A PRELIMINARY DEVELOPMENT OF BASELINE FOR NORMAL CONDITION OF LOCAL EXHAUST VENTILATON SYSTEM (LEV) BY USING MAHALANOBIS DISTANCE (MD) METHOD

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A PRELIMINARY DEVELOPMENT OF BASELINE FOR NORMAL CONDITIONS OF LOCAL EXHAUST VENTILATION SYSTEM (LEV) BY USING MAHALANOBIS DISTANCE (MD) METHOD

NUUR HUSNA BT HASNIN

A thesis submitted in fulfillment
of the requirements for the award of the Degree of
Bachelor of Chemical Engineering

Faculty of Chemical & Natural Resources Engineering
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JANUARY 2012

I declare that this thesis entitled "A Preliminary Development Of Baseline For Normal Conditions Of Local Exhaust Ventilation System (Lev) By Using Mahalanobis Distance (Md) Method " is the result of my own research except as cited in references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree."

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Name : Nuur Husna Bt Hasnin
Date :

Special Thanks to supervisor, Mr Azizan B Ramli
for all of your Care, Support and Best Wishes.

And,

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ABSTRACT

Ventilation is the mechanical system in a building that brings in fresh outdoor air and removes the contaminated indoor air. In a workplace, ventilation is used to control exposure to airborne contaminants. It is commonly used to remove contaminants such as fumes, dusts, and vapors, in order to provide a healthy and safe working environment. Therefore, the LEV system is considered as an important system that should have in every single workplace so that all the workers are not exposed to the hazardous. In measuring the LEV systems, the study has come out with a new approach which is *Mahalanobis Distance* method (MD). It is believe that this new method is one of the first attempts to evaluate local exhaust ventilation performance by using multi-dimensional approach. The previous method of measuring the local exhaust ventilation system is time consuming which means it took a long period of time in order to measure the point. Besides, not all the measuring points give a significant value for the overall performance of local exhaust ventilation systems. The purposed of this study is to develop the preliminary baseline on normal conditions that will be a starting point on solving the time consuming problem on measuring the local exhaust ventilation systems.

ABSTRAK

Sistem pengudaraan adalah sistem mekanikal di dalam bangunan yang membawa masuk udara dari luar yang segar dan menyingkirkan udara dalam bangunan yang tercemar. Sistem pengudaraan ini digunakan untuk mengawal pendedahan kepada bahan cemar yang dibawa oleh udara di tempat kerja. Ia biasanya digunakan untuk membuang bahan-bahan pencemaran seperti asap, habuk dan wap untuk menyediakan persekitaran tempat kerja yang sihat dan selamat. Oleh itu, sistem pengudaraan dianggap sebagai satu sistem yang penting yang perlu ada di setiap tempat kerja supaya semua pekerja tidak terdedah kepada risiko kesihatan yang bahaya. Di dalam proses untuk mengukur sistem pengudaraan, satu kajian telah dikeluarkan dengan menggunakan pendekatan baru yang dinamakan kaedah ‘Mahalanobis diatance’(MD). Ia dipercayai bahawa kaedah baru ini adalah satu percubaan yang pertama untuk menilai prestasi sistem pengudaraan dengan menggunakan pendekatan pelbagai dimensi. Kaedah mengukur sistem pengudaran sebelum ini mengambil masa yang lama bermaksud ia mengambil masa yang panjang untuk mengukur setiap titik . Selain itu, tidak semua titik yang diukur memberikan nilai yang ketara ke atas prestasi keseluruhan sistem pengudaraan. Kajian ini adalah bertujuan untuk membentuk garis dasar awal dalam keadaan normal yang akan menjadi titik permulaan kepada penyelesaian masalah masa untuk mengukur sistem pengudaraan.

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Ventilation is considered an engineering control to remove or control contaminants released in indoor work environments. It is one of the preferred ways to control employee exposure to air contaminants. There are two types of mechanical ventilation systems used in industrial. The first type is dilution or general ventilation that reduces the concentration of the contaminant by mixing the contaminated air with clean, uncontaminated air and second type is local exhaust ventilation that captures contaminates at or very near the source and exhausts them outside.

Every day the workers all over the world are facing with a multitude of health hazards, such as dusts, gases, noise, vibration, extreme temperatures and many more hazardous in the workplace. In order to obtain a safety places in a manufacturing industry, an efficient and appropriate system of safety and health are considerable importance beside the requirement of the legislation. Thus, occupational safety and health (OSH) have work to promote a number of safety and health related behaviour of the workplace. One of the systems that have been develops to control those hazardous in the workplace is local exhaust ventilation (LEV) systems.

Local exhaust is generally a far more effective way of controlling highly toxic contaminants before they reach the workers breathing zones. The importance of these systems is it will control the hazardous airborne contaminant by capturing and removing the contaminant at or near it source of generation and it prevent the contaminant from release into the workplace. Local exhaust ventilation is required when employee exposed to an airborne emission is not satisfactorily controlled by dilution or general ventilation.

The Regulation 17 by DOSH (2004) stipulated that any engineering control equipment has to be inspected at an interval not longer than one month and has to be examined and tested by Hygiene Technician at an interval not longer than twelve months. In order to do the inspection activities in ventilation systems, it required very long time duration.

