ARCHITECTURAL ACOUSTIC IN FACTORY

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A project report submitted in partial fulfilment of the requirements for the award of the degree of Bachelor (Hons.) of Mechanical Engineering

Faculty of Engineering and Science
Universiti Tunku Abdul Rahman

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DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR or other institutions.

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APPROVAL FOR SUBMISSION

I certify that this project report entitled **"ARCHITECTURAL ACOUSTIC IN FACTORY"** was prepared by **Lim Koo Ho** has met the required standard for submission in partial fulfillment of the requirements for the award of Bachelor of Engineering (Hons.) Mechanical Engineering at Universiti Tunku Abdul Rahman.

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Signature : _______________________

Supervisor : Mr. King Yeong Jin

Date : _______________________

Specially dedicated to

my beloved grandmother, mother and father

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Other than that, I would like to express my sincere appreciation to the KLG COTTON TWINE, the incharge manager, Mr Lim Ah Deh, for sharing his knowledge about the manufacturing process of cotton twine. Mr Lim also provides some important and useful comment to this research and his precious time spent. This research may not turn out to be success without his assistance.

In addition, I would also like to express my gratitude to my loving parent for their support and encouragement during my final year project period.

Last but not least, thanks to all of my friends for their advice, helpful, encouraging and supportive throughout the entire duration.

INDUSTRIAL ACOUSTIC

ABSTRACT

This research is related to the industrial acoustic. It emphasized on noise level study on a selected factory: KLG COTTON TWINE, located at Johor. The literature of permissible noise exposure limits is briefly surveyed. This study sought to determine the industrial noise level and the daily noise dose of the selected factory. The device used is type II sound level meter Proskit MT 4008. Besides, Site survey is done to get the value area and absorption coefficient materials. Samplings are taken at various locations within the factory. The obtained results were compared to theoretical results which is calculated results. All values obtained are compared with Malaysian Factories and Machinery (Noise Exposure) Regulations 1989. The obtained were then constructed the noise mapping. Suggestions on noise control were been discussed. Recommendations were been made.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS / ABBREVIATIONS

L_{eq}	equivalent sound pressure level, dBA
α	Sabine absorptivity
R	Room constant
$L_{p'}$	Measure sound pressure level, dBA
K_1	Correction factor related to the bottom noise (background noise)
K_2	Correction factor related to the surroundings reflections
A	equivalent sound absorption area of the room
S_v	total area of the surface of the test room
r	distance between receiver and sound source

SLM	sound level meter
SPL	sound pressure level
SWL	sound power level
Q	directivity factor
PEL	permissible exposure limit

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

Noise problems are eminent in industrial workplaces. In a manufacturing facility where a number of machines are concurrently operating, workers are constantly exposed to noise hazard. Generally, industrial noise control can be achieved by various means. Through proper design, maintenance, lubrication, and alignment of machines, vibration can be reduced which will subsequent lower machine noise levels.

In numerous reports the effects of high level of noise on auditory and non-auditory function have been well established. Hearing loss is the most obvious and the best quantified of the effects of noise. High blood pressure, poor work efficiency, annoyance and sleep disturbances are some of the non-auditory effects of noise.

The factory which considered in this report is Klg Cotton Twine and it specializes in manufacturing high quality cotton twine with distinctive design. Klg Cotton Twine located at 48, Jalan Kinabalu, Taman Koperasi, 86000 Kluang Johor. It is one of the leading twine and string manufactures and has been supplying innovative to the packaging industry in Malaysia.

Klg Cotton Twine manufactures twines in an infinite variety of sizes, thicknesses and specifications for a multitude of packaging and food requirements.

These products are used in the following industries: packaging, sewing, baling, butchery and general food. Cotton Twines are used very largely by the more traditional packaging Companies. Their uses are mainly the stationery trade, and for general purpose tying. The twines are made from cotton yarn.

Figure 1.1: Cotton twine

1.2 Problem statement

No one on earth can escape the sounds of noise - an unwanted, disturbing sound that causes a nuisance in the eye of the beholder. Noise is a disturbance to the human environment that is escalating at such a high rate that it will become a major threat to the quality of human lives. In the past thirty years, noises in all areas, especially in urban areas, have been increasing rapidly. There are numerous effects on the human environment due to the increase in noise pollution. Although we attempt to set standards for some of the most major sources of noise, we often are unable to monitor them.

There is an increasing rate of complaination by workers regarding to their hearing loss. Besides that, non-auditory problem such as high blood pressure, lazy also induced to industrial worker due to the noise pollution.

1.3 Aims and Objectives

The aim of this study is to make workers and management more fully aware of the risk of noise induced hearing loss.

The objectives of this project are identified as follow:

a) Provide a better understanding to the concept of noise pollution in industrial area
b) To find out the maximum allowable sound pressure level in industrial workforce
c) To find out the noise sources in industrial area
d) Investigate the sound pressure level and daily noise dose of a selected factory
e) Construct a noise contour map

1.4 Scope and Limitation of Study

This study is covered (23m x 68.5m) area of factory which manufactures high quality of cotton twine. The scope of this study is to understand, measure the sound level of the selected factory. The result obtained is then compared to the set of standards to make sure the sound level is within the noise limit.

In preparing this study, some of the limitations need to be considered. Equipment availability factor is one of major constraint and obstacle. Due to an only set of sound level meter available and provided by UTAR, I have to share this device with other students. A discussion is needed among other students and schedule is planned so as the devices can be shared and utilized. Besides, it is difficult to get forma approval from factory so as data can be recorded and obtained. After sent out several official letter to some of factories, that is one factory replied and allowed me to perform measurement in the factory.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

You have probably heard that loud noise can cause deafness. Various media articles tell us about teenagers losing their hearing at ear-splitting rock concerts, soldiers developing hearing loss from artillery fire, and people going deaf after an explosion. It also happens on the job when workers in factory are exposed to less intense but sustained noise over time. Construction workers seem especially affected because they often work around noisy vehicles and power equipment.

2.1.1 Characteristic of Sound versus Noise

A vibrating source produces vibration into the medium in which it is placed. These vibrations are propagated as waves in the form of pressure variations and are termed as acoustic waves. If they fall within the range capable of exciting the sense of hearing, they are called as **sound waves**. An acoustic waves travels in a given medium at a constant velocity. When the level of the sound becomes objectionable, it is called **noise.** Thus in general, the sound can be referred as a physical or mechanical disturbance capable of being detected by the human ear. The human ear can detect sounds from 20 Hz to 20,000 Hz. The frequencies most important for understanding normal speech like between 300 Hz. to 5,000 Hz.

The discrimination and differentiation between sound and noise also depends upon the habit and interest of the person/species receiving it, the ambient conditions and impact of the sound generated during that particular duration of time. There could be instances that, excellently rendered musical concert for example, may be felt as noise and exceptional music as well during the course of the concert.

Sounds of frequencies less than 20 HZ are called infrasonic and greater than 20, 0000 HZ is called ultrasonic. Since noise is also a sound, the terms noise and sound are synonymously used and are followed in this module.

In layman's terminology, noise is just unpleasant sound. Broadly speaking, Intensity is the energy of sound waves and Frequency is the number of times per second the sound waves hit the ear of man. On the basis of the above definition, the loudness which is the more commonly understood source of noise, is in fact a Combination of Intensity and Frequency which can be measured in DECIBELS**.** If we view through an oscilloscope, noise makes an uneven and jagged track on the screen in sharp contrast to the following track by a harmonious sound. Decibel is a unit of sound, name after Alexander Graham Bell**.**

Intensity – The level of sound is usually expressed in terms of the Sound Pressure Level (SPL) in decibels, which is defined as

SPL = 20 $\log_{10}$ P/P_O dB where P is the pressure variation measured in N/ m^2 and P_O is the standard reference pressure taken as 2 x 10^{-5} N/m^2

Frequency – Frequency of a sound wave is the number of times it repeats itself in each sound Human beings generally have the ability to hear sounds in the frequency range 20 to 20,000 Hz

(1 Hz = 1 cycle per second) The point at which the limit of the hearing threshold i.e., O dB, the sound pressure is equal to the standard reference pressure of 2 x 10^{-5} N /m^2. Human hearing is most sensitive to frequencies in the range 500 to 6000 Hz and less sensitive both at lower and higher frequencies.

2.1.2 Addition and subtraction of sound level

- Addition of sound level

If the sound levels from two or more machines have been measured separately and you want to know the total SPL made by the machines when operating together, the sound levels must be added. However, dBs cannot just be added together directly due to the logarithmic scale. Addition of dBs can be done simply using the chart opposite and the following procedure:

1. Measure the SPL of each machine separately (L1, L2).
2. Find the difference between these levels (L2 - L1).
3. Enter the bottom of the chart with this difference. Go up until you intersect the curve and then go to the vertical axis on the left.
4. Add the value indicated (ΔL) on the vertical axis to the level of the noisier machine (L2), this gives the sum of the SPLs of the two machines.
5. If 3 machines are present, repeat steps 1 to 4 using the sum obtained for the first two machines and the SPL for machine three.

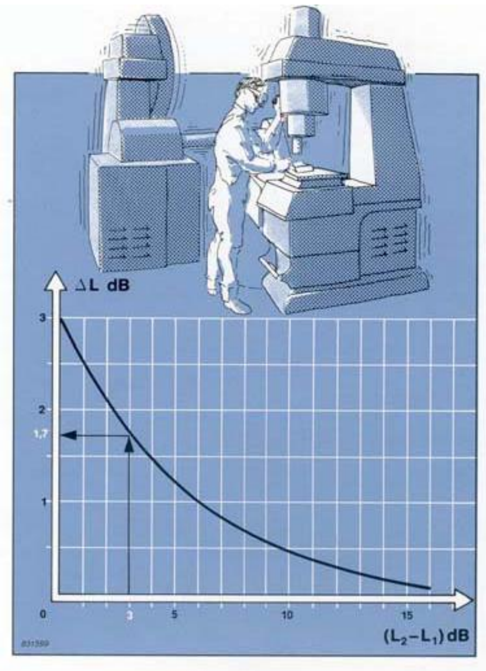


Figure 2.1.2a: Addition of sound level

- Subtraction of sound level (background noise)

One factor that may influence the accuracy of measurements is the level of the background noise compared to the level of the sound being measured. Obviously, the background noise must not "drown out" the sound of interest. In practice, this means that the level of the sound must be at least 3 dB higher than the background noise. However, a correction may still be necessary to get the correct result. The procedure for measuring the sound level from a machine under conditions of background noise is as follows:

1. Measure the total noise level (L_{S+N}) with the machine running.
2. Measure the background noise level (L_N) with the machine turned off.
3. Find the difference between the two readings ($L_{S+N} – L_N$). If this is less than 3 dB, the background noise level is too high for an accurate measurement. If it is between 3 and 10dB, a correction will be necessary. No correction is necessary if the difference is greater than 10 dB.
4. To make corrections, the chart shown may be used. Enter the bottom of the chart with the difference value ($L_{S+N} - L_N$) from step 3, go up until you intersect the curve and then go to the vertical axis on the left.
5. Subtract the value on the vertical axis (ΔL_N) from the total noise level in step 1. This gives the sound level L_S of the machine.

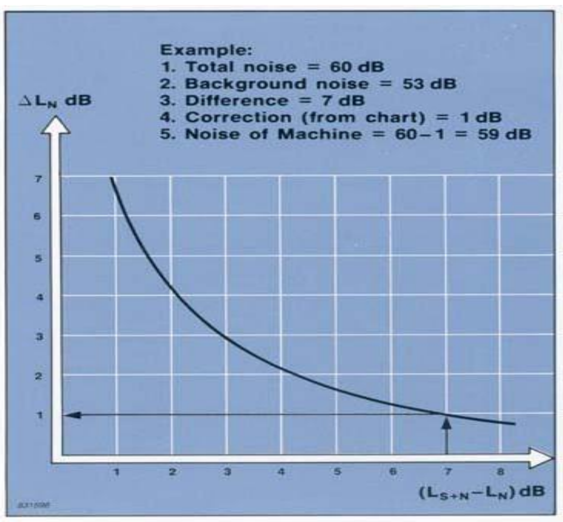


Figure 2.1.2b: Subtracting of background noise

2.1.3 Noise Pollution to Human Ears

Litter on the side of the road, junk floating in the water, and smokes spewing into the atmosphere from factory smokestacks are obvious forms of pollution**.** There are other types of pollution that are not as obvious. **Noise pollution** is one form. What is noise pollution? It is defined as sounds, or noises, that are loud, annoying and harmful to the ear. Often, sound pollution is thought to be a sound so intense that it could shatter glass, or crack plaster in rooms or on buildings. That is not so. It can come from sources such as jet airplanes, constant droning of traffic, motorcycles, high-power equipment, or loud music.

Most of society is now aware that noise can damage hearing. It is unlikely that many people today would become strongly motivated to do something about the problem. Yet, the evidence about the ill effects of noise does not allow for complacency or neglect. For instance, researchers working with children with hearing disorders are constantly reminded of the crucial importance of hearing to children. In the early years the child cannot learn to speak without special training if he has enough hearing loss to interfere effectively with the hearing of words in context (Bugliarello, et al., 1976).

We can hear a wide range of pitches from the squeak of a mouse to the low roar of a waterfall. We can hear over a loudness range from a pin dropping to the same roaring waterfall or a jet engine. But our ears do have their limits. Excessive noise can cause damage to the nerves in the inner ear. Our ears can recover from a short exposure to loud noise, but being around too much noise over an extended period of time will eventually cause nerve damage and hearing loss. The louder the noise and longer the exposure, the greater chance permanent damage will occur. A really loud noise, such as a gunshot, can cause immediate hearing loss, but that doesn’t happen too often on the job. Continued exposure to workplace noise over a number of years often leads to gradual, but permanent hearing loss.

Damage and hearing loss occurs in cochlea of inner ear.

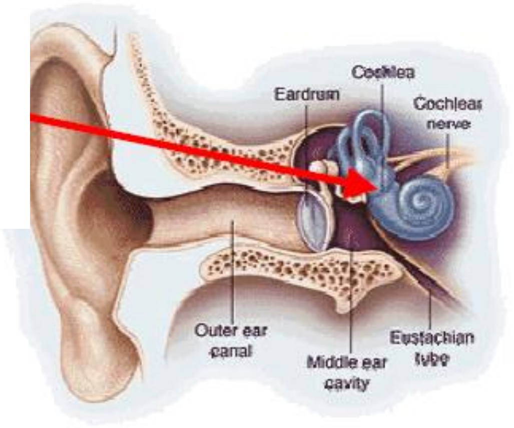


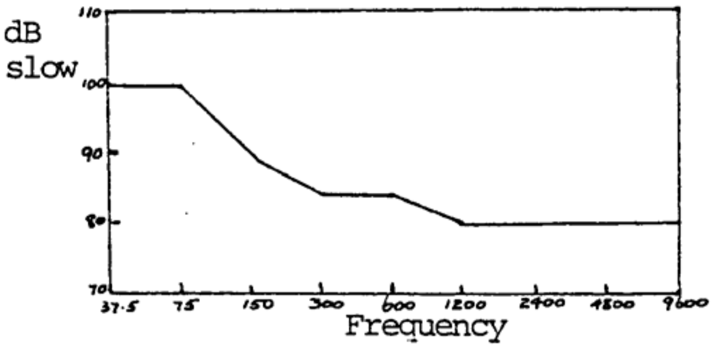
Figure 2.1.3: Hearing loss in cochlea of inner ear.

