


**GUIDELINE FOR LOCAL EXHAUST VENTILATION
MANAGEMENT OF COATING PROCESS IN MEDICATED
MANUFACTURING**


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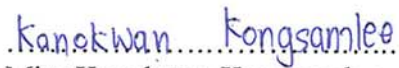

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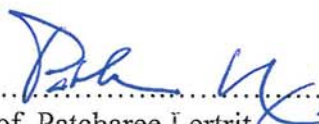
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ABSTRACT

The objective of this study was to develop guidelines for the management system of the local exhaust ventilation system in the adhesive coating processes of a medical plaster manufacturer. The adhesive coating process consists of three coating machines namely; coating machine CT-3, CT-4, and CT-5. The main chemical used in the adhesive coating processes is dearomatized hydrocarbon, used as a solvent to mix the bonding agent in the coating process to laminate on the fabric. Dearomatized hydrocarbon contained cyclohexane, heptane, methyl cyclohexane, and n-haxane. The ventilation systems in the adhesive coating room were a general exhaust ventilation system operated in combination with the local exhaust ventilation system.

The results showed that concentrations of chemicals in the workplace atmosphere in the adhesive coating processes for the past 3 years, during 2012-2014 AD. were higher than the recommendations of the American Conference of Governmental Industrial Hygienist (ACGIH) The results of additive mixture formula the calculations were mostly greater than 1. The measurement of capture velocities and air duct velocities of local exhaust ventilation at the coating machine CT-3, CT-4, and CT-5 were lower than the recommendations of the ACGIH. It requires a capture velocity of not less than 1 m/s and there were 10 measurement points of duct velocities of each coating machine (point B to K). The study found that the duct velocities from B to K of each coating machine complied with the recommendations of the ACGIH. Only one duct velocity at point K was below the recommendations of the ACGIH. It requires a duct velocity of not less than 5 m/s. The supply air flow rate into the adhesive coating process (supply airflow rate) was calculated, the result was equal to 26.43 m³/s and the total exhaust air flowrate of the adhesive coating processes (exhaust airflow rate) was 42.14 m³/s. Therefore, the exhaust airflow rate was larger than the supply airflow rate by 15.71 m³/s which led to static pressures in the adhesive coating room being negative all the time.

Because the chemicals concentrations were exceeded the recommendations of the ACGIH. The solution to this problem was to develop the guidelines for management of local exhaust ventilation system in the adhesive coating room. The organization did not have concrete guidelines on the management of the local exhaust ventilation system. In this regard, the organization should provide the following; standardization on responsibility and accountability, action plans, auditing system and a management review on the occupational safety and health system.

KEY WORDS: MANAGEMENT / LOCAL EXHAUST VENTILATION / COATING PROCESS

105 pages

แนวทางในการบริหารจัดการระบบระบายอากาศเฉพาะที่ในกระบวนการเคลือบกาว โรงงานผลิตอุปกรณ์ทางการแพทย์

GUIDELINE FOR LOCAL EXHAUST VENTILATION MANAGEMENT OF COATING PROCESS IN MEDICATED MANUFACTURING

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บทคัดย่อ

การวิจัยนี้มีวัตถุประสงค์เพื่อพัฒนาแนวทางในการบริหารจัดการเรื่องระบบระบายอากาศเฉพาะที่ในกระบวนการเคลือบกาว โดยทำการศึกษาระบบระบายอากาศเฉพาะที่ในห้องเคลือบกาวที่มีอยู่ในปัจจุบันของโรงงานผลิตอุปกรณ์ทางการแพทย์แห่งหนึ่ง กระบวนการเคลือบกาวประกอบด้วย เครื่องเคลือบกาวทั้งหมด 3 เครื่อง ได้แก่ เครื่องเคลือบกาว CT-3 ,CT-4 และCT-5 สารเคมีหลักที่ใช้ในกระบวนการเคลือบกาวคือ Dearomatised Hydrocarbons ใช้เป็นสารละลายสำหรับผสมกาวในกระบวนการเคลือบผิวประกอบด้วย Cyclohexane ,Heptane , Methyl Cyclohexane และ n-Hexane โดยในกระบวนการเคลือบกาวมีการติดตั้งระบบระบายอากาศเฉพาะที่ร่วมกับการระบายอากาศแบบทั่วไป