The present study aims to reduce the number of measuring the LEV points and at the same time reduce the measuring time in inspections activities. The Mahalanobis–Taguchi System (MTS), developed by Taguchi, is a method proposed for a feature selection technique using multivariate data. In this study, MTS is used to develop the preliminary baseline for the normal condition of LEV systems. Besides, the reference points for the future pattern recognition also will be constructed using this method.

1.2 Problem Statement

The inspection of local exhaust ventilation system has to be done at least once a month as required by the regulations 17 by DOSH (2004) or at shorter interval as specified by the designer. The inspection process took long procedures. The previous method of measuring the local exhaust ventilation system is time consuming. The process took a long period of time because all the point on the systems need to be consider even though certain reading are not give significant value that represent the overall performance. Therefore, the process of local exhaust ventilation monitoring required quite tedious measuring activity.

1.3 Objective

Based on the problem statement described in the previous section, the following are the objectives of this research:

1. To develop a preliminary baseline of normal condition of local exhaust ventilation systems using *Mahalanobis distance* method.

2. To construct a reference point for the future local exhaust ventilation pattern recognition.

1.4 Scope of Study

In order to achieve the above mentioned objective the following scopes were drawn. The study is only conducted at local exhaust ventilation pilot plant Ftech. By doing the research, a parameter that to be consider is velocity pressure that measured by using micro manometer that connecting with pitot tube. The research is measure the normal condition only up to the creation of the preliminary baseline.

1.5 Benefit and Significant of Study

The purposed of the study is to develop a preliminary baseline for the normal condition of local exhaust ventilation system. The preliminary baseline will be using for the continuous study on pattern recognition on normal condition of local exhaust ventilation system. The baseline creation is the important part in Mahalanobis method where the baseline will be reference points for the other group in distinguish the pattern. In addition, the preliminary baseline will be a starting point on solving the time consuming problem of measuring the local exhaust ventilation systems.

1.6 Definition of Key Terms.

- **Local Exhaust Ventilation (LEV) system –** systems capture or contain contaminates at their source before they escape into the workplace environment. The main advantage of these systems is that they remove contaminates in place of diluted them depending upon 100% collection efficiency

- **Mahalanobis Distance (MD) –** the method that used to distinguish the pattern of a certain group from other groups.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Ventilation is used to control toxic airborne chemicals, to prevent a buildup of flammable gases or vapors and to comfort the inhabitants of the area. Health effects of chemicals are occurring at air concentrations that below the lower explosive limits of solvents and gases. Therefore, it can say that ventilation also can prevent a buildup of vapors that could catch fire or explode besides to prevent health effects.

There are two major types of industrial ventilation system that usually used in the industry as a method for reducing employee exposures to airborne contaminants. The industrial ventilation types are dilution ventilation and local exhaust ventilation. The purposed of those ventilation systems is to provide a continuous supply of fresh outside air, maintain temperature and humidity at comfortable levels reduce potential fire or explosion hazards and to remove or dilute airborne contaminants (CCOHS, 2008).

Dilution ventilation involves bringing in clean air to dilute the contaminated air, and then exhausting the diluted air to the outside via exhaust fans. An open door or window, or recirculation air-conditioning system is not adequate dilution ventilation for toxic gases and vapors while local exhaust ventilation involves trapping airborne contaminants at their source before they contaminate the air which is breathed. (McCann, M. 1992)

2.2 Local Exhaust Ventilation Systems

According to Socha (1979) local exhaust ventilation system is one of the "standard engineering methods of control" used to prevent excessive employee exposure to airborne contaminant .According to Canadian Centre for OSH, local exhaust system is used to control air contaminants by trapping them at or near the source, differs with dilution ventilation systems which lets the contaminant spread throughout the workplace.

This type of system is usually the preferred control method if the air contaminants pose serious health risk to the workers, the large amounts of dusts or fumes are generated in the workplaces, the emission sources are few in number and the emission sources are near the workers breathing zones. In a general way, a local exhaust system operates similar to a household vacuum cleaner with the hose as close as possible to the place where dirt would be created. (Socha, 1979)

A local exhaust system consists of a hood to capture the contaminants, ducts to transport them to the outside, an exhaust fan to move the air, and sometimes air cleaners to remove particulates from the air.

The Regulation for Health Care and Residential Facilities (1992) made under the Occupational Health and Safety Act (OHSA) requires that mechanical ventilation systems in the workplaces to which the regulation applies be inspected by a qualified person at least every six months.

2.3 Properties of Airborne Material

Dusts, fumes, vapours and gases are the type of airborne materials. The dust solid particles are generated by handling, crushing, grinding and detonation of materials such as rock, metal and wood. Dust particles vary widely in size, with the finer particles remaining airborne for long periods. Dust particles that less than 5 microns can reach the lungs. (Alden *et.al*, 1982)

Fumes are small solid particles created by condensation from the gaseous state, generally after the application of heat to substances or by chemical reaction such as oxidation. Most fumes are usually submicron in size, and have a tendency to flocculate and coalesce into long chains or clumps. (Alden *et.al*, 1982)

Vapours are the gaseous forms of substances which are normally in the liquid or solid state and which can be changed to these states either by increasing the pressure or decreasing the temperature. The last but not least, gases are normally compressible, formless fluids which occupy the space of their enclosure and which can be changed to the liquid or solid state only by the effect of increased pressure and decreased temperature or both (Alden *et.al*, 1982)

Those types of airborne material are harmful to the human. People that exposed directly to the airborne contaminant will have a lung problem and may be suffering from lung cancer. Local exhaust ventilation is one of the most common ways of controlling exposure to hazardous substances, so reducing the risk of respiratory diseases.