2.2 Indices of Noise Risk Level

In 1957 the American Academy of Ophthalmology and Otolaryngology accepted an 85dB level as a damage-risk level cut-off point for white sound in the 300 – 1200 c/s range. Previous studies had specified a damage risk level of 110dB for the 375 – 75 c/s range, reducing to approximately 95dB in the 300 – 600 c/s range.

American Standards Association data specified a 70dB cut off point for the 1200 – 1600 c/s range. (Litter, TS, Annals of Occupational Hygienists Association, Vol 1, 1958, p286).However, in 1960 Litter modified his work when he specified a damage risk curve based upon an eight hour day, five day week for a working life time. This measuring approach is known as the Burns-Litter damage risk curve and noise environments below the curve are preferred environments.

The Burns-Litter approach is unsatisfactory in that it is less flexible concerning age and ageing, individual susceptibility, exposure time and noise type, e.g., differing combinations of these factors are not easily incorporated in it.

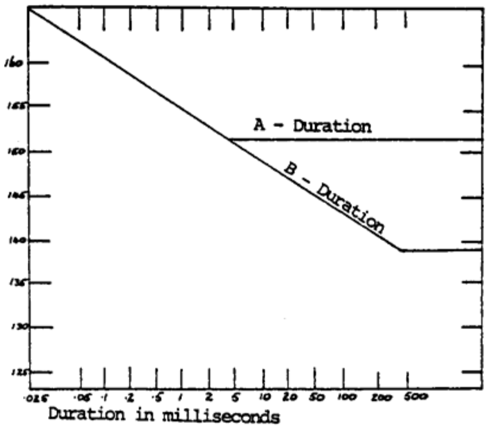


Source: Murrell, KFH, “Ergonomics: Man in His Working Environment”, London, Chapman & Hall, 1975, p285.

Figure 2.2a: the Burn-Litter damage risk criterion

These factors have been increasingly acknowledged in risk criteria developed subsequent to the Burns and Litter publications.

In 1966, the Committee on Hearing, Bioacoustics and Biomechanics of the US National Research Council established a criterion (the CHABA criterion- Figure 2.3b) based on the octave band analysis of sound.



Source: ILO, Noise and Vibration in the Working Environment, Geneva, ILO, 1976

Figure 2.2b: CHABA criterion for impulsive noise

This was followed by the ACGIH criterion in 1969 when the American Conference of Governmental Industrial Hygienists expressed risk levels in dB (A). They used a total noise level concept.

Table 2.2a: the ACGIH criterion

Noise Intensity in dB(A)	Length of authorized presence during one working day
90	4 – 8 h
95	2 – 4 h
100	1 - 2 h

Source: ILO, *Noise and Vibration in the Working Environment*, Geneva, ILO, 1976

In the same year the Japanese Industrial Hygiene Association set down a criterion. Like the CHABA criterion, it is an octave band analysis approach and is said to roughly correspond to a 90dB (A) fence (Geneva, ILO, 1976,).

In 1971, the International Standards Organization published an octave band analysis criterion based upon a 50 week working year over a 45 year working life. In this criterion a relationship is established between the noise to which an occupation is exposed and the % of workers whose hearing threshold has been raised by 25dB (A) or more when audiometric testes are made at 500, 1000 and 2000 Hz. The ISO criterion incorporates impulsive noise by adding 10dB (A) to the measured level.

Also in 1971, the British Occupational Hygiene Society published a criterion (BOHS criterion based upon dB (A) maximums over an eight hour day, five day week for a 30 year working life. It is briefly surveyed in Table 2.2b.

Table 2.2b: The BOHS criterion

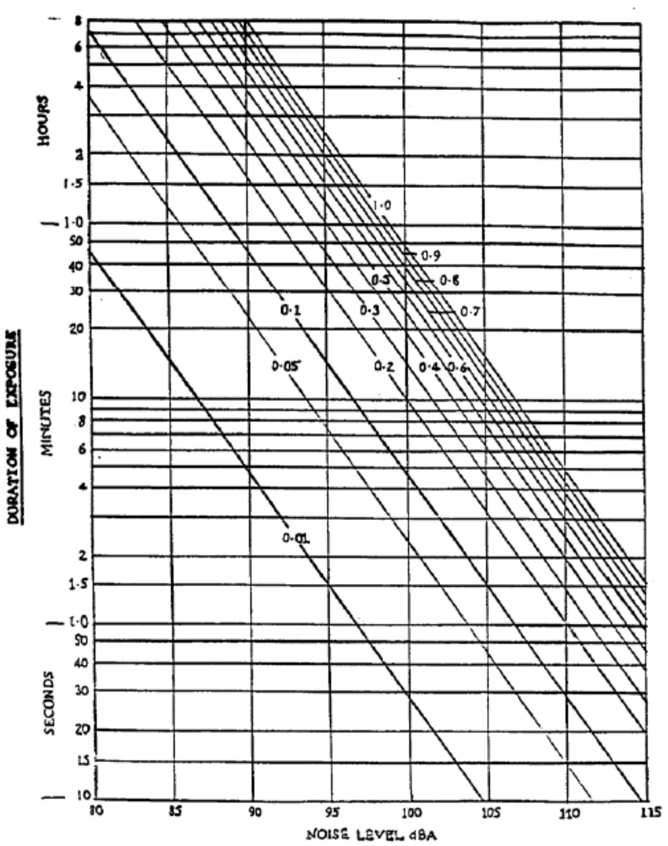
Duration of exposure in hours per day	Maximum noise level in dB (A)
8	90
6	91
5	92
3	94
2	96
1	99
0.5	100

Source: ILO, *Noise and Vibration in the Working Environment*, Geneva, ILO, 1976

It is difficult to compare these criteria to select the most appropriate one because they differ in the units in which comparison could be made. They can all be shown to correspond to a criterion which has a 90dB (A) fence as its upper total noise risk level.

Subsequently and more recently, individual countries have begun to set codes which are based very closely in prescription upon the ones surveyed above. In Australia, regulations have been drafted to incorporate a 90dB (A) maximum permissible level with a reduction to 85dB (A) within five years. No worker is to be exposed to noise levels in excess of 115dB (A). The regulations also address the medical examination of workers at risk, hearing tests, and the provision of protective strategies and equipment. Rule 11 of the Factories and Shops Act, 1960-1970, Queensland, is an example of the state of the art in Australia.

It is interesting to note that the nomogram incorporated in Rule 11 (Figure 2.2c) is also the one used by the National Health and Medical Research Council in its 1976 publication. This body also espouses the idea of a 90dB (A) come 85dB (A) fence, but Rule 11 makes no mention of this figure using a more general statement of upper limits around.



Source: Queensland Government, Queensland Factories and Shops Act 1960, Brisbane, Government Printer, 1960, Rule 11.

Figure2.2c: Daily noise dose calculation chart

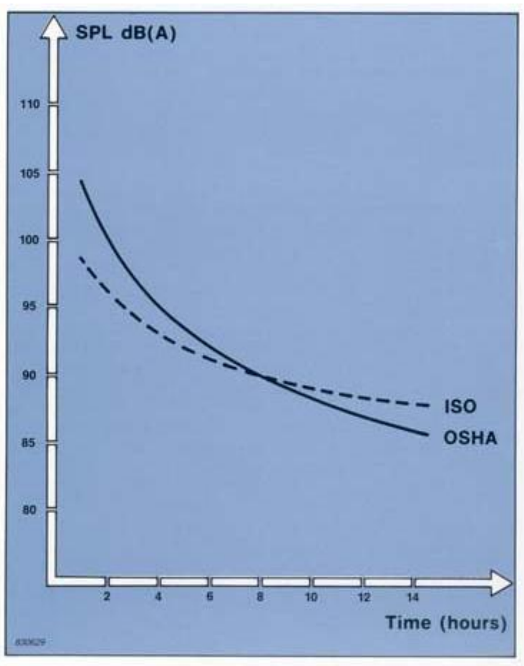
2.3 Noise Dose

Noise exposure measurements on individuals who move between many different noises environments during the working day can be obtained using Noise Dose Meters**.** These instruments are portable and can be carried in a person's pocket. The microphone can be separated from the dose meter body and should preferably be mounted close to the individuals more noise exposed ear.

Noise dose meters display the percentage of the daily allowable noise dose. Two different ways of calculating the noise dose are used. The difference between the two methods is due to the allowance incorporated for the recovery of hearing during quiet periods. Currently, both methods essentially use a basis of 90 dB (A) for an 8 hour day.

The International Standards Organization (ISO) 1999 defines one method which uses only the energy criteria and makes no allowance for the recovery of hearing. Thus, an increase of 3dB in the sound pressure level halves the permissible exposure period. For example an increase in sound level from 90 dB (A) to 93 dB (A) must be accompanied by a halving of the permissible exposure duration from 8 hours to 4 hours.

In the United States the Occupational Safety and Health Administration (OSHA) defines another relationship which permits a 5dB increase in sound level for each halving of the allowable exposure period. Thus, an increase in sound level from 90 dB (A) to 95 dB (A) is accompanied by a halving of the allowable exposure duration from 8 to 4 hours.



Source: Bruel & Kjaer br0047

Figure 2.3 Noise dose meter

2.4 Acoustic in Industrial Area

Industrial machinery and processes are composed of various noise sources such as rotors, stators, gears, fans, vibrating panels, turbulent fluid flow, impact processes, electrical machines, internal combustion engines etc. The mechanisms of noise generation depend on the particularly noisy operations and equipment including crushing, riveting, blasting (quarries and mines), shake-out (foundries), punch presses, drop forges, drilling, lathes, pneumatic equipment (e.g. jack hammers, chipping hammers, etc.), tumbling barrels, plasma jets, cutting torches, sandblasting, electric furnaces, boiler making, machine tools for forming, dividing and metal cutting, such as punching, pressing and shearing, lathes, milling machines and grinders, as well as textile machines, beverage filling machines and print machines, pumps and compressors, drive units, hand-guided machines, self-propelled working machines, in-plant conveying systems and transport vehicles. On top of this there are the information technology devices which are being encountered more and more in all areas.

Noise is therefore a common occupational hazard in a large number of workplaces such as the iron and steel industry, foundries, saw mills, textile mills, airports and aircraft maintenance shops, crushing mills, among many others. In many countries, noise-induced hearing loss is one of the most prevalent occupational diseases. According to a Environmental Protection Agency (EPA)/USA report in 1981, there are more than nine million Americans exposed to a daily average occupational noise level above 85 dB (A); this number has increased to about 30 million in 1990. Most of these workers are in the production and manufacturing industries (Table 2.4).

Studies in Germany and other industrialized countries have shown that the proportion of those exposed to daily average noise levels above 85 dB(A) can generally be taken as 12 % to 15% of all employed persons; that is 4 to 5 million persons in Germany (Pfeiffer 1992). After many years of exposure to noise, there are numerous cases of occupationally related hearing damage recognized as the occupational disease "noise-related hearing impairment" according to the Occupational Diseases Ordinance.

Table 2.4: Workers exposed to daily L_{Aeq} exceeding 85 dB (A)

Sector	Workers exposed to daily L_{Aeq} exceeding 85 dB (A)
Agriculture	323000
Mining	400000
Construction	513000
Manufacturing and Utilities	5124000
Transportation	1934000
Military	976000

Source: EPA, 1981

An analysis in Germany of working equipment and processes in operational noise areas with a hearing impairment hazard has shown that 80 % of the - several million – sound sources can be attributed to machine operations, conveying systems, control and regulation devices and turbo machines, while 20 % are accounted for by manual working and conveying operations. About three quarters of the machine operations can be attributed to machine tools (Damberg, Foss 1982).

2.4.1 Sources of Industrial Noise

Sound fields in the workplace are usually complex, due to the participation of many sources: propagation through air (air-borne noise), propagation through solids (structure-borne noise), diffraction at the machinery boundaries, reflection from the floor, wall, ceiling and machinery surface, absorption on the surfaces, etc. Therefore any noise control measure should be carried out after a source ranking study, using identification and quantification techniques. The basic mechanism of noise generation can be due to mechanical noise, fluid noise and/or electromagnetic noise (Allen, 1970 and ISO/TR 11688).

Below table illustrated the example of machinery noise sources. It presented most common machine used in industrial installation. For each case, the mechanism, of noise generation is discussed.

Table 2.4.1: Examples of machinery noise sources

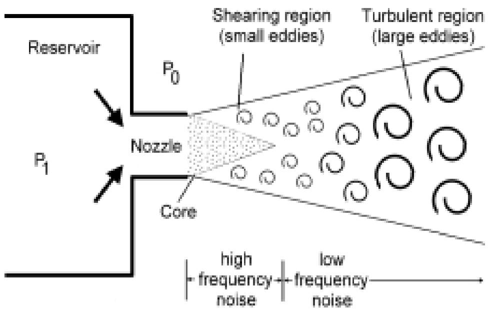
<table>
<tr><th>Machine</th><th>Mechanism</th></tr>
<tr><td>Industrial Gas Jet


Figure 2.4.1a: Noise Source in Gas Jet</td><td>Reservoir compressed air pressure is usually in the range of 300 to 700 kPa. The air acceleration varies from near zero velocity in the reservoir to peak velocity at the exit of the nozzle. The flow velocity through the nozzle can become sonic (reaches the speed of sound). This result in a high generation of broad-band noise with the highest values at frequency band between 2 to 4 kHz.</td></tr>
<tr><td>Ventilator and Exhaust Fans

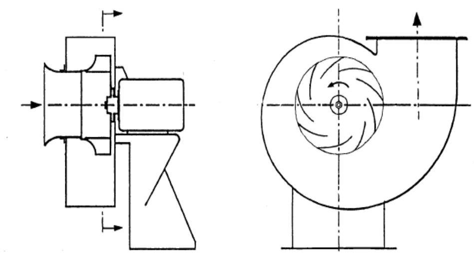
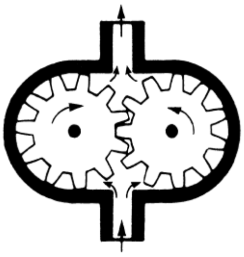
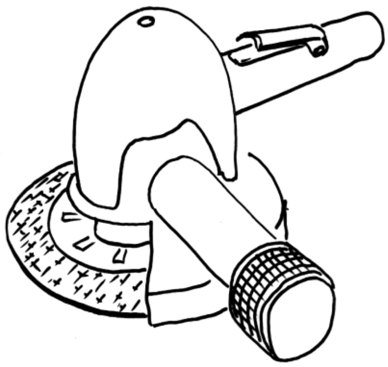



Figure 2.4.1b: Centrifugal Fan</td><td>Fans are used to move a large volume of air for ventilation, by bringing in fresh air from outside, blowing out dust, vapor or oil mist from an industrial environment, and for a drying or cooling operation. Basic noise sources are:
Broadband aerodynamic noise generated by the turbulent flow.
Mechanical noise due to mounting, bearing , balancing , etc.</td></tr>
<tr><td>Compressor</td><td>Compressors are usually very noisy machines with high pressure. The basic noise sources are caused by trapping a definite volume of fluid and carrying it</td></tr>
</table>

 Figure 2.4.1c: Gear Compressor	around the case to the outlet with high pressure. The pressure pulses from compressors are quite severe, and equivalent sound pressure level can exceed 105 dB (A).
Electric Motor	Noise from the electrical equipment such as motors and generators is generally a discrete low frequency, superimposed on a broadband cooling system noise. Basic sources involved in the noise generated by electric motors: • Broad-band aerodynamic noise generated from the end flow at the inlet/ outlet of cooling fan. • Discrete frequency components caused by the blade passing frequencies of the fan. • Mechanical noise caused by bearing, casing vibration, motor balancing shaft misalignment and motor mounting.
Woodworking Machines	The basic noise elements in woodworking machines are cutter heads and circular saws. Equivalent sound pressure level, L_{Aeq} in the furniture manufacturing industry can reach 106 dB (A). basic noise sources involved: • Structure vibration and noise radiation of the work piece or cutting tool such as a circular saw blade • Aerodynamic noise caused by turbulence, generated by tool

	rotation and workplace in the air flow field. • Fan dust and chip removal air carrying systems.
Pneumatic Tools  Figure 2.4.1d: Typical grinding Air Power Hand Tool	Basic types of noise sources are involved: • Noise produce by contact between the machine and the working surface. The vibration transmitted from the tools tends to vibrate the working surface and work bench, generating high radiation noise. • Exhaust air noise caused by turbulent flow generated as the compressed air passes the motor and by the aerodynamic noise generated in the air exhaust. • Sound radiation from tool vibration caused by air flow inside the tool. The noise level of hand held tool can reach as high as 110 dB (A) at operator’s ear.