ผลการวิจัยพบว่า ค่าความเข้มข้นของสารเคมีในบรรยากาศการทำงานระยะเวลา 3 ปีที่ผ่านมา ปี ค.ศ. 2012-2014 เกินค่าแนะนำโดยองค์กรองค์กรนักสุขศาสตร์อุตสาหกรรมภาคีรัฐแห่งประเทศอเมริกา (ACGIH) โดยเมื่อคำนวณแบบสารผสมพบว่าบางครั้งมีค่ามากกว่า 1 และเมื่อทำการตรวจสอบระบบระบายอากาศเฉพาะที่ของเครื่องเคลือบกาว CT-3 ,CT-4 และCT-5 พบว่า ค่าความเร็วในการจับมลสารต่ำกว่าค่าแนะนำของ ACGIH ที่กำหนดให้ 1 เมตรต่อวินาที และทำการวัดความเร็วในท่อของเครื่องเคลือบกาว 10 ตำแหน่ง จากจุด B ถึง K โดยทุกตำแหน่งมากกว่าค่าแนะนำของ ACGIH ที่กำหนดให้ 5 เมตรต่อวินาทียกเว้นที่ตำแหน่ง k มีค่าต่ำกว่าค่าแนะนำของ ACGIH เมื่อคำนวณอัตราการไหลของอากาศที่ดูดเข้ากระบวนการเคลือบกาวได้ 26.43 ลูกบาศก์เมตรต่อวินาที และอัตราการระบายอากาศจากกระบวนการเคลือบกาว 42.14 ลูกบาศก์เมตรต่อวินาที มีอัตราการระบายอากาศออกมากกว่าอัตราการดูดเข้าระบบ 15.71 ลูกบาศก์เมตรต่อวินาที ทำให้ค่าความดันห้องติดลบตลอดเวลา

จากปัญหาระดับความเข้มข้นของสารเคมีในบรรยากาศเกินค่ามาตรฐาน เพื่อแก้ปัญหาดังกล่าวควรมีการทบทวนแนวทางในการบริหารจัดการระบบระบายอากาศเฉพาะที่ในกระบวนการเคลือบกาว จากการศึกษาพบว่าองค์กรยังไม่มีแนวทางในการบริหารจัดการระบบระบายอากาศเฉพาะที่ในกระบวนการเคลือบกาวอย่างเป็นทางการ ดังนั้น องค์กรจึงจัดทำแนวทางในการบริหารจัดการเรื่องระบบระบายอากาศเฉพาะที่ในกระบวนการเคลือบกาว โดยการกำหนดหน้าที่และความรับผิดชอบตามโครงสร้างขององค์กร การกำหนดแผนงาน การตรวจสอบ และการดำเนินงานทบทวนการจัดการระบบความปลอดภัยและอาชีวอนามัยโดยผู้บริหารระดับสูง

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LIST OF ABBREVIATIONS

LEV	Local Exhaust Ventilation
GEV	General Exhaust Ventilation
°C	Degree Celsius
TLV	Threshold Limit Value
TWA	Time Weighted Average
ppm	Part Per Million
Q	Volumetric flow rate
V	Velocity
A	Area
m ³ /s	Cubic Meters Per Second
m/s	Meters Per Second
m ²	Square Meter
SP	Static Pressure
VP	Velocity pressure
TP	Total pressure
ACGIH	American Conference of Governmental Industrial Hygienists
LEL	Lower Explosive Limit
UEL	Upper Explosive Limit
HP	Horsepower
Pa	Pascal

CHAPTER I

INTRODUCTION

1.1 Background and Rationale

In recent days, the global concerned to the quality of indoor air were significant since most people spent more than 90 percent of daily time indoors. The concentration of pollutants indoor was usually about 2 - 5 times higher than those of outdoors. The World Health Organization (WHO) was anticipating that 30 percent of the buildings around the world might have an issue of the indoor air quality (IAQ). This issue would lead to outbreak of occupational disease syndrome in the closed buildings (1, 2).

The quality of indoor air provided for not only the convenience and comforts of human but also affected the occupational health of workers. If the indoor air quality was not desirable, a number of diseases were occurred such as headache or fatigue. In addition, there were also some diseases related to contaminants in the air and indoor environment including asthma, respiratory diseases, heart diseases, and cancer (2, 3).