2.4 The Basic Component of Local Exhaust Ventilation System

The local exhaust ventilation systems have five basic components which are hood, duct, air cleaning device, a fan and exhaust stack. Kane claims that the economics and the effectiveness of controlling contaminants at their source of generation through local exhaust ventilation became evident, and many of the guides in texts today covering exhaust volumes and hood designs were compiled in those early days (Kane, 1967). Figure 2.4 shows the basic components in local exhaust ventilation system.

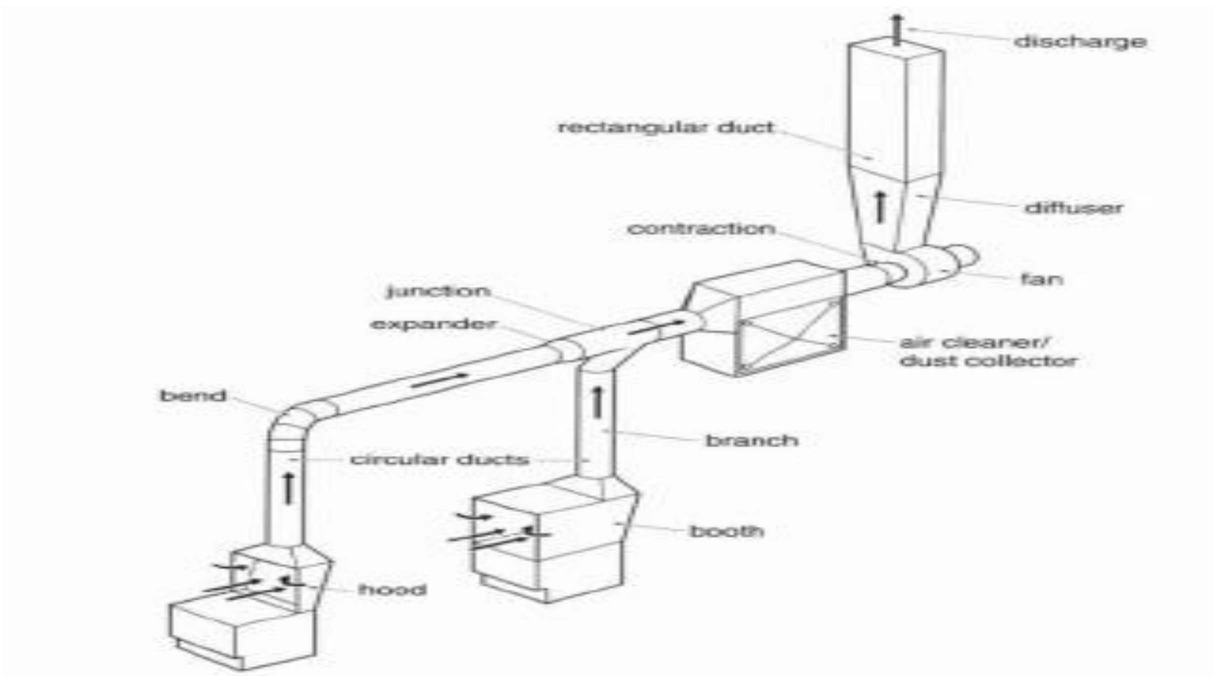


Figure 2.4: Basic Component of LEV System (CCOHS, 2008)

According to the guideline on OSH, hood is the most important component of the local exhaust ventilation system because local exhaust ventilation system will not be effective unless enough of contaminants are retained or captured by the hoods as to ensure that the concentration of contaminants in the workroom is below the acceptable limits.

2.5 The Function and Components Design

2.5.1 The Hood

The function of hood is to collect the emitted contaminants. A hood is a structure design to enclose or partially enclosed a contaminant producing and to guide air flow in an efficient manner to capture a contaminant (Mutchler. J. E, 1990). The hood should not draw contaminated air through the breathing zone of the employee.

2.5.2 The Ducts

The function of the ducts in an exhaust system is to provide a channel for flow of the contaminated air exhausted from the hood to the point of discharge. The importance of the duct design in the case of dust, the duct velocity must be high enough to prevent the dust form settling out and plugging the duct (Alden *et.al*, 1982)

2.5.3 The Air Cleaner

The function of air cleaner is to remove contaminant from the air stream (Alden *et.al*, 1982). Air cleaners can be classified as air filters, particulate dust and fume collectors and devices to remove mists, gases and vapours. Filters are mainly used for cleaning air and are designed to handle large air volumes with low resistance to airflow, although high-resistance high-efficiency filters are used for ultra-clean applications and for the control of hazardous dusts such as asbestos (Mutchler. J. E, 1990).

2.5.4 The Fan

The function of the fan is to supply required static pressure and physically removed the air. Fans in LEV systems fall into two main categories which is centrifugal and axial flow. In Local Exhaust Ventilation systems, centrifugal fans are more widely used. Centrifugal fans move air by blades on rotating fan wheel throwing air outward from the centre inlet at a higher velocity or pressure than air entering the fan (Industrial Ventilation, 1972). Exhaust fans must be located at the point of the final discharge. An exhaust fan located at other than this point can pressurize the duct with contaminated air, fume hood ducts must be maintained under negative pressure (UCSB, 2007).