Source: Federal University of Santa Catarina, Mechanical Engineering Department, Noise and Vibration Laboratory Cx.P.476, Brazil.

2.4.2 Typical Noise Level

Data collected in Denmark on 55 pneumatic and electric hammers in different industries show an SPL of between 88 to 103 dB(A). Planing wood machine operators are exposed to an SPL maximum of 101 dB (A) and an SPL minimum of 96 dB (A) with a *LAeq* = 98 dB (A) for 8 hours, which is far above the acceptable risk values (AIHA-USA).

Data collected in a cigarette factory in Brazil show an SPL level of a compressed air cleaning process of up to 103 dB(A), with an L_{Aeq} = 92 dB(A) for 8 hours (Fredel 1990). Economic calculations have shown that administrative and technical preventive measures are profitable. Technical progress during recent years has led to a decrease of the very high noise exposures, but not much change in moderate and low noise exposures. Measurements taken at some typical occupations show that the L_{Aeq} levels in the occupations shown by experience to have the worst noise have been 88-97 dB with highest peak levels of 101-136 dB (Table 2.4.2a). In the referenced study, there were no findings of peak levels exceeding 140 dB (Pekkarinen,
Starck, 1997).

Table 2.4.2a: Average L_{Aeq} values and L_{cpeak} values at different industrial workplaces

Industrial Branch	L_{Aeq}, dB (A)	L_{cpeak}, dB (C)
Foundry	93	127
Plastic Packing	83	112
Metal Packing	92	119
Shipyard	92	134
Glass Factory	95	113
Weaving Factory	95	119
Stretch Factory	88	114
Paper Mill	92	130
Saw Mill	94	123
Copper Tube Factory	96	136

Source: Pekkarinen, Starck, 1987

The Malaysian Factories and Machinery (Noise Exposure) Regulations 1989 were legislated for occupational safety and health relating to noise. It stipulates the maximum permissible noise levels and exposure limits that can be allowed at work place. The maximum permissible noise level for a continuous eight hour working day exposure is 90 dBA. This corresponds to a maximum allowable 100 percent noise exposure. A summary of the pertinent permissible noise limits are tabulated in Table 2.4.2b

Table 2.4.2b: Maximum permissible occupational noise limits

Permissible Limits	Noise level	Exposure Limit
Maximum Permissible Noise Exposure Limit	90 dBA 8 hour work period	100%
Maximum Permissible Instantaneous Noise Limit at Instance	115 dBA	
Maximum Permissible Instantaneous Peak Noise Limit	140 dBA	

Source: Malaysian Factories and Machinery (Noise Exposure) Regulation 1989

The exposure level depends on the noise level and total time duration of exposure. Table 2.4.2c presents a summary of time duration allowed for different noise levels for a 100 percent and 50 percent dose. In instances where noise levels are fluctuating, as in most practical situations, the equivalent continuous sound pressure level representing the fluctuating noise is used. This is often measured directly using an integrating sound level meter or a noise dose meter (where the cumulative dose is measured directly). While the permissible exposure is 100 percent, the action level upon which an employer is required to act is at 50 percent. The regulations also stipulate necessary actions to be taken by the employer and employee, including audiometric testing and the reduction of noise exposure at the work place. This regulation is currently under review by DOSH to update the regulation reflecting current international norms and latest recommendations of the ISO standards (ISO 1999), (Dr. Ir. Mohd Salman Leong).

Table 2.4.2c: Allowable time exposure for occupational noise

Noise Level, L_{eq}	100% Exposure	50% Exposure
85 dBA	8 hrs	16 hrs
90 dBA	8 hrs	16 hrs
95 dBA	4 hrs	8 hrs
100 dBA	2 hrs	4 hrs
105 dBA	1 hrs	2 hrs
110 dBA	30 minutes	1 hrs

Source: Malaysian Factories and Machinery (Noise Exposure) Regulation 1989

CHAPTER 3

METHODOLOGY

In this chapter, it will discuss process flow chart, how to calculate the sound pressure level (SPL), and also briefly explained the way to function the sound level meter nor 140 model.

3.1 Gantt chart and Process Flow Chart

Table 3.1a: project design process

		Duration	Prerequisite
A	Introduction project title by UTAR	1	nil
B	Select project title	1	A
C	Gathering information from SAE, library, etc	3	B
D	Analysis and arrangement of information	2	C
E	Planning and draft of paper work	3	C
F	Paper work (report)	5	D & E
G	Preparing of presentation slide	1	F
H	Presentation	1	G

Table 3.1b: Gantt chart

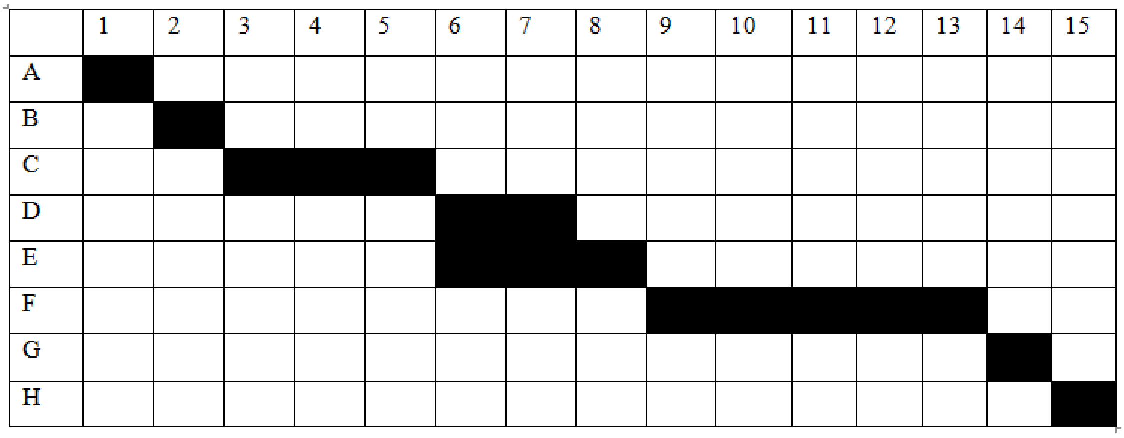
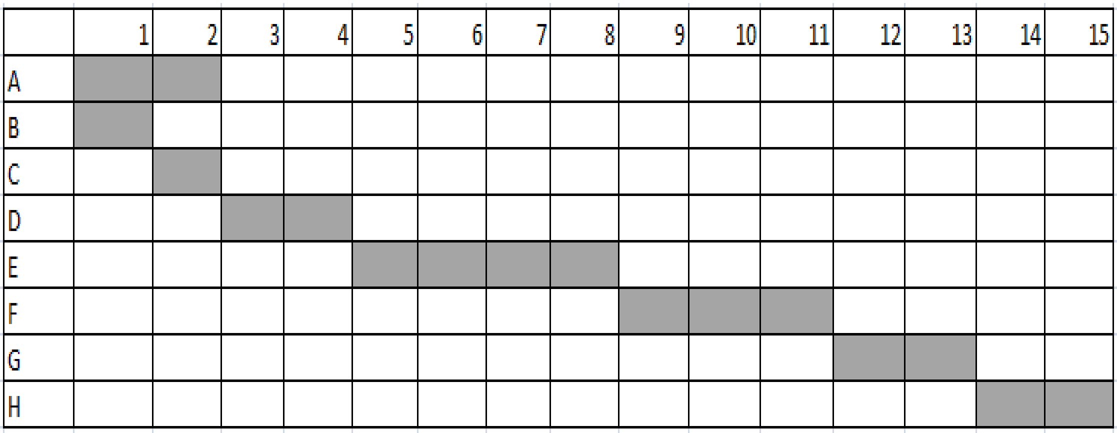


Table 3.1c: project design process phase 2

		Duration	Prerequisite
A	Confirmation from factory	2	nil
B	Surveyed on SLM	1	A
C	Purchased SLM	1	B
D	Data sampling	2	C
E	Result calculation	4	D
F	Discussion	3	E
G	Conclusion	2	F
H	Presentation phase 2	2	G

Table 3.1d: Gantt chart phase 2



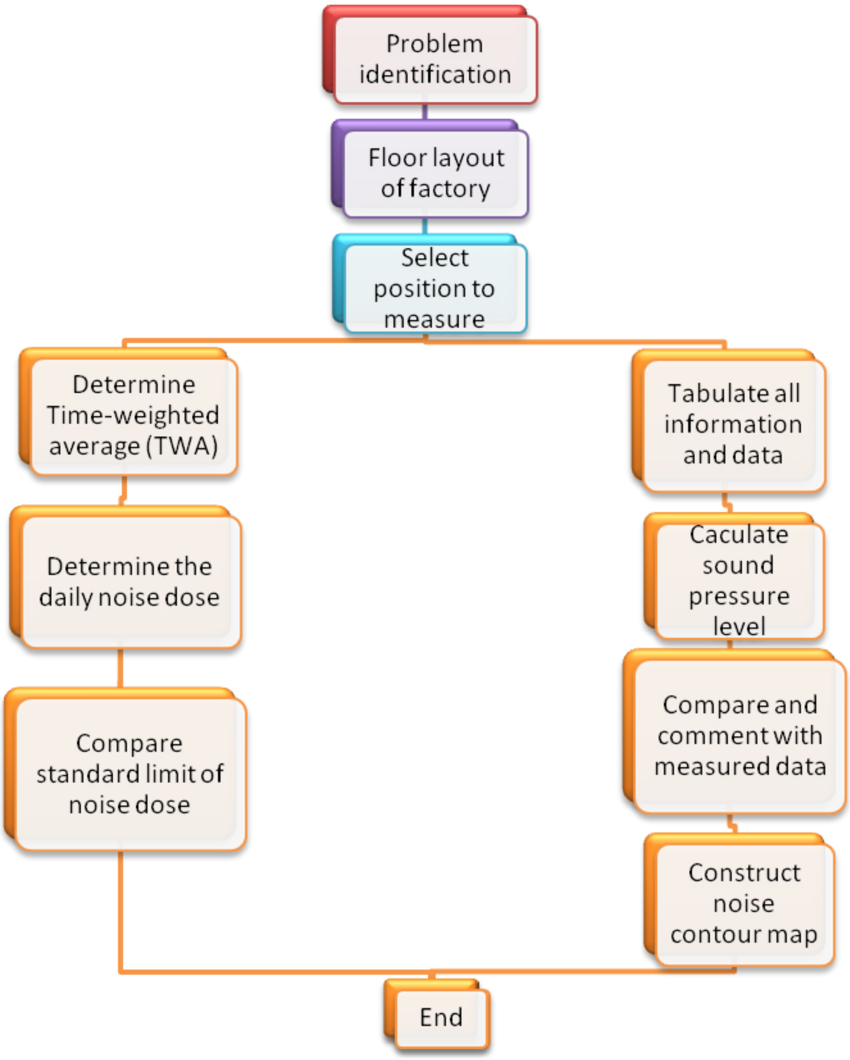


Figure 3.1: Process flow chart

3.2 Sound Level Meter

Noise is measured with a sound level meter. These instruments measure noise in decibels. An inexpensive sound level meter can be purchased at an electronics store for as little as RM2000 and is suitable for measuring most workplace noise. More advanced and accurate sound level meters cost RM30000 or more.

Noise measurement is an important diagnostic tool in noise control technology. The objective of noise measurement is to make accurate measurement which gives us a purposeful act of comparing noises under different conditions for assessment of adverse impacts of noise and adopting suitable control techniques for noise reduction. Below table shown the sound level meter features for model range.

Table 3.2: Common features for model range

		
ANSI Accuracy	Type 1	Type 2
Frequency analysis capability	broadband & octave and third octave band	broadband only
Frequency analysis method	Internal parallel analysis method - all bands at same time	None
Display method	Display memory PC download direct printing	manually record
Key benefits	Real time audio analyzer, fast frequency analysis measurements, multiple modes, upgradeable to add	-

	new measurement options	

In my project, I will use type 2 model Proskit MT4008 of sound level meter to perform measurement due to the availability of device in UTAR. This sound level meter consists of a microphone, electronic circuits and a readout display. The microphone detects the small air pressure variations associated with sound and changes them into electrical signals. These signals are then processed by the electronic circuitry of the instrument. The readout displays the sound level in decibels. The sound level meter takes the sound pressure level at one instant in a particular location.

Before taking any measurement, some of the precautions have to take in consideration. The sound level meter is held at arm's length to keep away from the observer body. This is because the observer’s presence will block the sound coming from a given direction and also act as sound reflection, therefore influence measurement results. Besides that, the distance of sound source to sound level meter is another step that we need to consider. If measurements are made too close to the machine, the SPL may vary significantly with a small change in sound level meter position. This will occur at a distance less than the wavelength of the lowest frequency emitted from the machine, or at less than twice the greatest dimension of the machine, whichever distance is the greater. This area is termed the **near-field** of the machine, and measurements in this region should be avoided if possible. Therefore a distance of 1.5m away from the sound point is recommended.

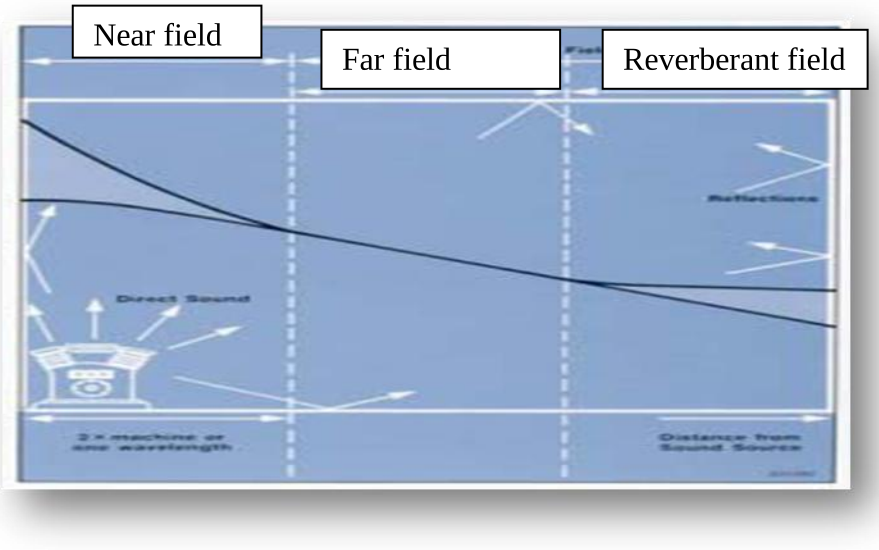


Figure 3.2: Sound fields

A-weighting filter (dBA) is generally built into all sound level meter and can be switched ON or OFF. A-weighted decibel is the relative loudness of sounds in air as perceived by the human ear. A-weighted system is made because the human ear is less sensitive at low audio frequencies, especially below 1000 Hz, than at high audio frequencies.