Industrial raw materials, products, and by-products from the mass production were classified as hazardous to human health. They were actually released from the manufacturing processes into the environment. They induced the workplace pollution that might be in a state of dust, mist, vapor, gas, fume, and other forms. Most of these pollutants mingled and floated in the air. They were ready to enter the human body and harmed workers inside the workplace (4)

If the amount of contaminants were below the levels that could pose a problem or the pollution concentrations were within the specified standards, or most people more than 80 percent of human enjoyed satisfaction that the indoor air quality was deemed within the acceptable levels, suitable for residential or office lives. On the other hand, if the amount of contaminants was equal to or higher than the level to

cause health problems, the air quality in the area was neither deemed well nor fit for living or work (5, 6).

Ongoing business competition forces workplaces to increase profitability and customer credentials. The business organization wanted to expand the market through merger (business takeover) of medical equipment manufacturing units by focusing on higher productivity gains to keep pace with rising market demands. However, the organization neither improved nor changed any infrastructure to expand the production capacity. This caused complaints about environmental issues of working areas and worker wellness of the production lines. Medical production processes with the most complaints were the adhesive coating processes.

There were health complaints of certain worker e.g. numbness of fingertips and tiptoes, headache, dizziness, vomit and eyes irritation. These were symptoms of central nervous system (CNS) (7).

The adhesive coating processes were conducted in the coating room. In the facility, it was typically composed of 17 workers. Three coating machines were provided for instance the coating machine CT-3, the coating machine CT-4, and the coating machine CT-5. The working area was an air-closed tight room. The main chemicals applied in the adhesive coating processes were dearomatized hydrocarbon, used as solvent to mix adhesive to laminate on the fabric. Dearomatized hydrocarbon contained cyclohexane, heptane, methyl cyclohexane, and n-hexane. The workers exposed to these chemicals through the vapor in the environment of the adhesive coating room. The effects of exposure to this chemical group in the workplace where the concentration of chemicals is high or exceeds the standards (8). Dearomatized hydrocarbon was a flammable liquid. When it evaporates and it was mixed with air, the gaseous mixture possibly causes explosion and fire (11).

The observations of the measurement data of the concentration of chemicals at the workers in the workplace by personal sampling in 2014 indicated that the intensities of n-hexane were as follows: Coating machine CT3: 19.86 ppm, Coating machine CT4: 31.79 ppm, and Coating machine CT5: 24.72 ppm. The observed data exceeded the “action level” where the organization needed to control and prevent exposure to hazardous substances among workers. Indeed, it is required

that 50% of Threshold Limit Value-Time Weighted Average (TLV-TWA) of n-hexane (50 ppm). The action level of n-Hexane is 25 ppm (8).

The inspection of safety at the workplace found that workers had modified the fire protection system that the adhesive coating machine could operate without intermission by readjusting the sensor of the lower explosive limit (LEL) of each of the adhesive coating machine did not to detect concentration in air absolutely. The reason was that during the adhesive coating process percentage LEL of the adhesive oven rose to 50% LEL, and the adhesive coating machine stopped immediately due to the interlock. Basically, such actions were extremely dangerous to health of workers.

In the coating processes, the organization installed a local exhaust ventilation (LEV) system in combination with the general exhaust ventilation system. This was to solve the chemical exposure issue in the workplace for workers in the coating processes since the efficient ventilation system could prevent and resolve the indoor air quality issues (2), the health of workers, the fire, and the explosion risks.

Such issues in that organization induced the researcher to investigate the air quality by observing the concentration of the chemicals in the environment of the adhesive coating processes, and performance of the local exhaust ventilation system of the adhesive coating processes. The aims were to propose the management system of the local exhaust ventilation in the adhesive coating processes. It was anticipated that this study could reduce the impact on health, and could reduce the risks of fire and explosion as well.

1.2 Objective

To develop guidelines for the management system of the local exhaust ventilation system in the coating processes of a medicated plaster manufacturing.