2.5.5 The Exhaust Stack

The function of the exhaust stack is to disperse contaminant to ambient air and reduce their reintroduction to the plant environment. Fume hood exhaust stacks must extend at least seven feet and ten feet preferred above the roof or at least two feet above the top of a parapet wall, whichever is greater (UCSB, 2007) .The discharge must be directed vertically upward.

All LEV systems need to be subject to commissioning to ensure that they are capable of meeting their design specifications. Under the Control of Substances Hazardous to Health Regulations 1999 all control measures need to be maintained in an efficient state, in efficient working order and in good repair.

2.6 Inspections of Local Exhaust Ventilation Systems

Inspection of local exhaust ventilation system has to be done at least once a month as required by the regulations or at shorter interval as specified by the designer. (DOSH, 2004). The purpose of inspection is to ensure the system functioning properly and effectively. The inspection can be done by any person that has been taught the procedure to carry out the inspection.

Inspection of local exhaust ventilation system consists of the inspection of physical condition of all component of local exhaust ventilation system, the observation of how the work carried out in relation to the utilization of local exhaust ventilation system, the smoke tube tracer test, an identifying any thing that can be obstruction of flow, the observation of condition surrounding and near the hood, the inspection on the air cleaner device and the maintenance of the fan’s motor. The inspection process will go through long procedures. Table 2.6 shows the procedures that took place on the ducting.

Table 2.6: Inspection, Testing and Examination Procedure on Ducting (DOSH, 2004)

Inspection Item	Inspection Procedure	Inspection Indicator
1. Physical condition of duct outer surface	Inspect the condition of the outer surface of the duct system. Start the inspection from the hood and inspect all duct connections. Inspect the main duct and branch duct.	The following condition should not occur - • Abrasion, corrosion and dents and other damages which can affect air flow or cause leakages. • Damages of coating which can cause corrosion of the duct.
2.Physical condition of inner surface of the ducts.	Inspect the condition of the inner surface of the duct system through the inspection holes. If there is no inspection holes, disconnect duct joints for inspection	The following condition should not occur - • Abrasion, corrosion and dents and other damages which can affect air flow or cause leakages. • Damages of coating which can cause corrosion of the duct.
3. Loose joints	a. Inspect for any crack, missing and uneven tightness of tightening bolts and nuts, gaskets, etc. b. Test for leakages at joints with smoke when in LEV system is in operation.	Should not have any crack, missing, uneven tightening bolt and nut, missing or damaged gasket, etc. Smoke from a smoke tester must not be sucked or blown out
4. Condition of Inspection holes.	a. Inspect whether inspection holes can be open or close easily.	The inspection holes be opened and shut smoothly and must be closed without leak.
5. Static Pressure	Measure the static pressure in the duct with a manometer at measuring holes	Static pressure in the duct must be within the range of + 10% of baseline static pressure (SP + 10%).
6. Duct Velocity	Measure velocity pressure in the duct with a traverse pitot tube connected to a manometer	Duct velocity in the duct must be within the range of + 10% of baseline duct velocity (V + 10%)

2.7 Historical Development of Mahalanobis Distance

Prof. Prasad Chandra Mahalanobis and Prof. Genichi Taguchi was the persons that develop the *Mahalanobis distance* method. Prof P.C. Mahalanobis was a famous Indian statistician who established the Indian Statistical Instituted. In 1930, Mahalanobis introduce a statistical tool called *Mahalanobis Distance* (MD) that used to distinguish the pattern of a certain group from other groups (Genichi Taguhi *et al*, 2004).

Mahalanobis used the *Mahalanobis Distance* (MD) for an ethnological application that to characterize the differences among Asian races and tribes. The main objectives of his application were to make statistical judgements to distinguish one group from another.

As for Prof. Genichi Taguchi , he has design the Mahalanobis–Taguchi System (MTS) which is the systematic method for using the *Mahalanobis Distance*. The objectives of the Mahalanobis–Taguchi System (MTS) are to develop and optimized a diagnostic system with a measurement scale of abnormality. Moreover, Taguchi used the system not only for diagnosis but also for forecasting or prediction systems.

2.8 Mahalanobis-Taguchi System (MTS)

Genichi Taguchi, Subir Chowdhury and Yuin Wu claim that the Mahalanobis–Taguchi System (MTS) is used to developed and optimize a system of multivariable diagnosis, pattern recognition, and prediction of occurrence of particular event (Genichi Taguhi *et al*, 2004). Besides, *Mahalanobis Distance* underlies the theory of discriminate analysis and it also often used in cluster that may be treated as a part of pattern recognition (E.Krusinska, 1987).

According to T.Yang and Y.T.Cheng, Mahalanobis–Taguchi System (MTS) is a method proposed for a diagnostic and forecasting, binary classification and feature selection technique using multivariate data (T.Yang and Y.T.Cheng, 2009). It is contains two phases in Mahalanobis–Taguchi System (MTS). The first phase uses *Mahalanobis Distance* to construct a multidimensional measurement scale and define a reference point of the scale with a set of observations from a reference group. In addition, the reference group is used to construct the Mahalanobis space (MS) which is a database containing the means, standards deviataions and correlation structure of variables in the reference group.