3.3 Calculation of sound pressure level

Step 1: Obtain absorption of coefficient, room constant and surface area.

The value of the Sabine absorptivity, α can be obtained from appendix A

Table 3.3a: surface area and Sabine absorptivity, α

Surface, S	Type	Area (m^2)	Sabine Absorptivity, α				
			125	250	500	1000	2000
Wall	Concrete block, painted	(23 x 15) + (68.5 x 15)x2 = 2400	0.10	0.05	0.06	0.07	0.09

Door	Sheet metal	16 x 10 = 160	0.15	0.19	0.22	0.39	0.38
Ceiling	50 mm thickness rock wool	23 x 68.5 = 1575.5	0.2	0.45	0.65	0.75	0.80
floor	Concrete with epoxy finish	23 x 68.5 = 1575.5	0.01	0.01	0.015	0.02	0.02
Total Area		5711					

Absorption	Area	125	250	500	1000	2000
Wall	2400	240	120	144	168	216
Door	160	24	30.4	35.2	62.4	60.8
Ceiling	1575.5	315.1	708.975	1024.075	1181.625	1260.4
Floor	1575.5	15.755	15.755	23.6325	31.51	31.51
Total Absorption		594.855	875.13	1226.9075	1443.535	1568.71
Mean alpha		0.1042	0.1532	0.2148	0.2528	0.2747
Room constant, R		664.31	1033.21	1562.31	1932.20	2162.98

<u>Example of calculation</u>

Frequency of 1000 Hz

Mean alpha, $\alpha = \frac{\sum_{i=1}^{n} Si\alpha i}{\sum_{i=1}^{n} Si}$

$$= \frac{Total\ absorption}{Total\ area}$$

$= \frac{1443.535}{5711}$

= 0.2528

Room constant, R = $\frac{Total\ area \times mean\ alpha}{1 - mean\ alpha}$

$= \frac{5711 \times 0.2528}{1 - 0.2528}$

$= 1932.20\ m^2$

Step 2: Calculation of sound pressure level

The sound pressure level (SPL) at a receiver position is governed by the sound power level (SWL) of sound source, the distance (r) between the source and the receiver, the room absorption (R), and the position of the sound source is located in the room space. Sound pressure levels are computed from the following equation:

$$SPL = SWL + 10 \log \{ \frac{Q}{4\pi r^2} + \frac{4}{R} \}\ dBA \qquad (3.1)$$

Where SPL = Sound Pressure Level, dB

SWL = Sound Power Level, dB

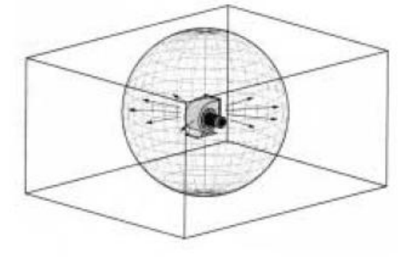
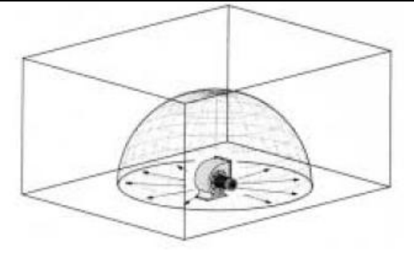
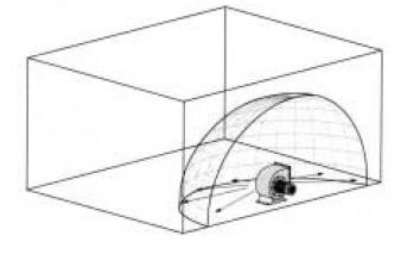
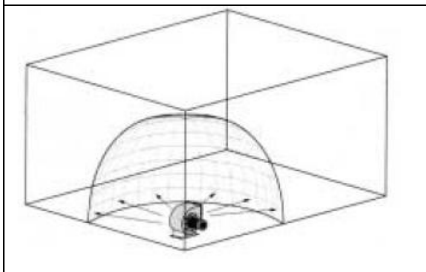
Q = Directivity factor (1, 2, 4, 8)

r = Distance source and receiver, m

R = Room constant (Sabins m^2)

Table 3.3b: Directivity factors,Q

	Location	Directivity

		Factor, Q
	Middle of Room in mid-air	1
	On the middle of floor, wall or ceiling	2
	At the edge in the middle between two edge	4
	At the corner of the room (corner of 3 edges)	8

Step3: Sound Power Level

In the case that the sound power level (SWL) is not provided by the manufacturer data, theoretical method is used. In this approximate method, the sound power level (SWL) is calculated according to ISO 3744 standard:

$$L_W = L_{p'} - K_1 - K_2 \quad (3.2)$$

L_W = sound power level

$L_{p'}$ = measured sound pressure level

K_1 = Correction factor related to the bottom noise (background noise)

K_2 = Correction factor related to the surroundings reflections and is calculated from the formula:

$$K_2 = 10.\log\left(1+4\left(\frac{S}{A}\right)\right) \tag{3.3}$$

A = equivalent sound absorption area of the room is obtained from

$$A = \alpha \cdot S_v \tag{3.4}$$

Where S_v is the total area of the surface of the test room (walls, ceiling, door and floor) and α is the mean sound absorption coefficient, α is obtained from the appendix B.

In this case, Mean sound absorption coefficient, α = 0.15 is selected due to the description of room and the $S_v = 5711\ m^2$

A = α . S_v

= 0.15 x 5711

=856.65 m^2

S = measure surface area where it shows on below:

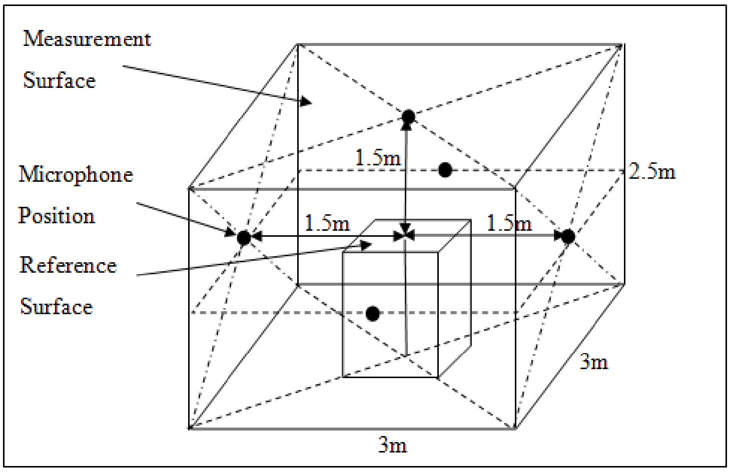


Figure 3.3: Measurement surfaces for each machine

S = (3 x 2.5) . 4 + (3 x 3)

= 39

$$K_2 = 10.\log\left(1 + 4\left(\frac{39}{856.65}\right)\right)$$

$$K_2 = 10.\log\,(1 + 0.182)$$

$$K_2 = 0.73$$

3.4 Measure of Sound Pressure Level

Step 1: Floor layout of factory

The layout of the entire area must be obtained and the locations of all existing machines (or noise sources) must be plotted on the layout map. Since the computation requires the assumption of a pointed source, each machine must be represented by a point on the x-y plane. By selecting one corner of the layout map as the reference origin (usually the lower left corner), each machine location can be expressed as a pair of x and y coordinates which are measured from that reference point.

Table 3.4a: coordinates of each machine

A(10, 4.5)	Finish part stock room	F(9.25, 53.75)	Rewinding machine
B(7.5, 15.5)	Spinning machine	G(9.5, 42.5)	Packaging department
C(20.25, 18.5)	Raw material stock room	H(19.5, 47)	Twine making machine
D(11, 32.25)	Partially finished goods	I(8.75, 62.5)	Partially finish good
E(2.5, 46)	Heater and oven	J(18.25, 63.5)	Rest room

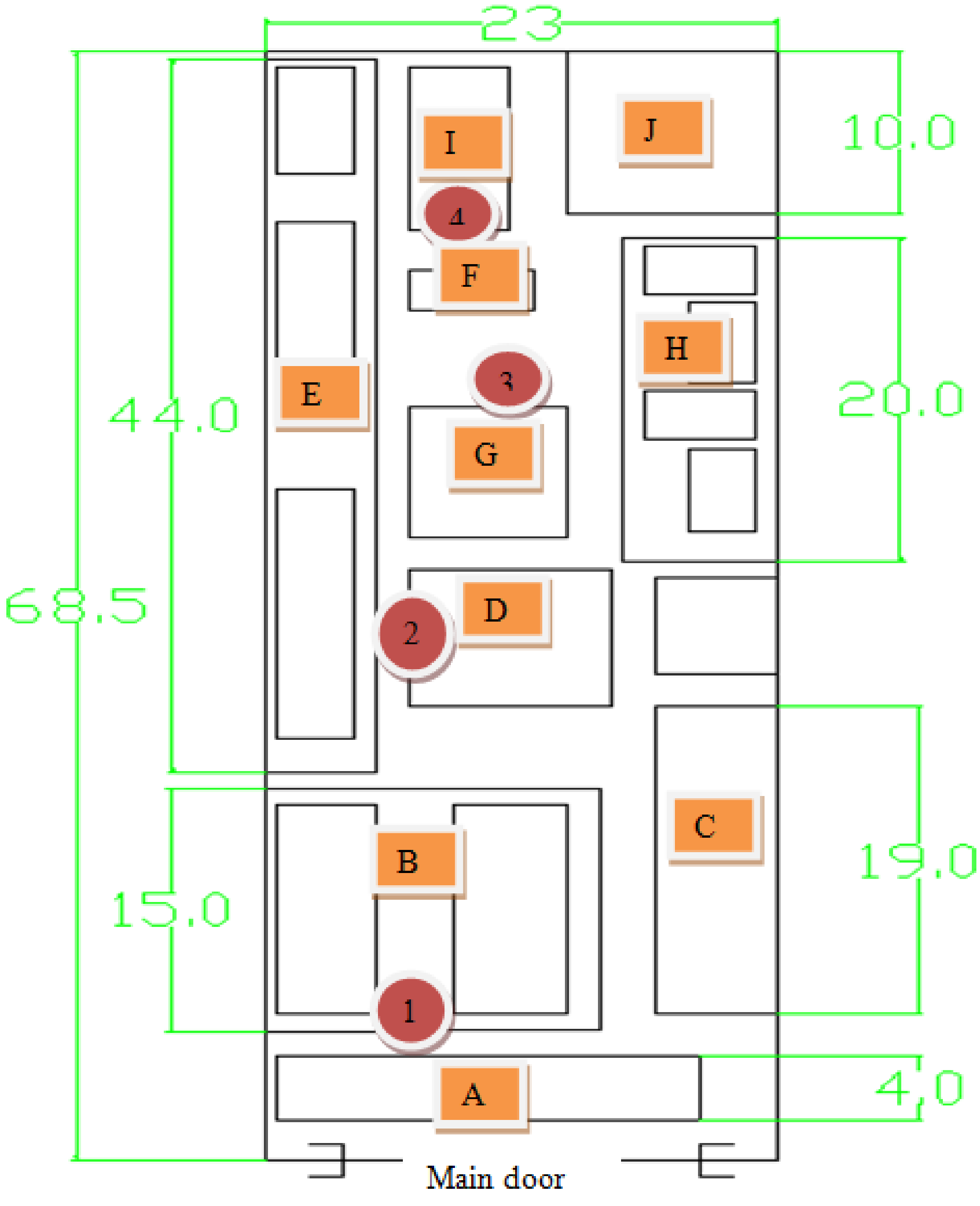


Figure 3.4a: Factory floor layout

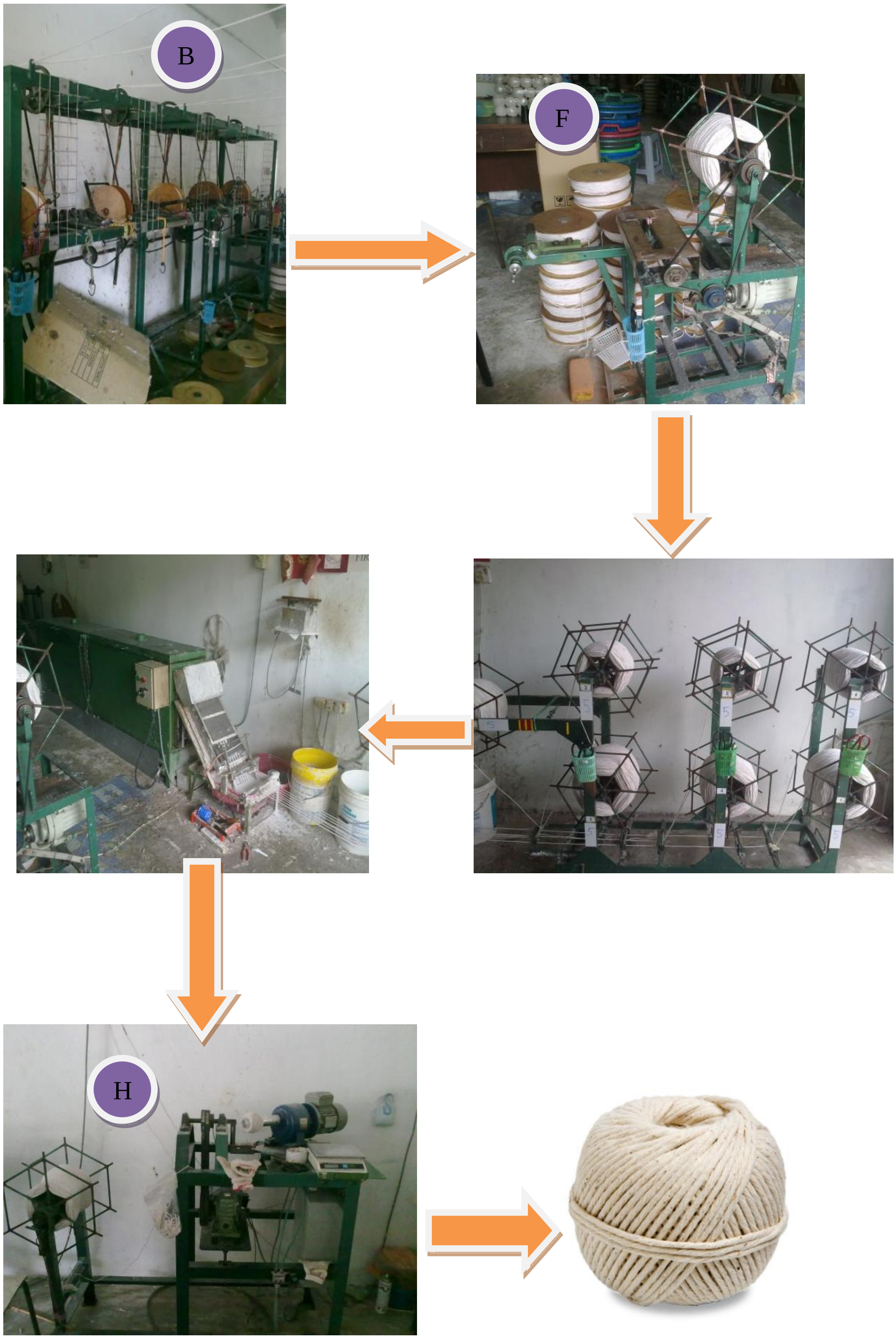


Figure 3.4b: cotton twine manufacturing process

Step 2: Selection position to measure

The selected positions are nearer to the noise source. The selected positions are always the operators stand position. Position 1 is selected due to the spinning machine generated most noises. Position 3 is selected to measure how much noise that received by the worker where most of the time sat on the chair to do packaging. Position 2 and position 4 are selected to measure the sound pressure level of rewinding machine and twine making machine respectively.