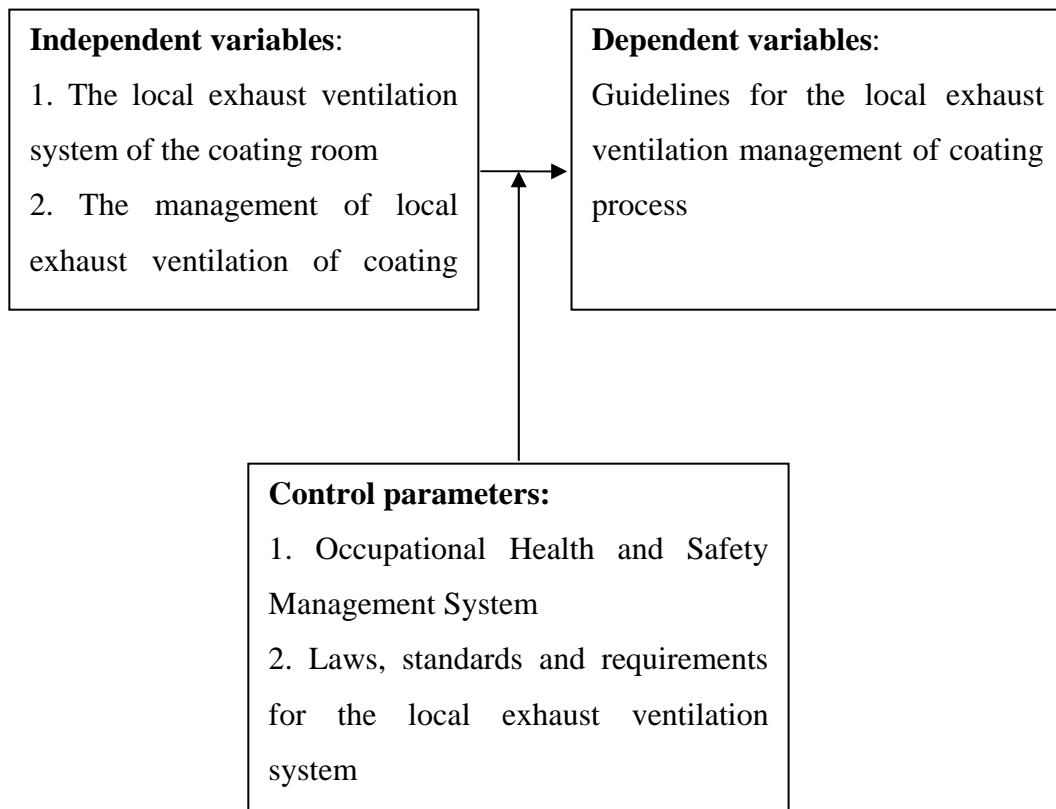
1.3 Scope of study

The author studies the local exhaust ventilation system of the coating room in a medicated manufacturing in order to develop guidelines for management system of the local exhaust ventilation.

1.4 Benefits of the study

Guidelines for the local exhaust ventilation management system could provide controlling measures or ~~could~~ reduce risks to the acceptable levels.

1.5 Conceptual Framework



1.6 Glossaries and Terms of Definitions

1.6.1 Management was defined as using of science and arts of two or more people in collaboration activities or in task to achieve results as in targets efficiently.

1.6.2 Guidelines for management was defined as the guidelines for the management of occupational safety, health and work environment of the adhesive coating processes to reduce health problems in the work regarding safety that have been established under the collaboration of workers and under maximum benefits out of available resources.

1.6.3 Coating process was defined as the adhesive layer coating onto one side or both sides of the fabric materials. The adhesive was controlled for toughness and the viscosity with the distance of the coating head and the fabric. The fabric coated with adhesive would be heated to stimulate the polymerization reaction so that the adhesive stuck to the surface of the fabric (10).

1.6.4 Local exhaust ventilation (LEV) was defined as the ventilation system to conveyed contaminants, which dispersed from the source to the environment by applying the principle of the airflow from a high pressure point to a lower pressure point (9).

1.6.5 Threshold Limit Value -Time-Weighted Average (TLV-TWA) was defined as the concentration for a conventional 8-hour workday and a 40-hour workweek, to which it was believed that nearly all workers might be repeatedly exposed, day after day, for a lifetime working without adverse effect or the concentration level of hazardous chemicals allowed to the existing environmental atmosphere in the workplace where the workers with the normal health could be exposed or absorbed into their bodies daily the whole working time without health hazards in which it was established by the organization of the American Conference of Governmental Industrial Hygienists (ACGIH) (8).