For the second phase of MTS, the applicability of orthogonal arrays (OAs) and signal-to-noise (SN) ratios are used to select the critical variables. Das and Data claim that when searching for patterns, the MTS is a good and an effective algorithm (Das and Data ,2007).The MTS developed by Taguchi is a novel method that combines the *Mahalanobis Distance* (MD), orthogonal arrays (OA) and the signal-to-noise (SN) ratio. The MTS is a diagnostic and forecasting method. The main aim of the MTS is to make accurate predictions in multidimensional attributes by constructing a global measure meter. The application of MTS in the pattern-recognition area such MTS based to resolve classification problems.

2.9 The Application of Mahalanobis Distance Method

Mahalanobis–Taguchi System (MTS) method is used to reduce the number of bump height measurement points whilst maintaining a high-accuracy inspection level (Taho Yang *et al*, 2009). The numbers of bump height inspection features are significantly reduced from 10 to 6 without losing classification accuracy and inspection time can be reduced by 40%. Based on the previous study, Mahalanobis distance method is proved as the method of reducing the time consuming.

The Mahalanobis–Taguchi System (MTS) also used in detection and quantify the changes in exhaust sensor signal performance (S.Teshima *et al,* 1997). The feasibility of use of MTS multivariate approach is successfully demonstrated by the improvement of discrimination. Besides, The Mahalanobis-Taguchi System is a diagnosis and predictive method for analyzing patterns in multivariate cases (E. A. Cudney *et al*, 2007). The advantage of Mahalanobis Distance is that it takes into consideration the correlations between the variables and this consideration is very important in pattern analysis.

Well-known statistician, Professor P.C. Mahalanobis, introduced *Mahalanobis Distance* (MD) in 1930 to distinguish patterns of a certain group from another group while Dr. Genichi Taguchi led the development of MTS by providing a means to define the reference group and measure the degree of abnormality of individual observations (Taguchi and Jugulum, 2000).

CHAPTER 3

METHODOLOGY

3.1 Instrument

The instrument use to measure the velocity pressure is called micro manometer. The DP-CALC 5815 is simple to operate. The instrument is easy to operate by hand with the digital micro manometer that gives a reading for fast. Besides, the instrument gives an accurate differential and static pressure measurements. To collect the velocity pressure data, the micro manometer is attached with a pitot tube. Figure 3.1 shows the image of the instrument.

Figure 3.1: DC-CALC Micro manometer 5815 (Google image)

3.2 Measuring the Velocity Pressure (Vp)

The research is conducted in local exhaust ventilation pilot plant Ftech. The LEV systems consist of thirteen points. Figure 3.2 shows the image of LEV pilot plant Ftech.

Figure 3.2(a): Local Exhaust Ventilation Pilot Plant Ftech

A pitot traverse involves measuring the velocity at a number of points across the duct area because velocity distribution is not uniform within the duct. The number and location of measuring points within the duct depend on the duct size and shape. The idea is to divide the duct into enough zones of equal area to give accurate results (DOSH, 2008).

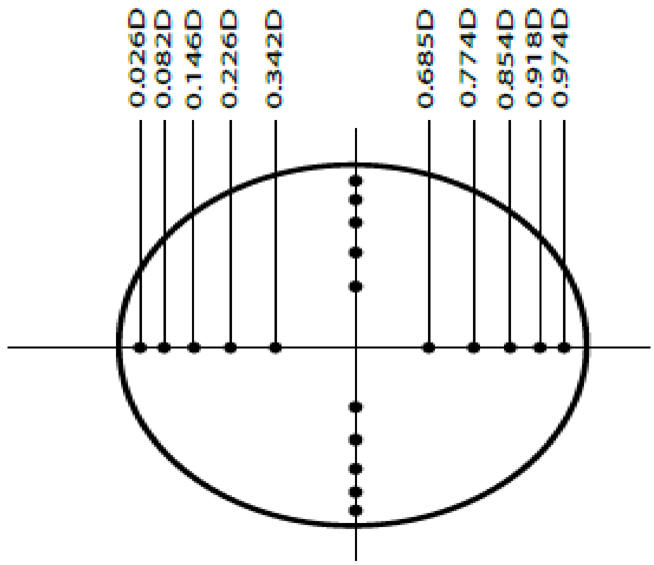


Figure 3.2 (b): Measuring location for 10 points pitot transverse (DOSH, 2008)

The LEV systems have divided into three different duct diameters which are 20.5 cm, 25.8 cm and 30.6 cm. The duct diameters are multiply with the measuring location to get the distance from it wall. Therefore, twenty readings are obtained for each point horizontally and vertically.