Table 3.4b: measure position

Position	Coordinate
1	(7.2, 8)
2	(8, 35)
3	(9, 47)
4	(8.5, 61)

3.5 Determination of Permissible Exposure Limit (PEL) exposure duration

The Occupational Safety and Health Administration (OSHA) have established the permissible noise exposure limit (PEL) for industrial workers. The OSHA reference specifies the permissible noise level and exposure durations. The higher the exposed noise level, the shorter the reference duration is. The PEL is 90 dBA and action limit (prevent noise hazards) is 85 dBA time weighted average (TWA) for an 8 hour exposure. The exposed noise level measure using an A-weighted sound meter and the reference duration T (in hours) can be determined from:

$$T = 8\left[2^{(L-90)/5}\right]^{-1} \tag{3.5}$$

Where L = a worker continuously exposure to noise level L.

When a worker has to work in several work stations and is exposed to different noise level during an 8 hour working day, the daily noise exposure can be said that is composed of two or more periods of noise exposure at different levels, their combined effect shall be considered rather than the individual effect. If the sum of the following fractions exceed one (e.g. D = 1.0 or 100 % noise dose), the combine exposure has exceeded the permissible exposure limit.

The daily noise dose, D can be calculated by the following equation:

$$D = \frac{t1}{T1} + \frac{t2}{T2} + \ldots + \frac{tn}{Tn} = \sum_{i=1}^{n} \frac{ti}{Ti} \qquad (3.6)$$

Where ti indicates the duration of exposure at specific noise level

Ti indicates the duration of exposure permitted at that level

For example, a worker is exposed to different sound pressure levels for different duration. The noise levels and duration of exposure are as follows:

$L_{Aeq,\,t,}$ dBA	ti, Hr	Ti, Hr
85	4	8
88	3	4
91	1	2

Noise dose = $\frac{4}{8} + \frac{3}{4} + \frac{1}{2} = 1.75 = 175\ \%$

Therefore the daily permissible noise dose had been exceeded.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

Calculated SWLs, SPLs are obtained. Noise level of the factory is analyzed, and presented in noise contour map using cadnA Demo software. Permissible Noise Exposure Limit (PEL)also will be discussed in this chapter.

4.2 Calculated Sound Pressure Level

Before taking any readings, assumptions or conditions are made. Firstly, I have to obtain the background where all the machines are in idle condition. Then I need to measure the noise level of individual machine in order to calculate sound power level of each machine. Next I will stand at the position (chapter 3.4) to measure noise level. Lastly, I will determine the permissible noise exposure limit. Each measurement is repeated at least 3 times in order to increase the accuracy of the results.

4.2.1 Background noise

Assumptions

- All machines are in idle condition
- Weather condition: sunny day
- Readings are taken for every 30 seconds and assumed the noise patterns are repeated

Table 4.2.1: Background noise level

	Sound Pressure Level			
	No.	Max	Min	Average
Background noise	1	53.6	52.7	53.15
	2	53.4	51.8	52.6
	3	54	52.2	53.1
	Average, dBA			52.95

The background noise is measure in 3 different random locations in the factory and the average sound level is 52.95 dBA.

4.2.2 Sound Power Level (SWL) of Machines

Assumptions:

- Weather condition: sunny day
- When one machine is operated other machines are in idle condition
- The noise pressure level due to ventilation system is negligible
- Readings are taken for every 30 seconds and assumed the noise patterns are repeated
- Machines are in well function. (noise due to misalignment shaft, bearing damaged are ignored)

Table 4.2.2: Sound Power Level (SWL)

	Sound Pressure Level(L_p'), dBA				Sound Power Level(SWL), dBA
Twine making Machine, H1,H2,H3,H4	No	Max	Min	Average	
	1	83.6	76.3	79.95	
	2	83	77.5	80.25	
	3	83.2	76.2	79.7	
	Average			79.96667	79.24
Spinning machine B1,B2,B3,B4,B5	No.	Max	Min	Average	
	1	89.3	82.8	86.05	
	2	88.9	82.6	85.75	
	3	88.7	83	85.85	
	Average			85.88333	85.15
Rewinding Machine, F	No.	Max	Min	Average	
	1	70	65.8	67.9	
	2	72.4	66.2	69.3	
	3	71.6	65	68.3	
	Average			68.5	67.77

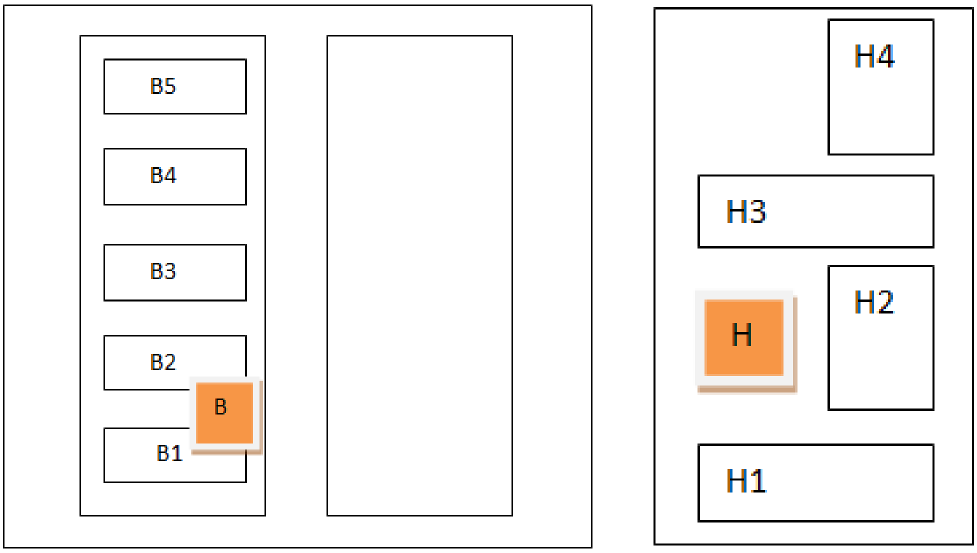


Figure 4.2.2: Individual machine in the factory. (Refer figure 3.4)

From Eqn. 3.2, K_1 is equal to zero because the difference is greater than 10dBA therefore no correction is needed (Section 2.1.2). In order to calculate L_w, K_2 must be determined using Eqn. 3.3. Lastly, from Eqn. 3.2, the sound power level of the machine can be determined.

Example calculation: Twine Making Machine

$$L_w = L_{p'} - \overset{0}{\cancel{K_1}} - K_2$$

$$L_w = 79.97 - 0.73$$

$$L_w = 79.24\ dBA$$

4.2.3 Sound Pressure level at each position

Assumption

- Weather condition: sunny day
- The noise pressure level due to ventilation system is negligible
- Readings are taken for every 30 seconds and assumed the noise patterns are repeated

1. Location 1 (7.2, 8)

Sound sources: B1, B2, B3, H1, H2, F

Table 4.2.3a: Sound sources measured at location 1

Spinning Machine, B1 (2.75, 10.5)

Frequency	1000
SWL	85.15
Q	4
Distance,r	5.104
Room Constant	1932.2
$Q/4\pi r^2$	0.012
4/R	0.00207
$Q/4\pi r^2+4/R$	0.014
$10\log(Q/4\pi r^2+4/R)$	-18.451
SPL	66.70

Spinning Machine, B2 (2.75, 13)

Frequency	1000
SWL	85.15
Q	4
Distance,r	6.69
Room Constant	1932.2
$Q/4\pi r^2$	0.00711
4/R	0.00207
$Q/4\pi r^2+4/R$	0.00918
$10\log(Q/4\pi r^2+4/R)$	-20.372
SPL	64.78

Sample calculation: Spinning machine, B1

$$r = \sqrt{(7.2-2.75)^2+(8-10.5)^2}$$

= 5.104

Spinning Machine, B3 (2.75, 15.5)

Frequency	1000
SWL	85.15
Q	4
Distance,r	8.72
Room Constant	1932.2
$Q/4\pi r^2$	0.004
4/R	0.00207
$Q/4\pi r^2+4/R$	0.006
$10\log(Q/4\pi r^2+4/R)$	-22.038
SPL	63.12

Twine Making Machine, H1 (20.5, 41.5)

Frequency	1000
SWL	79.24
Q	4
Distance,r	36.12
Room Constant	1932.2
$Q/4\pi r^2$	0.00024
4/R	0.00207
$Q/4\pi r^2+4/R$	0.00231
$10\log(Q/4\pi r^2+4/R)$	-26.356
SPL	52.88

Twine Making Machine, H2 (19.5, 46)

Frequency	1000
SWL	79.24
Q	4
Distance,r	39.94
Room Constant	1932.2
$Q/4\pi r^2$	0.000199
4/R	0.00207
$Q/4\pi r^2+4/R$	0.00227
$10\log(Q/4\pi r^2+4/R)$	-26.4404
SPL	52.80

Rewinding Machine, F (9.25, 53.75)

Frequency	1000
SWL	67.77
Q	2
Distance,r	45.81
Room Constant	1932.2
$Q/4\pi r^2$	7.58097E-05
4/R	0.00207
$Q/4\pi r^2+4/R$	0.00215
$10\log(Q/4\pi r^2+4/R)$	-26.684
SPL	41.09

Net SPL is calculated by:

$$L_{\Sigma 1} = 10.\,log_{10}\left(10^{\frac{L_1}{10}} + 10^{\frac{L_2}{10}} + \;\ldots\ldots\ldots + 10^{\frac{L_n}{10}}\right) \qquad (4.1)$$

Where: L_1, L_2, etc is the SPL that calculated from every source.

$$L_{\Sigma 1} = 10.\,log_{10}\left(10^{\frac{66.7}{10}} + 10^{\frac{64.78}{10}} + 10^{\frac{63.12}{10}} + 10^{\frac{52.88}{10}} + 10^{\frac{52.8}{10}} + 10^{\frac{41.09}{10}}\right)\ dBA$$

$$L_{\Sigma 1} = \ 70.05\ \text{dBA}$$

2. Location 2 (8, 35)

Sound sources: B1, B2, B3, H1, H2, F

Table 4.2.3b: Sound sources measured at location 2

Spinning Machine, B1 (2.75, 10.5)

Frequency	1000
SWL	85.15
Q	4
Distance,r	25.06
Room Constant	1932.2
$Q/4\pi r^2$	0.001
4/R	0.00207
$Q/4\pi r^2+4/R$	0.003
$10\log(Q/4\pi r^2+4/R)$	-25.889
SPL	59.26

Spinning Machine, B2 (2.75, 13)

Frequency	1000
SWL	85.15
Q	4
Distance,r	22.62
Room Constant	1932.2
$Q/4\pi r^2$	0.00062
4/R	0.00207
$Q/4\pi r^2+4/R$	0.00269
$10\log(Q/4\pi r^2+4/R)$	-25.699
SPL	59.45

Spinning Machine, B3 (2.75, 15.5)

Frequency	1000
SWL	85.15
Q	4
Distance,r	20.19
Room Constant	1932.2
$Q/4\pi r^2$	0.001
4/R	0.00207
$Q/4\pi r^2+4/R$	0.003
$10\log(Q/4\pi r^2+4/R)$	-25.4504
SPL	59.70

Twine Making Machine, H1 (20.5, 41.5)

Frequency	1000
SWL	79.24
Q	4
Distance,r	14.1
Room Constant	1932.2
$Q/4\pi r^2$	0.00160
4/R	0.00207
$Q/4\pi r^2+4/R$	0.00367
$10\log(Q/4\pi r^2+4/R)$	-24.353
SPL	54.88

Twine Making Machine, H2 (19.5, 46)

Frequency	1000
SWL	79.24
Q	4
Distance,r	15.91
Room Constant	1932.2
$Q/4\pi r^2$	0.001257
4/R	0.00207
$Q/4\pi r^2+4/R$	0.00333
$10\log(Q/4\pi r^2+4/R)$	-24.7792
SPL	54.46

Rewinding Machine, F (9.25, 53.75)

Frequency	1000
SWL	67.77
Q	2
Distance,r	18.79
Room Constant	1932.2
$Q/4\pi r^2$	0.000451
4/R	0.00207
$Q/4\pi r^2+4/R$	0.00252
$10\log(Q/4\pi r^2+4/R)$	-25.985
SPL	41.79

From (Eqn. 4.1):

$$L_{\Sigma 1} = 10.\,log_{10}\left(10^{\frac{L1}{10}} + 10^{\frac{L2}{10}} + \dots\dots\dots + 10^{\frac{Ln}{10}}\right)\ dBA$$

$$L_{\Sigma 1} = 10.\,log_{10}\left(10^{\frac{59.26}{10}} + 10^{\frac{59.45}{10}} + 10^{\frac{59.70}{10}} + 10^{\frac{54.88}{10}} + 10^{\frac{54.46}{10}} + 10^{\frac{41.79}{10}}\right)\ dBA$$

$$L_{\Sigma 1} = 65.13\ \ dBA$$

3. Location 3 (9, 47)

Sound sources: B3, B4, B5, H3, H4, F

Table 4.2.3c: Sound sources measured at location 3

Spinning Machine, B3 (2.75, 15.5)

Frequency	1000
SWL	85.15333
Q	4
Distance,r	32.11
Room Constant	1932.2
$Q/4\pi r^2$	0.0003
4/R	0.00207
$Q/4\pi r^2+4/R$	0.002
$10\log(Q/4\pi r^2+4/R)$	-26.236
SPL	58.92

Spinning Machine, B4 (2.75, 18)

Frequency	1000
SWL	85.15333
Q	4
Distance,r	29.67
Room Constant	1932.2
$Q/4\pi r^2$	0.00036
4/R	0.00207
$Q/4\pi r^2+4/R$	0.00243
$10\log(Q/4\pi r^2+4/R)$	-26.141
SPL	59.01

Spinning Machine, B5 (2.75, 20.5)

Frequency	1000
SWL	85.15333
Q	4
Distance,r	27.22
Room Constant	1932.2
$Q/4\pi r^2$	0.000
4/R	0.00207
$Q/4\pi r^2+4/R$	0.002
$10\log(Q/4\pi r^2+4/R)$	-26.0213
SPL	59.13

Twine Making Machine, H3 (21.5, 49.5)

Frequency	1000
SWL	79.24
Q	4
Distance,r	12.75
Room Constant	1932.2
$Q/4\pi r^2$	0.00196
4/R	0.00207
$Q/4\pi r^2+4/R$	0.00403
$10\log(Q/4\pi r^2+4/R)$	-23.950
SPL	55.29

Twine Making Machine, H4 (19.5, 55)

Frequency	1000
SWL	79.24
Q	4
Distance,r	13
Room Constant	1932.2
$Q/4\pi r^2$	0.001883
4/R	0.00207
$Q/4\pi r^2+4/R$	0.00395
$10\log(Q/4\pi r^2+4/R)$	-24.0308
SPL	55.21

Rewinding Machine, F (9.25, 53.75)

Frequency	1000
SWL	67.77
Q	2
Distance,r	6.75
Room Constant	1932.2
$Q/4\pi r^2$	0.003492
4/R	0.00207
$Q/4\pi r^2+4/R$	0.00556
$10\log(Q/4\pi r^2+4/R)$	-22.548
SPL	45.22