CHAPTER II

LITERATURE REVEIWS

2.1 Medicated plaster manufacturing process

The medicated plaster manufacturing processes in this study consist of the following sub-processes: mixing, coating, perforating, slitting, converting, sterilization, and packing. The process flow is depicted as in Figure 2.1

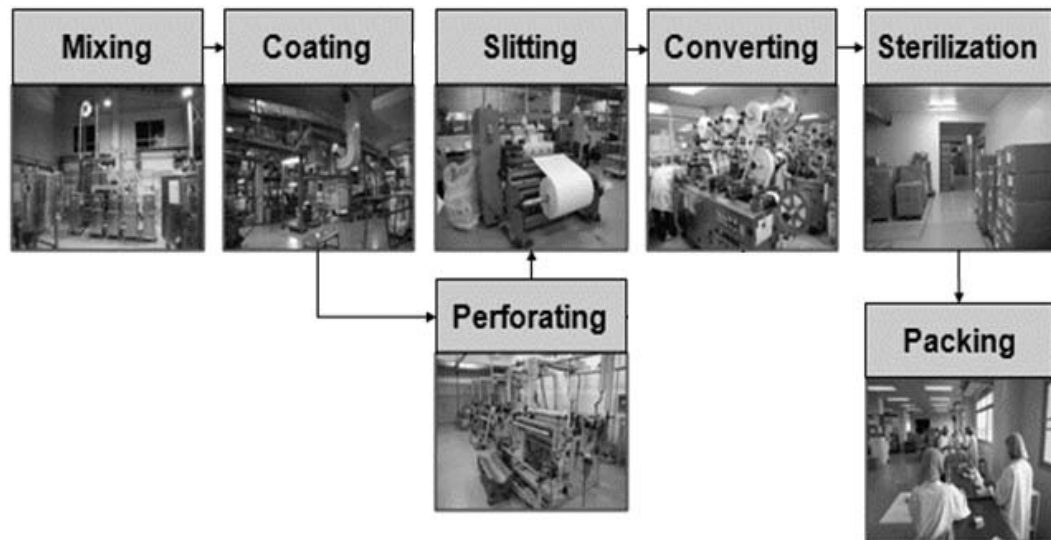


Figure 2.1 Medicated plaster manufacturing process flow

Step 1: Mixing: To prepare the adhesive for coating process, chemicals, natural rubber, and synthetic rubber are mixed together. It takes about 14-16 hours per batch and time varies with formulas.

Step 2: Coating: Mixed adhesive is pumped from a mixing storage tank to the coating head of the coating machine. The adhesive is spread across the fabric by means of the coater blade. Next, the adhesive is applied to the one surface of the fabric. The adhesive coated fabric moves through the oven with a belt conveyor. The oven temperature is set between 110-130 °C. The hot adhesive coated fabric decreases

its temperature through the cool water roller to finish into adhesive coated fabric roll shape.

Step 3: Perforating: The adhesive coated fabric is perforated to make small holes.

Step 4: Slitting: To slit the adhesive coated perforated, the fabric is cut into smaller width rolls to prepare materials for the converting process.

Step 5: Converting: This process is provided in a clean room. All of medicated plaster components such as small blood pads and adhesive coated perforated fabric rolls are combined and cut into small pieces.

Step 6: Sterilization: The medicated plaster is sterilized to eliminate or deactivate all forms of microbial, lives and other biological agents.

Step 7: Packing: The last process is packing in order to enclose or protect medicated plaster products for distribution, storage, and sale.

2.2 Coating Processes

The coating processes contain the highest risks of occupational health and safety in the medicated plaster manufacture.

The coating processes are where the adhesive layer is applied to one surface of the fabric. A coater blade regulates the thickness of the viscous adhesive. The coated fabric is heated and the adhesive is cured (10).



Figure 2.2 The coating machine

The coating processes operate in the coating room. The size of the coating room has a width of 28 meters, length of 30 meters and height of 6.5 meters. The medicated plasters are coated with adhesive by means of three coating machines; CT-3, CT-4 and CT-5. The entrance to the coating room consists of an airlock door and two fire doors that are normally closed when the coating processes run.

