitude scale, thereby compressing a wide range of amplitude values to a small set of numbers.

FREE-FIELD
An environment in which there are no reflective surfaces within the frequency region of interest.

FREQUENCY
Rate of repetition of a periodic event. Measured in cycles per second.

FREQUENCY ANALYSIS
Obtaining the contributions to the overall signal made by the individual frequency band by filtering the signal in bands, whose width depends largely on the ultimate use of the analysis results.

HEARING CONSERVATION PROGRAMMES
Employed to ensure that each worker is protected although Noise Codes are designed to protect the vast majority of workers. The programme includes plant noise surveys, pre-employment and periodic hearing tests, interpretation of hearing tests, and official recordkeeping of noise exposure and hearing tests.

HEARING LOSS
An increase in the threshold of audibility due to desease, injury, age or exposure to intense noise.

HERTZ (Hz)
The unit of frequency measurement, representing cycles per second.

IMPEDENCE, SPECIFIC ACOUSTIC
The complex ratio of dynamic pressure to particle velocity at a point in an acoustic medium. Unit called rayls.

INFRASONICS
Sound at frequencies below the audible range, below about 16 Hz.

ISO
International Standards Organisation

ISOLATION
Resistance to the transmission of sound by materials and structures.

Leq
Continuous noise which would have the same total A-weighted acoustical energy as the real fluctuating noise measured over the same period of time.A-weighted energy mean of the noise level averaged over the measurement period.

LOUDNESS
The intensive attribute of sound by which sounds are classified from quiet to loud.

NOISE REDUCTION COEFFICIENT(NRC)
The arithmetic average of sound absorption coeefficients of a material at 250, 500,1000 and 2000 Hz.

OCTAVE FILTER
A filter whose upper-to-lower passband limits bear a ratio of 2.

OSHA
Occupational Safety and Health Administration

RVERBERATION
The persistence of sound in an enclosure after a sound source has been stopped.

REVERBERATION TIME(RT)
The time, in seconds, for sound pressure of a specific frequency to decay 60dB after a sound source is stopped.

ROOT MEAN SQUARE(RMS)
The square root of the arithmetic average of a set of squared instantaneous values.

SABIN
A measure of sound absorption of a surface. One metric Sabin is equivalent to 1sq. metre of perfectly absorptive surface.

SOUND
Energy that is transmitted by pressure waves in air or other materials and is the objective cause of the sensation of hearing . Commonly called noise if unwanted.

SOUND LEVEL
The level of sound pressure measured with a sound level meter and one of its weighting networks. When A-weighting is used, the sound level is shown as db(A).

SOUND LEVEL METER
An electronic instrument for measuring the RMS level of sound in accordance with an accepted national or international standard..

SOUND POWER
The total sound energy radiated by a source per unit time.

SOUND POWER LEVEL(PWL)
The fundamental measure of sound power.

SOUND PRESSURE
The dynamic variation of atmospheric pressure. The pressure at a point in space minus the static pressure at that point.

SOUND PRESSURE LEVEL
The fundamental measure of sound pressure.

TRANMISSION LOSS (TL)
The amount in decibels by which sound is reduced by passing from one side of a structure to another.

ULTRASONIC
Sound at frequencies above the audible range, above about 20 kHz.

WEIGHTING NETWORK
An electronic filter in a sound level meter which approximates under defined conditions the frequency response of the human ear. The A-weighting network is most commonly used.

WHITE NOISE
A broadband noise having constant energy per unit of frequency.

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