From (Eqn. 4.1):

$$L_{\Sigma 1} = 10.\log_{10}\left(10^{\frac{L1}{10}} + 10^{\frac{L2}{10}} + \ldots\ldots\ldots + 10^{\frac{Ln}{10}}\right)\ dBA$$

$$L_{\Sigma 1} = 10.\log_{10}\left(10^{\frac{58.92}{10}} + 10^{\frac{59.01}{10}} + 10^{\frac{59.13}{10}} + 10^{\frac{55.29}{10}} + 10^{\frac{55.21}{10}} + 10^{\frac{45.22}{10}}\right)\ dBA$$

$$L_{\Sigma 1} = 64.91\ \ dBA$$

4. Location 4 (8.5, 61)

Sound sources: B3, B4, B5, H3, H4, F

Table 4.2.3d: Sound sources measured at location 4

Spinning Machine, B3 (2.75, 15.5)

Frequency	1000
SWL	85.15333
Q	4
Distance,r	45.86
Room Constant	1932.2
$Q/4\pi r^2$	0.0002
4/R	0.00207
$Q/4\pi r^2+4/R$	0.002
$10\log(Q/4\pi r^2+4/R)$	-26.534
SPL	58.62

Spinning Machine, B4 (2.75, 18)

Frequency	1000
SWL	85.15333
Q	4
Distance,r	43.38
Room Constant	1932.2
$Q/4\pi r^2$	0.00017
4/R	0.00207
$Q/4\pi r^2+4/R$	0.00224
$10\log(Q/4\pi r^2+4/R)$	-26.499
SPL	58.65

Spinning Machine, B5 (2.75, 20.5)

Frequency	1000
SWL	85.15333
Q	4
Distance,r	40.91
Room Constant	1932.2
$Q/4\pi r^2$	0.000
4/R	0.00207
$Q/4\pi r^2+4/R$	0.002
$10\log(Q/4\pi r^2+4/R)$	-26.4584
SPL	58.69

Twine Making Machine, H3 (21.5, 49.5)

Frequency	1000
SWL	79.24
Q	4
Distance,r	17.36
Room Constant	1932.2
$Q/4\pi r^2$	0.00106
4/R	0.00207
$Q/4\pi r^2+4/R$	0.00313
$10\log(Q/4\pi r^2+4/R)$	-25.050
SPL	54.19

Twine Making Machine, H4 (19.5, 55)

Frequency	1000
SWL	79.24
Q	4
Distance,r	12.31
Room Constant	1932.2
$Q/4\pi r^2$	0.0021
4/R	0.00207
$Q/4\pi r^2+4/R$	0.00417
$10\log(Q/4\pi r^2+4/R)$	-23.7988
SPL	55.44

Rewinding Machine, F (9.25, 53.75)

Frequency	1000
SWL	67.77
Q	2
Distance,r	7.29
Room Constant	1932.2
$Q/4\pi r^2$	0.002994
4/R	0.00207
$Q/4\pi r^2+4/R$	0.00506
$10\log(Q/4\pi r^2+4/R)$	-22.955
SPL	44.81

From (Eqn. 4.1):

$$L_{\Sigma 1} = 10.log_{10}\left(10^{\frac{L1}{10}} + 10^{\frac{L2}{10}} + \ldots\ldots\ldots + 10^{\frac{Ln}{10}}\right)\ dBA$$

$$L_{\Sigma 1} = 10.log_{10}\left(10^{\frac{58.62}{10}} + 10^{\frac{58.65}{10}} + 10^{\frac{58.69}{10}} + 10^{\frac{54.19}{10}} + 10^{\frac{55.54}{10}} + 10^{\frac{44.81}{10}}\right)\ dBA$$

$$L_{\Sigma 1} = 64.55\ \ dBA$$

4.3 Measure Sound Pressure Level and Permissible Exposure Limit (PEL)

- Measure sound pressure level

Table 4.3: Measured SPL at every location

Location 1

Noise source: B1, B2, B3, H1, H2, F

No.	Max	Min	Average, dBA
1	68.1	66.2	67.15
2	70.4	65.4	67.9
3	69.2	66	67.6
4	71.1	65.2	68.15
5	70.6	66.1	68.35
		Average	67.83

Location 2

Noise source: B1, B2, B3, H1, H2, F

No.	Max	Min	Average, dBA
1	66.5	61.5	64
2	67.3	61.7	64.5
3	68.2	60.8	64.5
4	66.8	61.2	64
5	67.4	60.6	64
		Average	64.2

Location 3

Noise source: B3, B4, B5, H3, H4, F

No.	Max	Min	Average, dBA
1	64.8	60.3	62.55
2	65.6	59.6	62.6
3	65.3	59.8	62.55
4	65	60	62.5
5	65.5	60.8	63.15
		Average	62.67

Location 4

Noise source: B3, B4, B5, H3, H4, F

No.	Max	Min	Average, dBA
1	63.8	58.5	61.15
2	64.3	57.6	60.95
3	64.2	60.2	62.2
4	63.6	59.7	61.65
5	63.2	60.5	61.85
		Average	61.56

- Permissible Exposure Level (PEL)

Workstation	Noise level, dBA	t	T
B	85	5	1
H	79.2	3	3

From section 3.5,

Eqn. 3.5 T = 8 $\left[2^{(L-90)/5}\right]^{-1}$

T_B = 8 x $\left[2^{(85-90)/5}\right]$ = 16

Eqn. 3.6 $D = \frac{t1}{T1} + \frac{t2}{T2} + \ldots + \frac{tn}{Tn} = \sum_{i=1}^{n} \frac{ti}{Ti}$