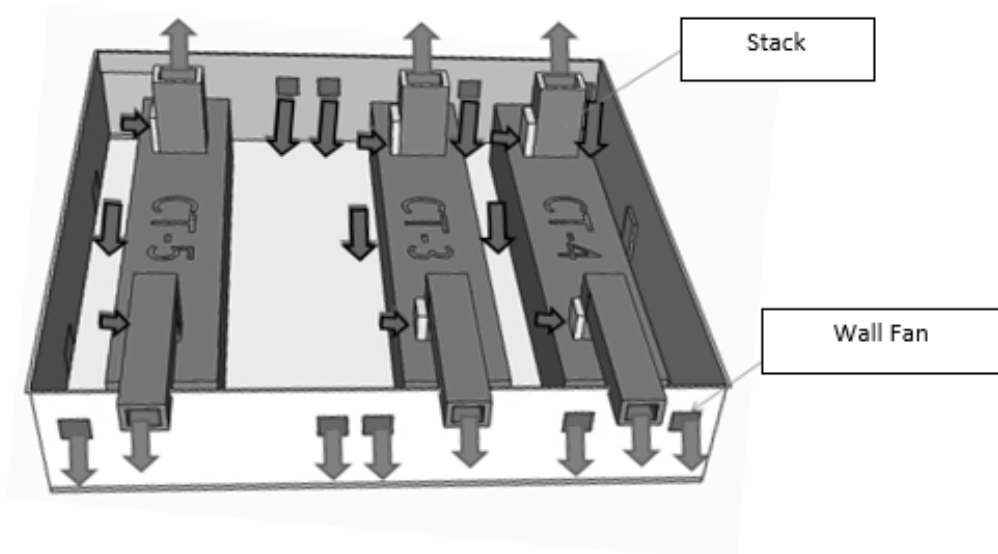


Figure 2.3 Air flow directions of coating room

The coating processes continuously run 24 hours per day and 5 days per week without interruption. Workers take turns working on 3 shift works. The length of a work shift is 8 hours per day. The coating processes have 17 workers. Two workers are in charge of each coating machine working at the coater head.

The coating processes have both the general exhaust ventilation (GEV) system for contaminant dilution and the local exhaust ventilation at the coater head of coating machine where two workers are working in each work shift.

Dearomatized hydrocarbon is used as the solvent of adhesive of the coating processes. The chemicals are dissolved into solvent to give a more or less efficient bonding adhesive in the form of adhesive solution. Dearomatized hydrocarbon mixture consists of cyclohexane, heptane, methyl cyclohexane, and n-hexane.

2.2.1 Physical and chemical properties of dearomatized hydrocarbon

(11)

Physical state:	Liquid
Form:	Clear
Color:	Colorless
Odor:	Mild petroleum/solvent
Specific gravity (at 15 °C):	0.71
Density:	720 kg/m ³
Flash point:	-15°C
Flammable limits (volume percentage in air):	LEL: 1.0, UEL: 7.0
Auto-ignition temperature:	>200 °C
Boiling point/range:	75 °C – 115 °C
Evaporation rate:	6

2.2.2 Physical and chemical hazards

This chemical can accumulate electrostatic charges, which may cause ignition. It releases vapors that readily form inflammable mixture. The accumulated vapors can flash and/or explode if being ignited.

2.2.3 Health hazards (8, 12, 13, 14)

2.2.3.1 n-hexane: The TLV-TWA of 50 ppm is the recommended threshold for occupational exposure to n-hexane. N-hexane can enter the body through the lungs if n-hexane is in breathing air and through the skin if the skin comes into contact. Exposure to n-hexane may have adversary effects to the central nervous system of polyneuropathy symptoms into peripheral nerves, resulting in neurotoxin with weakness or numbness of lower limbs as well as narcosis, eyes and mucous membrane irritation.

2.2.3.2 Methyl cyclohexane: The TLV-TWA of 400 ppm is the recommended threshold for occupational exposure to methyl cyclohexane. Exposure to methyl cyclohexane may have effects to central nervous system, irritation of organs, narcosis, and the possibility of liver and kidney disorders.

2.2.3.3 Cyclohexane: The TLV-TWA of 100 ppm is the recommended threshold for occupational exposure to cyclohexane. Exposure to cyclohexane may have effects to the central nervous system. The worker can have headache, dizziness, eyes and mucous membrane irritation.