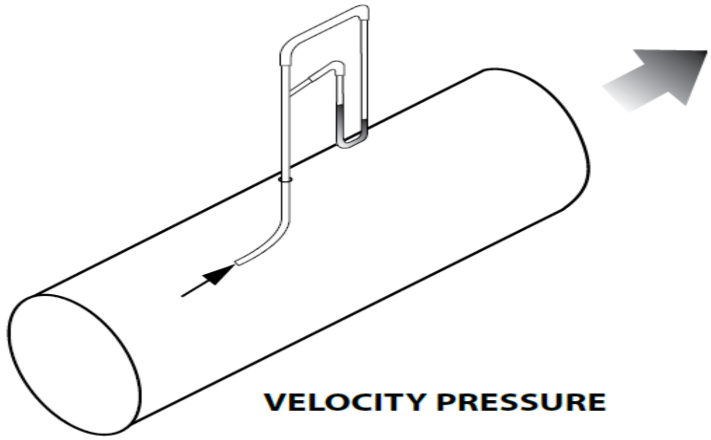
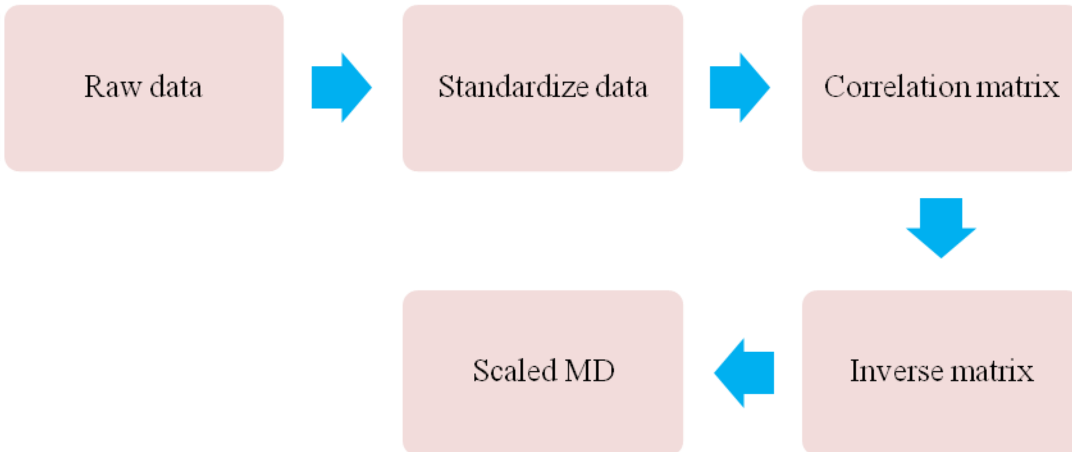


Figure 3.2 (c): Method of measurement with pitot tube (DOSH, 2008)

Figure 3.2 (c) shows the method of measuring the points of local exhaust ventilation systems. The measuring process is done within six cycles where every cycle took almost one hour duration. The measuring cycle is done in the morning, evening and at night. Therefore, there are 120 samples that been testing and 1560 data that obtain during the research for the normal condition.

3.3 Creation of Baseline Mahalanobis Space

The 1560 raw multivariate data for normal condition are collected. Stated below is the flow chart on computing the scale *Mahalanobis distance* that also known as *Mahalanobis space* (MS).



The normal raw multivariate test data were then used to create a baseline measurement scale for the normal group. The raw data that collected has the format as illustrated in the table 3.3 (a). The mean and standard deviation value is calculated by using the following equation respectively.

$$\bar{X}_i = \frac{1}{N}\sum_{k=1}^{N} x_{ki} \qquad\qquad s_i = \sqrt{\frac{\sum_{k=1}^{N}(x_{ki} - \bar{X}_i)^2}{N-1}}$$

Table 3.3 (a): Raw data format (McGraw-Hill, 2004)

	Variables (characteristics)						
Objects	X_1	X_1	$\dots$	X_i	$\dots$	X_{p-1}	X_p
1	x_{11}	x_{12}	$\cdots$	x_{1i}	$\cdots$	$x_{1,p-1}$	x_{1p}
2	x_{21}	x_{22}	$\cdots$	x_{2i}	$\cdots$	$x_{2,p-1}$	x_{2p}
$\vdots$	$\vdots$	$\vdots$	$\cdots$	$\vdots$	$\cdots$	$\vdots$	$\vdots$
k	x_{k1}	x_{k2}	$\cdots$	x_{ki}	$\cdots$	$x_{k,p-1}$	x_{kp}
$\vdots$	$\vdots$	$\vdots$	$\cdots$	$\vdots$	$\cdots$	$\vdots$	$\vdots$
N	X_{Nk}	x_{N2}	$\cdots$	x_{Ni}	$\cdots$	$x_{N,k-1}$	x_{Np}
Average	$\overline{X}_1$	$\overline{X}_2$	$\cdots$	$\overline{X}_i$	$\cdots$	$\overline{X}_{p-1}$	$\overline{X}_p$
Standard deviation	s_1	s_2	$\cdots$	s_i	$\cdots$	s_{p-1}	s_p

From the raw data, the standardize data can be calculated by subtracting the mean and dividing by the standard deviation. The standardized data that obtain has a format as illustrate in the table 3.3 (b). This process is a typical normalization process for multivariate data analysis. Then, the sample correlation matrix and inverse matrix is computed for the standardize variables by using the following equation respectively.

$$\mathbf{R} = \begin{bmatrix} 1 & r_{12} & \cdots & r_{1p} \\ r_{21} & 1 & \cdots & r_{2p} \\ \vdots & \vdots & \vdots & \vdots \\ r_{p1} & r_{p2} & \cdots & 1 \end{bmatrix}$$

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1k} \\ a_{21} & \cdots & \cdots & a_{2k} \\ \vdots & \vdots & \vdots & \vdots \\ a_{k1} & a_{k2} & \cdots & a_{kk} \end{bmatrix} = \begin{bmatrix} 1 & r_{12} & \cdots & r_{1k} \\ r_{21} & 1 & \cdots & r_{2k} \\ \vdots & \vdots & \vdots & \vdots \\ r_{k1} & r_{k2} & \cdots & 1 \end{bmatrix}^{-1}$$