Noise dose, D = $\frac{5}{16} + \frac{3}{32} = 0.41 = 41\ \%$

4.4 Noise Contour Map

Location 1

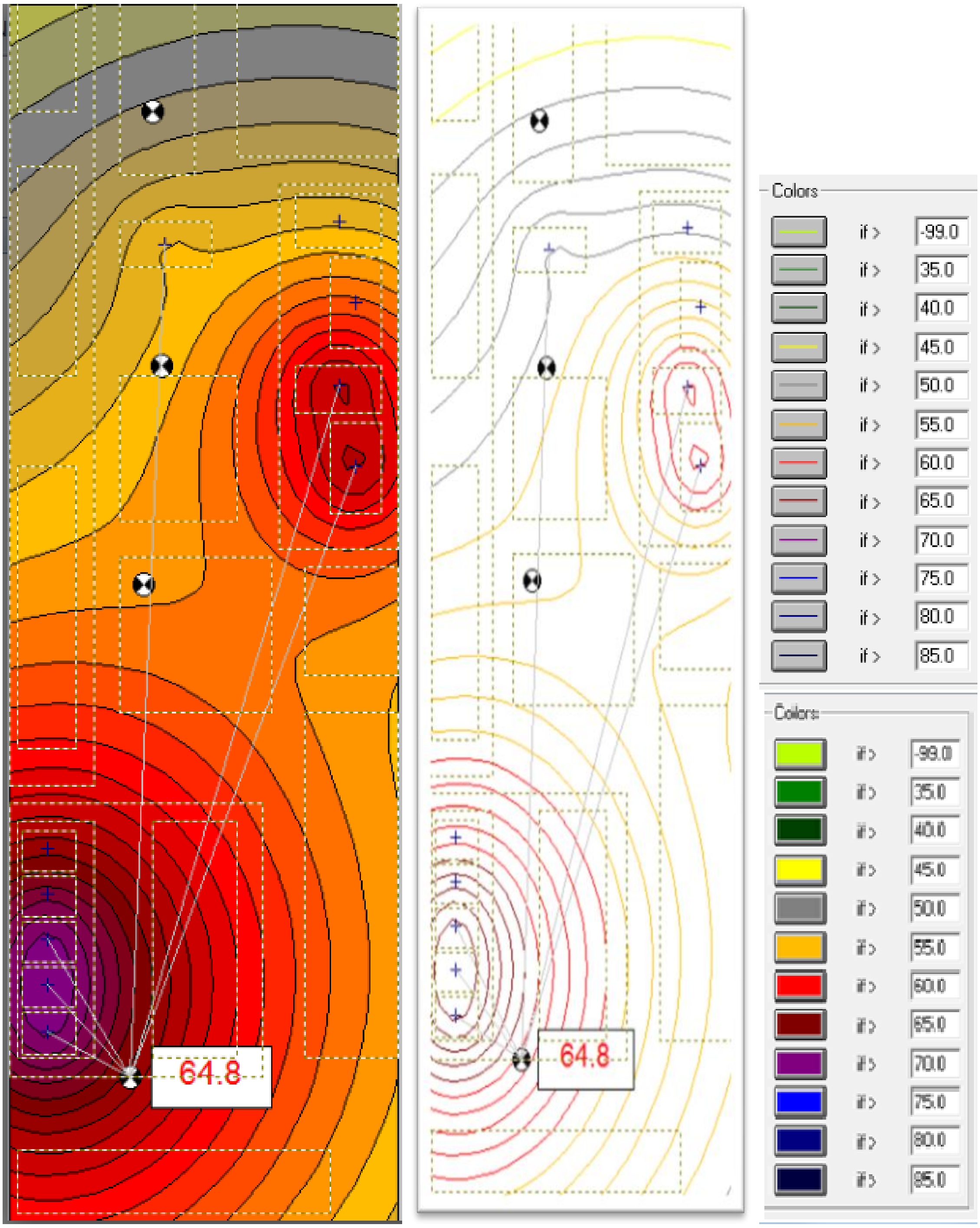


Figure 4.4a: Noise map of location 1

Location 2

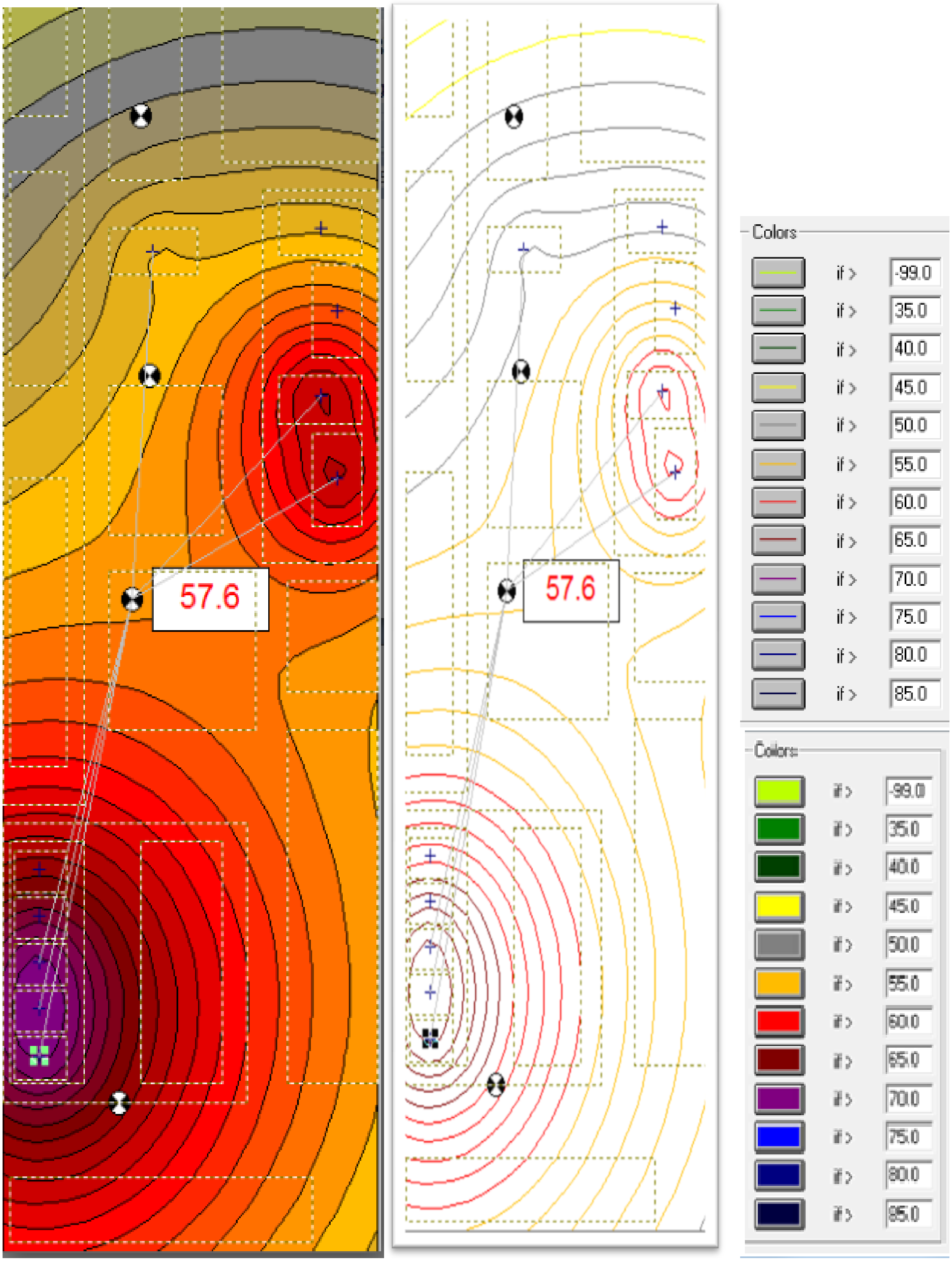


Figure 4.4b: Noise map of location 2

Location 3

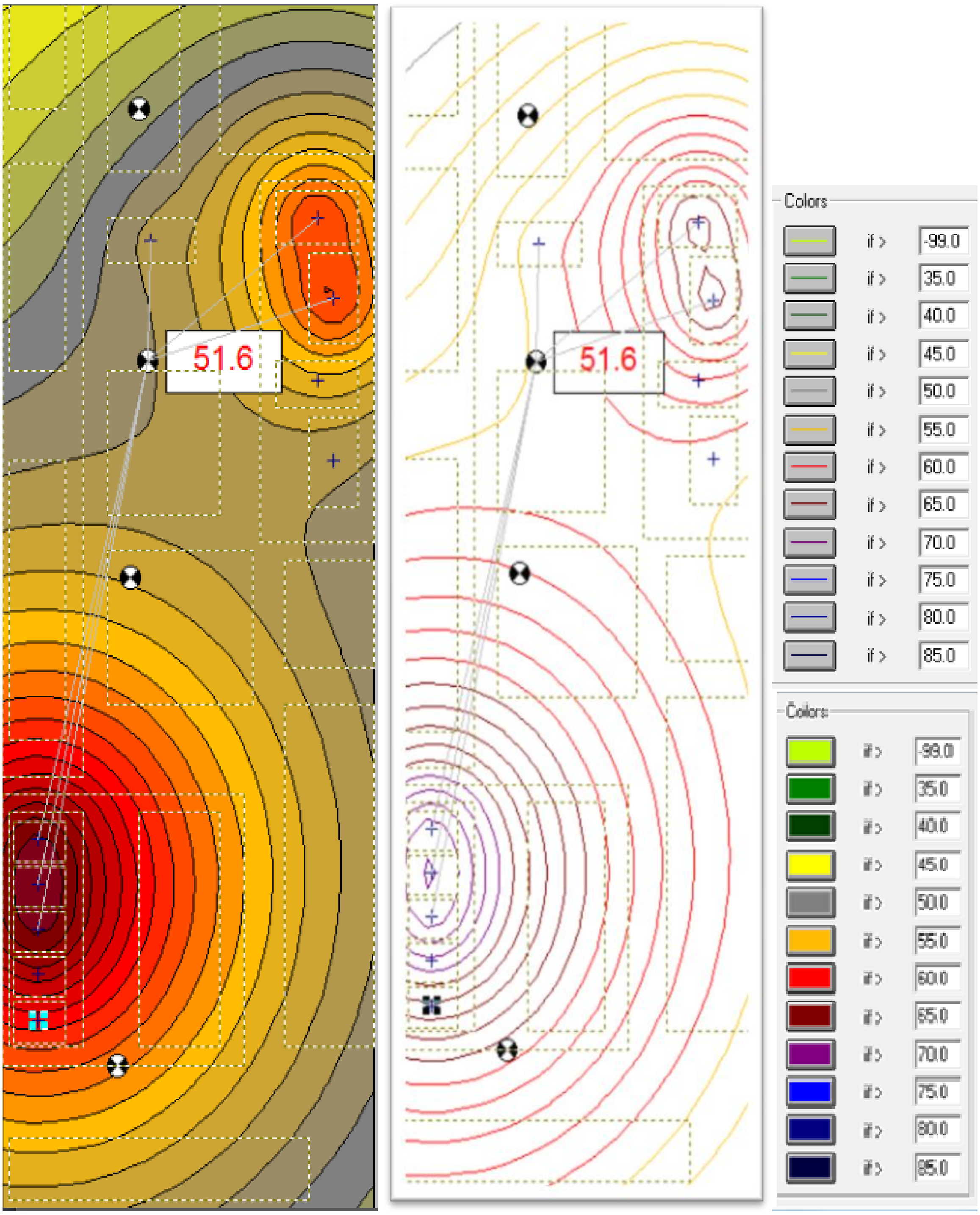


Figure 4.4c: Noise map of location 3

Location 4

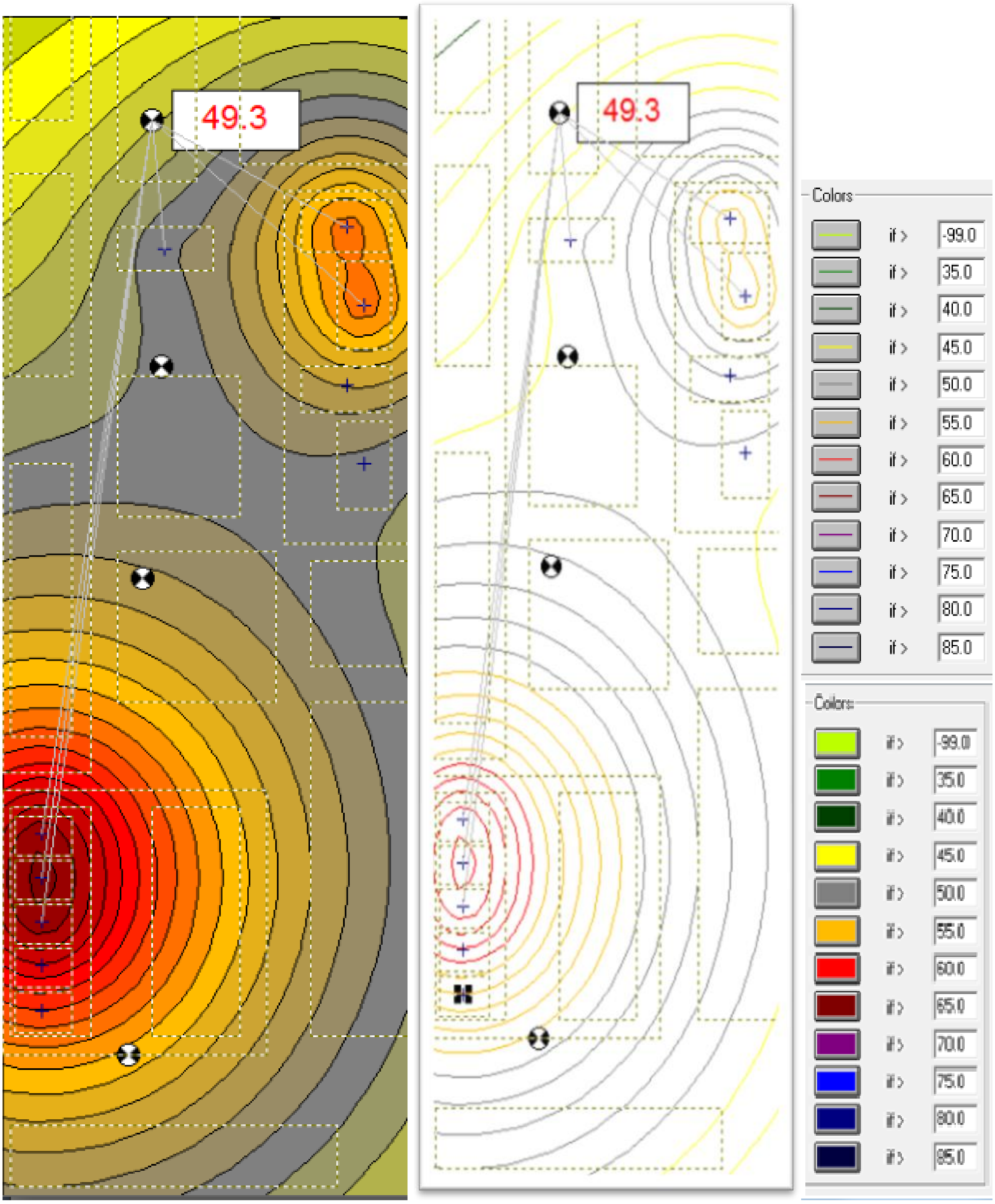


Figure 4.4d: Noise map of location 4

When all machines operating

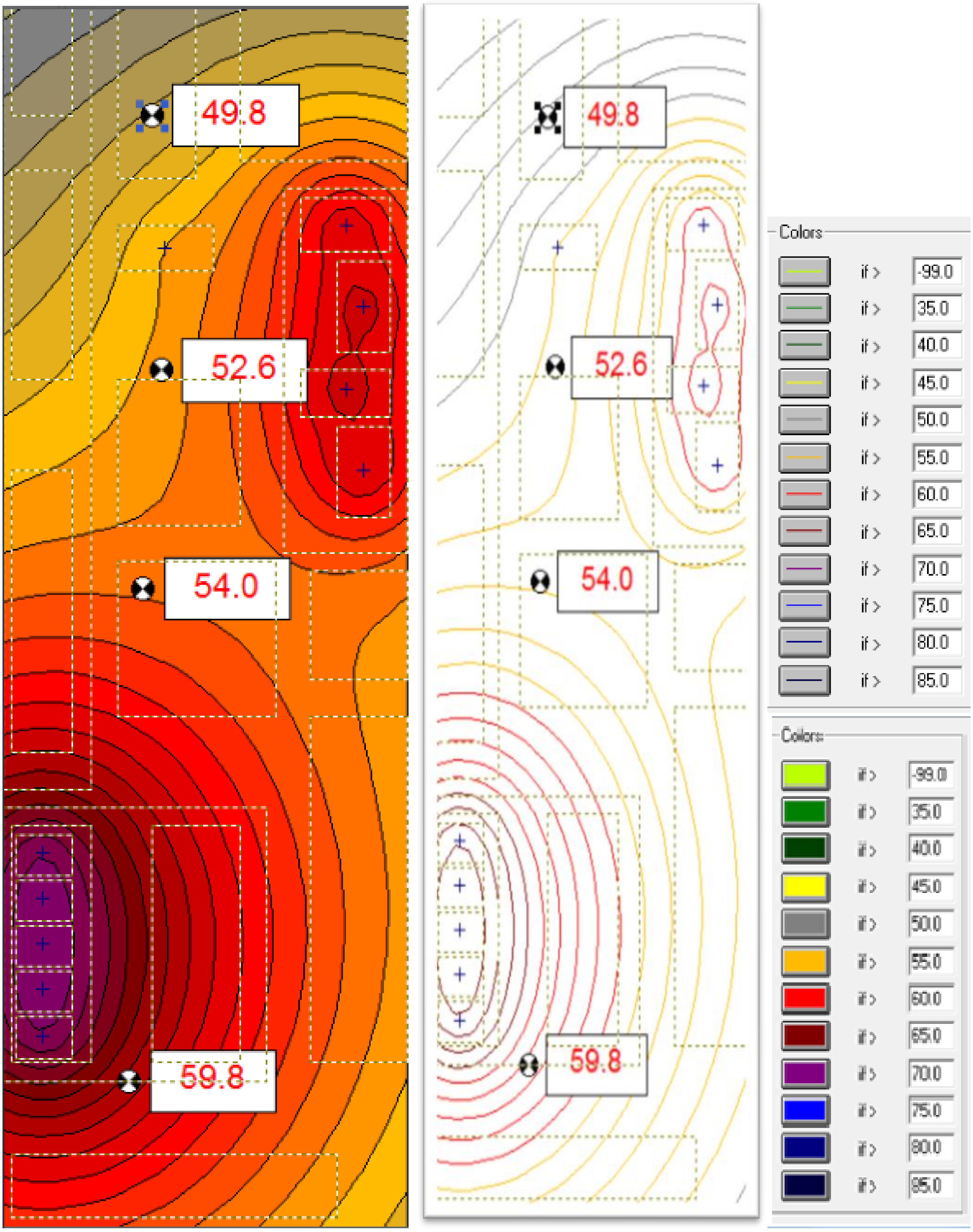


Figure 4.4e: Noise map when all machine are operated

4.5 Discussion

4.5.1 Calculated SPL and Measured SPL

The background noise of the factory is 52.95 dBA and when compare to other enclosed building, the background noise is around 45 dBA. It showed an additional of sound pressure level. This additional sound pressure level may due to the sound sources generated from the neighbour factory. The next door of factory is a printing factory which the machines are operated while the readings were recorded. However, the background level doesn't affect to the SPL since the difference between background noise level and sound sources is greater than 10 dBA (section 2.1.2 subtraction of sound level), the K1 value from eqn. 3.2 can be ignored.

There is unnecessary to calculate the sound power level of each machine as it given in the manufacturer data. However, I have been told that couldn't find any relevant data in the manufacturer data sheet. Therefore, an approximate calculation is used to determine the sound power level of each machine by eqn. 3.2. Once the mean sound absorption coefficient, α and measured surface area, s are determined, the correction factor related to the surroundings reflections, K2 is actually inversely proportional to total surface area Sv. In other words, the larger the factory is, the smaller the K2 value is.

$$K_2 = 10.\log\left(1 + 4\left(\frac{S}{A}\right)\right) \qquad (3.3)$$

This research is not conduct appropriately when determine the measured surface area. According to ISO 3744, a hypothetical rectangular parallelepiped reference box which is smallest and completely enclosed machine was first defined. The measuring system should consists of 9 microphones and a Racal A480 Digital Tape Recording System which is capable to perform measurements in 1/3 octave bands.

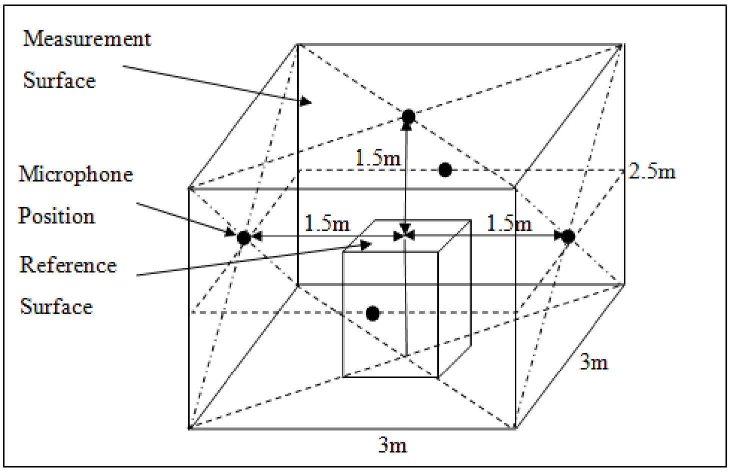


Figure 4.5.1a: Measuring surface and hypothetical rectangular parallelepiped reference box that defined by ISO 3744

Due to the only set of sound level meter, it is not capable to perform microphone array for the parallelepiped measurement surface. Also, the present of other machines not allow to perform microphone array. Thus, approximation method is used to calculate sound power level, SWL.

Certain assumptions which made early may raise some concerns about the validity of the results. For example, machines are considered as pointed sources and it is assumed that the noise sources and workers appear on the two-dimensional plane, thus ignoring their height. When standing, the workers' ear should be at the height range of 1.5- 1.8m approximately. The noise sources which are the industrial machines will be three- dimensional and not point on the floor. For each machine, it is reasonable to assume the height level of the noise source will be some distance above the floor. The correct distance between the noise source and receiver can be calculated from

$$r = \sqrt{x^2 + y^2 + z^2}$$

Where, z is the difference in the vertical heights between the noise source and receiver. When taking the reading, the z value is much smaller than x and y value, its effect becomes negligible. Thus, I dropped the z value from the calculation.

Another concern may arise from the fact that the workplace noise level is type of sound level meter used. The sound level meter used to measure the SPL is type 2 ANSI accuracy and it cannot record the readings. Therefore, I have to assume the worst-case situation by taking the average of maximum sound level and minimum sound level to represent the workplace noise level. The noise is fluctuated over time and therefore reading taken with longer time will have more accurate results. In my research, 30 seconds is counted to record the data. Besides, the sound level meter does not have octave bands function which only has single broadband function. So I could not analyses at which frequency will have the maximum noise level. This is important that if the frequency of maximum noise level is known, I can control the noise level by adding appropriate absorptive materials. Therefore, a suggested frequency of 1000 Hz was used in the sound pressure level calculation.

The net SPL can be calculated by using the graphical method (section 2.1.2 addition of sound level). In order to increase to accuracy, the calculation method is used (eqn. 4.1) instead of graphical method. After finishing all the calculations of all locations, location 1 has the highest SPL which is 70.05dBA followed by location 2 (65.13), location 3(64.91), location 4(64.55). It is very obvious that location 1 is near to spinning machine, B which is major sound sources of the factory. As the location far away from the spinning machine, the net SPL is reduced. The calculated SPL acts as theoretical value to compare with measured SPL in order to check the correctness of the results.

The below table show the comparison of calculated SPL and measured SPL:

Location	Calculated SPL, dBA	Measured SPL, dBA
1	70.05	67.83
2	65.13	64.2
3	64.91	62.67
4	64.55	61.56

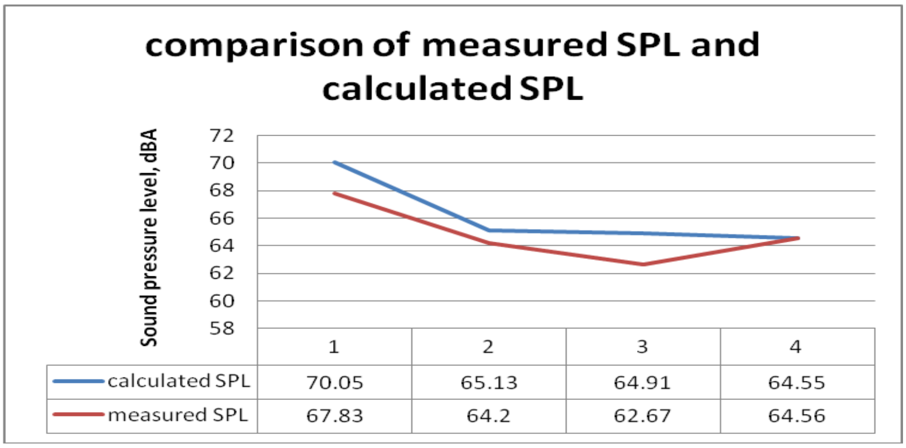


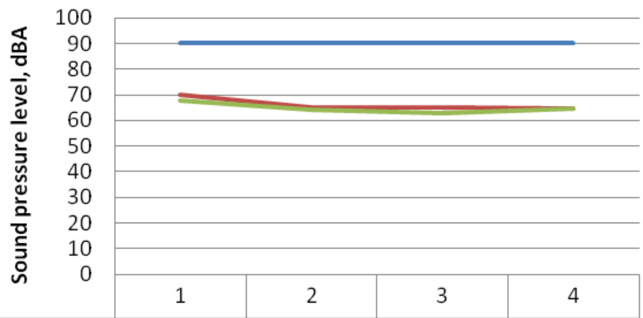
Figure 4.5.1b: comparison of measured SPL and calculated SPL

From the graph plotted, it can observe that the calculated SPL is always higher than the measured SPL. This may due to the presence of absorptive materials. The finishing goods and raw materials are soft materials and act as good absorptive materials. These materials will absorb the sound generated from the machine and result in reduction in SPL. This is not taking into account in calculation part and therefore, the measured SPL is always lower than calculated SPL. However, it is noteworthy that the plant might not be operated at the full capacity at the time of my survey. If it is, one could that SPL in the production sections would increase.