2.2.3.4 Heptane: The TLV-TWA of 400 ppm is the recommended threshold for occupational exposure to heptane. Exposure to heptane may have effects to the central nervous system, narcosis and respiratory irritation.

2.3 Application of the additive mixture equation (8)

When two or more hazardous substances exist, their combined effects, referred to as the indicator of additive effect, shall be given the primary consideration.

That is, if

$$(C_1/TLV_1) + (C_2/TLV_2) + \dots + (C_n/TLV_n) > 1$$

then the threshold limit of the mixture is judged to be violated.

Where,

C = the concentration of chemicals obtained in the air from measurements

T = the concentration limits of hazardous chemicals (Threshold Limit Value-Time Weighted Average (TLV-TWA)).

2.4 Hierarchy of health and safety controls (15, 16)

Unacceptable exposures must be prevented, when applicable, by considering their potential to cause harm in the early development of manufacturing products and processes, and designing against the problems must be carried out. Unacceptable exposures found in existing processes must be controlled quickly and reliably.

The following hierarchy for implementing exposure control strategies for unacceptable exposures must be applied:

Elimination: It is removal of the cause of the hazards. Elimination is the most effective hazard control method.

Substitution: Substituting with a less hazardous process or materials, for example, the solvent used in the coating process may be changed to the less hazardous chemicals.

Engineering controls: In general, engineering controls modify the source or reduce the quantity of contaminants released into the work place. These controls remove the hazardous substances at its source before the material has a chance to enter the worker's breathing zone.

Engineering controls include making changes to equipment or processes, isolating of workers or equipment and implementing of local exhaust ventilation.

Administrative controls: This approach applies the occupation health and safety management method to minimize risks, such as supervision, training, planned inspection audit, task observation etc.

Personal protective equipment (PPE): PPE is the equipment wearing by workers to minimize exposure to the hazards. PPE is the least effective hazard control method. PPE must be applied only when elimination, substitution, engineering control and administrative control do not provide adequate protection.

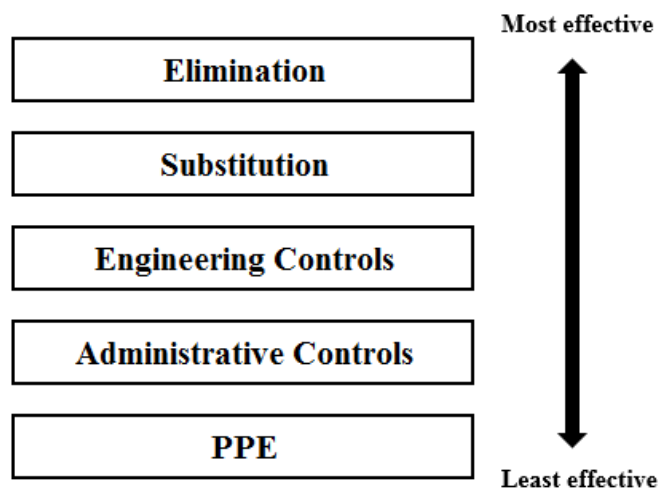


Figure 2.4 Hierarchy of health and safety control

2.5 Ventilation

2.5.1 Volumetric flow rate (17)

One of the most important assumptions of industrial ventilation is derived from the fact that matter cannot be created or destroyed. Once a mass of air is identified, confined, and moving, it cannot give up or create new mass.

Under the steady flow conditions, the same air mass moves through each point. If an incompressible flow is assumed, the same volumetric flow rate passes each point. The airflow has equation as follows.

$$Q = V \times A$$

Where,

- Q: Volumetric flow rate (cubic meters per second, m³/s)
- V: Velocity (meter per second, m/s)
- A: Area (sq. meters, m²)