Table 3.3 (b): Standardized data format (McGraw-Hill, 2004)

	Standardized variables (characteristics)						
Objects	Z_1	Z_2	$\cdots$	Z_i	$\cdots$	Z_{p-1}	Z_p
1	z_{11}	z_{12}	$\cdots$	Z_{1i}	$\cdots$	$z_{1,p-1}$	z_{1p}
2	z_{21}	z_{22}	$\cdots$	z_{2i}	$\cdots$	$z_{2,p-1}$	z_{2p}
$\vdots$	$\vdots$	$\vdots$	$\cdots$	$\vdots$	$\cdots$	$\vdots$	$\vdots$
k	z_{k1}	z_{k2}	$\cdots$	z_{ki}	$\cdots$	$z_{k,p-1}$	z_{kp}
$\vdots$	$\vdots$	$\vdots$	$\cdots$	$\vdots$	$\cdots$	$\vdots$	$\vdots$
N	z_{Nk}	z_{N2}	$\cdots$	z_{Ni}	$\cdots$	$z_{N,k-1}$	z_{Np}

The scale Mahalanobis distance can compute by using the following equation.

$$\mathrm{MD}_0 = \frac{1}{p}\mathbf{z}_0^T\mathbf{R}^{-1}\mathbf{z}_0$$

The Mahalanobis space is computed to get the average of the MS scaled approximately to one. Woodall has stated that,

$$E(\mathrm{MD}) = \frac{N}{N-1}$$

where N is the number of observations in the initial normal group (Woodall, 2003).

CHAPTER 4

RESULT AND DISCUSSION

1.1 Mahalanobis Space (MS) performance

Table 4.1: Scaled *Mahalanobis distance* for 120 samples

0.0160	0.0013	0.0749	0.0348	0.0539	0.1063	0.0170	0.1323	0.0898	0.1242
0.0060	0.0767	0.0093	0.0572	0.0437	0.0519	0.0875	0.0065	0.0048	0.2278
0.0363	0.0060	0.1166	0.0000	0.0748	0.0453	0.0132	0.0920	0.0268	0.0788
0.0038	0.0210	0.0629	0.0140	0.1738	0.0188	0.0521	0.0001	0.0321	0.5273
0.0038	0.0001	0.6480	0.0092	0.0728	0.0705	0.0378	0.0746	0.0200	0.1378
0.0005	0.0554	0.0728	0.0347	0.1298	0.0333	0.1614	0.0469	0.1244	0.2613
0.1603	0.0058	0.2103	0.0434	0.1822	0.1349	0.1134	0.2140	0.0131	0.2092
0.0005	0.0434	0.0806	0.0413	0.0462	0.0527	0.0116	0.0195	0.0335	0.0068
0.0005	0.0418	0.0371	0.0169	0.0740	0.0036	0.0829	0.0195	0.1349	0.0008
0.0413	0.0005	0.0434	0.0298	0.0276	0.0262	0.0191	0.0242	0.5232	0.0375
0.0280	0.0031	0.1960	0.0107	0.2152	0.0391	0.0059	0.1056	0.0527	0.2044
0.0355	0.0923	0.0025	0.0683	0.1244	0.0503	0.0031	0.0457	0.0213	0.5005

The result is summarized in Table 4.1. The average scaled Mahalanobis distance is 0.076 for the normal conditions. Figure 4.1 illustrates the scaled Mahalanobis distance for normal conditions.