Figure 4.5.1c: Absorptive materials

Besides, the coefficient of acoustics material obtained from appendix A may affect the result. In this case, the coefficient properties selected for all material is just approximation as some parts of selected factory was built up by others type of materials which is no specified in the appendix A. In addition, the value of mean sound absorption coefficient α is determined by own definition from appendix B. Therefore, this estimated coefficient of acoustics material would decrease the accuracy of final result.

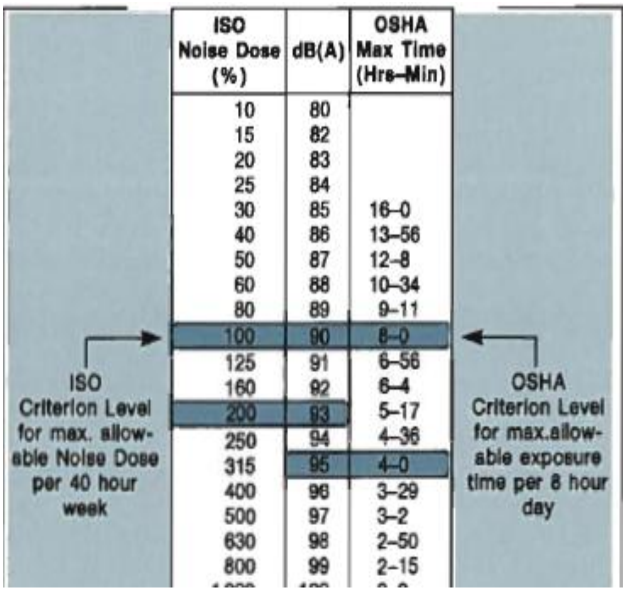
The both calculated SPL and measured SPL are within the limit of Malaysian Factories and Machinery (Noise Exposure) Regulation 1989. A worker who worked for a period of 8 hour per day, the maximum permissible noise level for 100% exposure limit is summarized in the table below:



	1	2	3	4
Malaysia factory and machinery regulation 1989	90	90	90	90
calculated SPL	70.05	65.13	64.91	64.55
measured SPL	67.83	64.2	62.67	64.56

Figure 4.5.1d: comparison of measure SPL & calculated SPL to standard

It can conclude that the selected factory follow the rule and regulation as stated in Malaysian Factories and Machinery (Noise Exposure) Regulation 1989. Also, the sound pressure level impose to workers on this factory is also within the limit of ISO and OSHA standard.



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
125	91	6–56
160	92	6–4
200	93	5–17
250	94	4–36
315	95	4–0
400	96	3–29
500	97	3–2
630	98	2–50
800	99	2–15

Figure 4.5.1e: ISO and OSHA standard

4.5.2 Noise Mapping and Permissible Exposure Level (PEL)

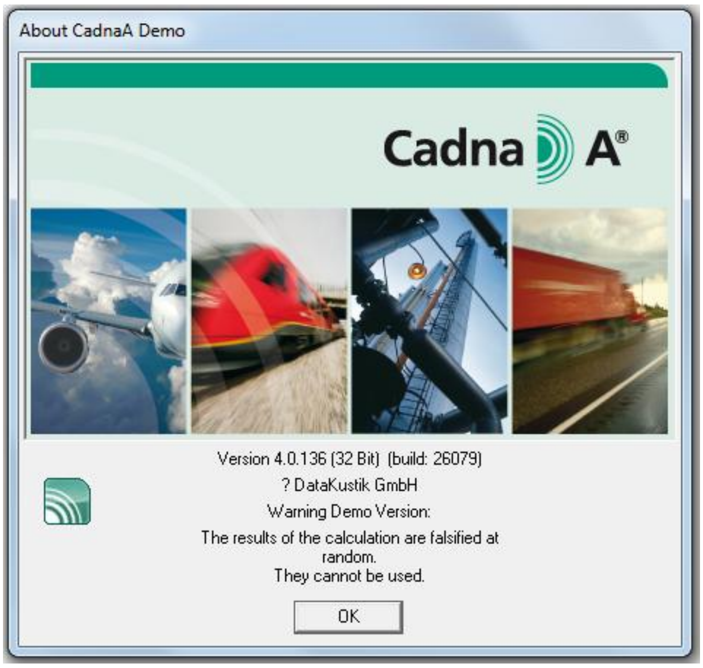
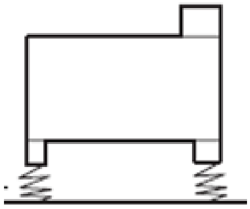
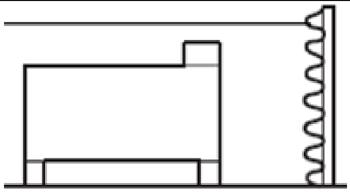
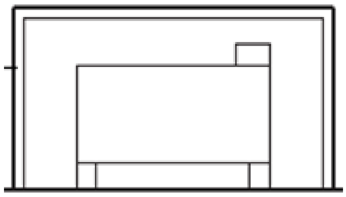
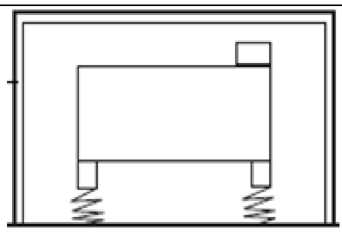


Figure 4.5.2: CadnA software

The cadnA software which used to construct the noise map is a demo version and therefore the value of SPL calculated by the software cannot be used. However, the

SPL value calculated by the software is not so important; the purpose of the software is acoustical design when setting up the factory. It means that before setting up the factory, the software is used to design the layout of the factory. From figure 4.4e, we can observe that the noisiest machine is spinning machine, B. It should be shielded away from other machines.

Table 4.5.2a: Noise reduction methods applied to machine.

		Approximate Sound Level Reduction, dBA
Vibration Isolator		2
Baffle		5
Right, rigid sealed enclosure		20- 25
Enclosure with Isolators		30- 35

From the table above, a proper design of the barrier can eventually reduced the sound level generated from the machines. A rigid enclosure is advisable to build to cover the spinning machine, B of the factory. Common and easiest ways to reduce the noise generated by the machine is periodic checking and do maintenance on the machine. Other suggestions to control the noise are summarized in the table below:

Table 4.5.2b: method of reduction

Equipment	Method of reduction
Motors	Intake silencer, absorbent duct liners, enclosure
Compressors	Inline silencer, use quiet valves and enlarge stream line piping
Engine	Silencer, enclosure intake, use quieter fan

A worker is assigned to work at workstation B for 5 hours continuously and then assigned to work at workstation H for 3 hours. When describing the effects of noise, exposure time should be taken into account. The daily noise dose, D can be calculated. The noise dose is 41% (<100%), it is within the allowable noise exposure of the present OSHA regulation. However, the workers are advised to wear the safety equipment like ear muff to protect their hearing system. The usage of appropriate hearing protective devices might also be considered as a noise control in this factory. However, it should be pointed out that hearing protectors are often unpopular among users for the reason such as discomfort and difficulty in speech communication.

Industrial now can easily predict the combined noise levels at individual workstations. The daily noise dose helps to enhance the occupational workplace safety which will subsequently reduce the number of workers suffering from occupation- induced hearing loss.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

From the results of the research, it shows that noise hazardous area within industrial workplace can be predicted by firstly constructing a noise contour map using the software. This map is then use to identify areas which have high noise levels. These areas should be marked as noise hazardous areas since worker who need to be present in these areas over an extended period may be subject to noise hazard. Mathematical formulas are given to help safety practitioners to calculate the daily noise dose. The result can be compared with permissible levels to determine if worker are being exposed to a noise hazardous environment. With this knowledge and suggested procedure, safety practitioners can easily develop suitable work assignment to ensure that workers' noise exposure level does not exceed the permissible level.

The objectives of this research are achieved which the calculated SPL and measured SPL are obtained. The mathematical expressions are used to determine the calculated SPL while the measured SPL at difference locations can be obtained by using sound level meter. Both results of calculated SPL and measured SPL are compared to check correctness, and also the measured SPL is compared with Malaysian Factories and Machinery (Noise Exposure) Regulation 1989. The purpose of this comparison is to make sure noise generated from the machines does not give impact on health of the workers leading to various kinds of illness as well as ecological imbalance. Fortunately, the SPL generated by operating machines is under the safety zone of permissible exposure level which is under 90dBA. However, some of the suggested methods are discussed in this research in order to attenuate the noise levels and controlling pollution of the factory.

5.2 Recommendation

Throughout this research, I have learnt a relatively new subject which is industrial acoustic. Acoustic subject which also includes environmental acoustic and building acoustic. These three areas of acoustic are actually no related to each other. However, I had learnt the fundamental of the industrial acoustic and also the acoustic design of a factory. This subject I never learn in university and secondary school. Therefore, I am hereby to suggest that UTAR can offer this subject to all engineering students. It may help students to build up their fundamental knowledge and occupational opportunity in their future.

In order to improve this study in future, the basic knowledge is important while the device of measuring the sound level is also play an important role to improve the study. When carried out this research, the only set of sound level meter which provided by UTAR is in servicing and I not managed to use it to record my data. Unfortunately I had used a type II sound level meter which only supports simple feature and function to perform measurement. The sound level meter does not have data acquisition function and I have to manually record the data. Therefore, the results are not so accurate and precise. I suggest UTAR to prepare another set of sound level meter for standby purpose. Another reason is the only set of sound level meter has to share among six students which having the same final year project title. With additional set of sound level meter, students become more convenience and can proper arrange their schedule to perform measurement.

Instead of using sound level meter, I proposed to use noise dose meter when to calculate the daily noise dose. Noise dose meter which is light in weight can actually put into the pocket of the worker and therefore the noise level exposed to the worker during the 8 hour working day can be observed.

Besides that, when come to the layout design, noise mapping software is important to illustrate the noise distribution of the workplace. In my research, the noise mapping software is a demo version which can perform simple drawing while other advance parameters such as wall properties are not available. So I am highly recommend UTAR to purchase a noise mapping software whereby students may have chance to experience it in future. In addition, I had faced difficulty when borrowed the acoustic book from UTAR library because it has limited set of reference book. I have to look through the acoustic information from internet. So I recommend UTAR library can have more reference books related to acoustic which may help students to get information easily.

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APPENDICES

APPENDIX A: Representative Sabine Absorptivities and absorption

Description	Frequency (Hz) 125	250	500	1000	2000	4000
	Sabine Absorptivity *a*					
Occupied audience, orchestra, chorus	0.40	0.55	0.80	0.95	0.90	0.85
Upholstered seats, cloth-covered, perforated bottoms	0.20	0.35	0.55	0.65	0.60	0.60
Upholstered seats, leather-covered	0.15	0.25	0.35	0.40	0.35	0.35
Carpet, heavy on undercarpet (1.35 kg/m^2 felt or foam rubber)	0.08	0.25	0.55	0.70	0.70	0.75
Carpet, heavy on concrete	0.02	0.06	0.14	0.35	0.60	0.65
Acoustic plaster (approximate)	0.07	0.17	0.40	0.55	0.65	0.65
Acoustic tile on rigid surface	0.10	0.25	0.55	0.65	0.65	0.60
Acoustic tile, suspended (false ceiling)	0.40	0.50	0.60	0.75	0.70	0.60
Curtains, 0.48 kg/m^2 velour, draped to half area	0.07	0.30	0.50	0.75	0.70	0.60
Wooden platform with airspace	0.40	0.30	0.20	0.17	0.15	0.10
Wood paneling, 3/8–1/2 in. over 2–4 in. airspace	0.30	0.25	0.20	0.17	0.15	0.10
Plywood, 1/4 in. on studs, fiberglass backing	0.60	0.30	0.10	0.09	0.09	0.09
Wooden walls, 2 in.	0.14	0.10	0.07	0.05	0.05	0.05
Floor, wooden	0.15	0.11	0.10	0.07	0.06	0.07
Floor, linoleum, flexible tile, on concrete	0.02	0.03	0.03	0.03	0.03	0.02
Floor, linoleum, flexible tile, on subfloor	0.02	0.04	0.05	0.05	0.10	0.05
Floor, terrazzo	0.01	0.01	0.02	0.02	0.02	0.02
Concrete (poured, unpainted)	0.01	0.01	0.02	0.02	0.02	0.02
Gypsum, 1/2 in. on studs	0.30	0.10	0.05	0.04	0.07	0.09
Plaster, smooth on lath	0.14	0.10	0.06	0.04	0.04	0.03
Plaster, smooth on lath on studs	0.30	0.15	0.10	0.05	0.04	0.05
Plaster, 1 in. damped on concrete block, brick, lath	0.14	0.10	0.07	0.05	0.05	0.05
Glass, heavy plate	0.18	0.06	0.04	0.03	0.02	0.02
Glass, windowpane	0.35	0.25	0.18	0.12	0.07	0.04
Brick, unglazed, no paint	0.03	0.03	0.03	0.04	0.05	0.07
Brick, smooth plaster finish	0.01	0.02	0.02	0.03	0.04	0.05
Concrete block, no paint	0.35	0.45	0.30	0.30	0.40	0.25
Concrete block, painted	0.10	0.05	0.06	0.07	0.09	0.08
Concrete block, smooth plaster finish	0.12	0.09	0.07	0.05	0.05	0.04
Concrete block, slotted two-well	0.10	0.90	0.50	0.45	0.45	0.40
Perforated panel over isolation blanket, 10% open area	0.20	0.90	0.90	0.90	0.85	0.85
Fiberglass, 1 in. on rigid backing	0.08	0.25	0.45	0.75	0.75	0.65
Fiberglass, 2 in. on rigid backing	0.21	0.50	0.75	0.90	0.85	0.80
Fiberglass, 2 in. on rigid backing, 1 in. airspace	0.35	0.65	0.80	0.90	0.85	0.80
Fiberglass, 4 in. on rigid backing	0.45	0.90	0.95	1.00	0.95	0.85

APPENDIX B: Approximate value of mean sound absorption coefficient, α

Mean sound absorption coefficient, α	Description room
0.05	Nearly empty with smooth hard walls made of concrete, brick, plaster or tile
0.1	Partly empty room with smooth walls.
0.15	**Room with furniture , rectangular machinery, rectangular industrial room**
0.2	Irregularly shaped room with furniture. Irregularly shape machinery room or industrial room.
0.25	Room with upholstered furniture, machinery or industrial room with a small amount of sound absorbing material (for example, partially absorptive ceiling) on ceiling or walls
0.35	Room with sound absorbing materials on both ceiling and walls
0.5	Room with large amount of sound absorbing material on ceiling and walls