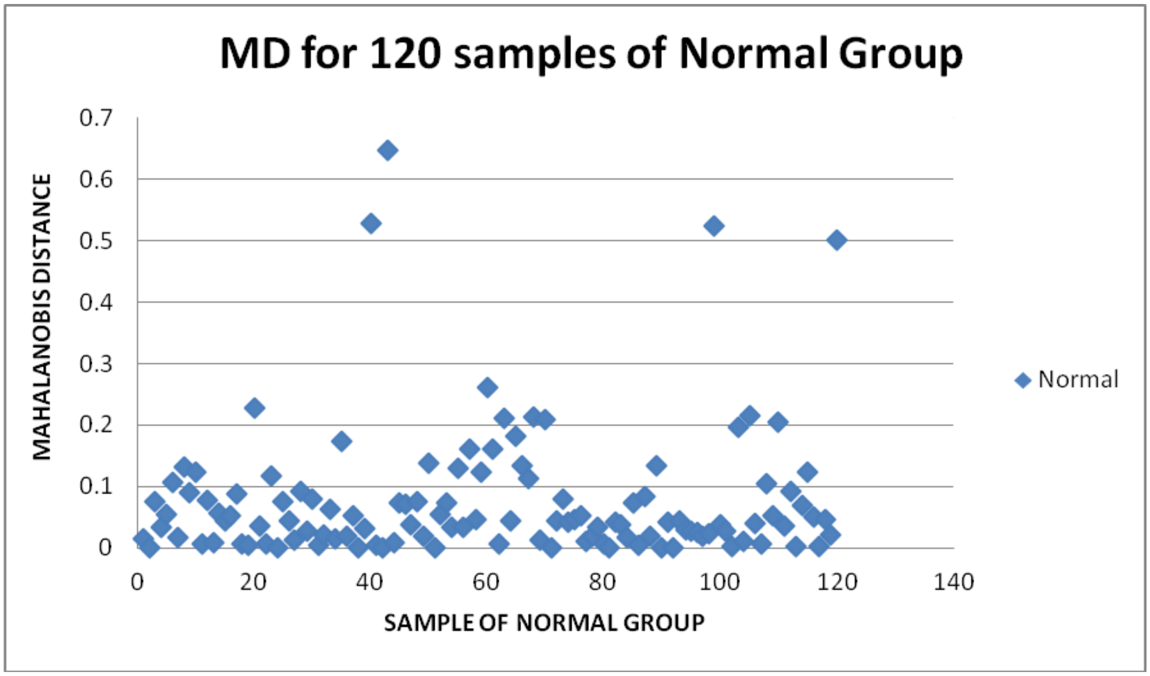


Figure 4.1: Scaled Mahalanobis Distance for normal conditions

Clearly, the scaled Mahalanobis distance for normal conditions is scatter and most of the points give the value of scaled MD around 0.2. The accurate value for the scaled MD is equal to one. Although the value of scaled MD is not equal to one, the initial baseline for the Mahalanobis space is successfully developed.

The presented method is enabled to evaluate the normal conditions even though there are some errors occur during collecting the data. The accuracy of the data is affected by three reasons during measured the points. The cleanliness and maintenance of the instruments contributes the worst effect of the readings. The accuracy of the readings may be influence by the cleanliness of the pitot tube.

Besides that, the accuracy of the data may be influence by the human error during measured the points. The readings are taken at each points based on the distance from the duct wall by using the pitot tube. During the measuring process, there must be a human error occur where the pitot tube is not measured at the right distance. In addition, the micromanometer does not give constant readings for the velocity pressure which means the reading is taken at random.

Last but not least, the accuracy of the data is affected by the number of the measurement cycle. In this study, the normal conditions are measure within six cycles. Based on the result, six times of measurement cycle does not give an accurate and precise data.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The research is about to develop the preliminary baseline for the normal conditions of the LEV systems using Mahalanobis distance approached. As a conclusion, the preliminary baseline is successfully developed. However, in order to get a precise and accurate data, there must be an improvement in the future study. Besides, the reference point for the future pattern recognition of local exhaust ventilation system has constructed.

The Mahalanobis distance method also can be used to develop the pattern recognition. In pattern recognition process, it also needs to construct the baseline that also called the reference points.

5.2 Recommendations

For this study, there are several improvements that should be applied in order to get a better Mahalanobis Space (MS) performance. Therefore, there are several recommendations for the future works. The cleanliness and the maintenance of the device used should to be considered at the first place. In this case, the cleanliness of the pitot tube must be monitor before start the measuring process. The cleanliness of the device will influence on the reading while taking the data.

Besides, the future researcher is recommended to increasing the number of measurement cycle. The present study has done for six cycles on normal condition. However the result is not giving an accurate and precise value of Mahalanobis Space. In the future, the number of measurement cycle is recommended up to 15 or above cycles to get an accurate and precise data. In addition, the selection of the normal data is very important before construct the baseline for the normal conditions.

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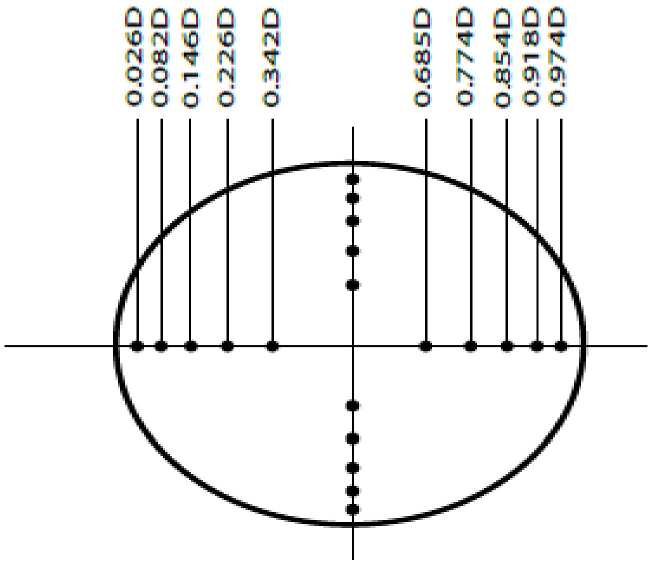
APPENDICES

APPENDIX A

Measurement of Velocity Pressure

Calculation on location of measuring points



The diameters of the duct are multiply with the following measuring point to get the distance from the duct wall.

Example:

Diameter ducting = 20.5cm

0.026 x 20.5 = 0.533 cm

0.082 x 20.5 = 1.681

0.146 x 20.5 = 2.911

Diameter ducting = 25.8 cm

0.026 x 25.8 = 0.6708

0.082 x 25.8 = 2.1156

0.146 x 25.8 = 3.7668

The cylindrical ducting readings are taken in accordance with the worksheet below.

THE SAMPLE OF PITOT TUBE TRAVERSE WORKSHEET FOR CYLINDRICAL DUCTING

Point:			
Date:	Time:	SP:	Temp.:
B.P:	d:	1/d:	
Equipment:		Location:	
Circumference:		Diameter:	
Area:		VP centreline:	

No.	Distance from duct wall	Vertical		Horizontal		Notes
		VP (mmHg)	Vel (ms^{-1})	VP (mmHg)	Vel (ms^{-1})	
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

APPENDIX B

Scaled Mahalanobis Distance Calculation using Microsoft Excel