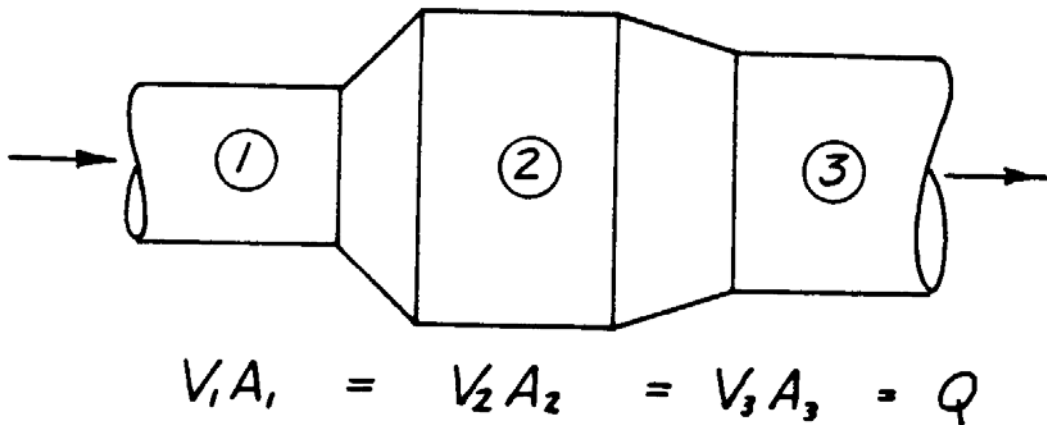


Figure 2.5 The same volumetric flow rate moves through each point

$$(V_1 A_1 = V_2 A_2 = V_3 A_3 = Q)$$

2.5.2 Air pressure (9, 19, 21)

There are three different but mathematically relate pressures associated with the moving airflow.

2.5.2.1 Static pressure (SP) is defined as the pressure in the duct that tends to collapse the duct. The static pressure is felt in all directions within a duct. It is generated by gravity and regulated by the fan. The static pressure can be positive or negative with respect to the atmospheric pressure.

2.5.2.2 Velocity pressure (VP) is defined as the pressure required accelerating of air from zero velocity to certain velocity (V), and is proportional to the kinetic energy of the airflow. The velocity pressure is measured parallel to the airflow by means of the measuring probe facing the intake air stream.

2.5.2.3 Total pressure (TP) is defined as the algebraic sum of the static pressure and the velocity pressure as follows.

$$TP = SP + VP$$

Total pressure can be positive or negative with respect to the local atmospheric pressure. The total pressure shall be larger than the static pressure.

2.6 Types of industrial ventilation system (4, 9, 17)

2.6.1 Dilution ventilation systems

Dilution ventilation, namely, the general exhaust ventilation, involves intake of clean air to dilute the contaminated air and then releases the diluted air to the outside by means of exhaust fans. This method allows chemical emissions to mix with the workplace air. Contaminated workplace air is diluted until the acceptable exposure levels. For purpose of fire prevention, concentrations in air are diluted to below certain non-explosive and nonflammable thresholds.

2.6.1.1 General dilution ventilation equation (18, 21)

The ventilation rate required to maintain a constant concentration at a uniform generation rate is derived by starting with a fundamental material balance and by assuming no contaminant in the air supply:

$$\text{Rate of accumulation} = \text{Rate of generation} - \text{Rate of removal}$$

2.6.1.2 Calculation of dilution ventilation for steady-state concentration (18, 21)

The rate of flow of uncontaminated air required to maintain the environment concentration of a hazardous material at an acceptable level can be calculated if the generation rate is determined. The effective ventilation rate (Q') has the algebraic equation as follows.

$$Q' = (24 \times 10^6 \times SG \times ER) / MW \times C$$

Where,

- Q': Effective volumetric flow rate
- SG: Specific gravity of volatile liquid
- ER: Evaporation rate of liquid
- MW: Molecular weight of liquid
- C: Corresponding threshold limit (TLV)

2.6.1.3 Rate of purging (18)

When generation of contaminants is discontinued, the rate of concentration drops over a period of time. Concentration of chemical vapor or vapor in the diluted exhaust air can be calculated as follows.

$$C_2 = C_1 \times e^{(Q' \times (t_2 - t_1) / V)}$$

Where,

- C₁: Initial concentration of chemical gas or vapor (ppm)
- C₂: Concentration of chemical gas or vapor (ppm)
- Q': Effective volumetric flow rate (m³/hour)

V:	Volume of room (m ³)
t ₁ :	Initial time
t ₂ :	Elapsed time

2.6.2 Local exhaust ventilation (LEV) (9, 17)

The local exhaust ventilation system captures the emitted contaminant near its source before the contaminant has the opportunity to disperse into the environment air. Contaminants can be the most efficiently controlled at the source. Most local exhaust ventilation systems are configured with the following main components: hood, duct, air cleaner, fan and stack.

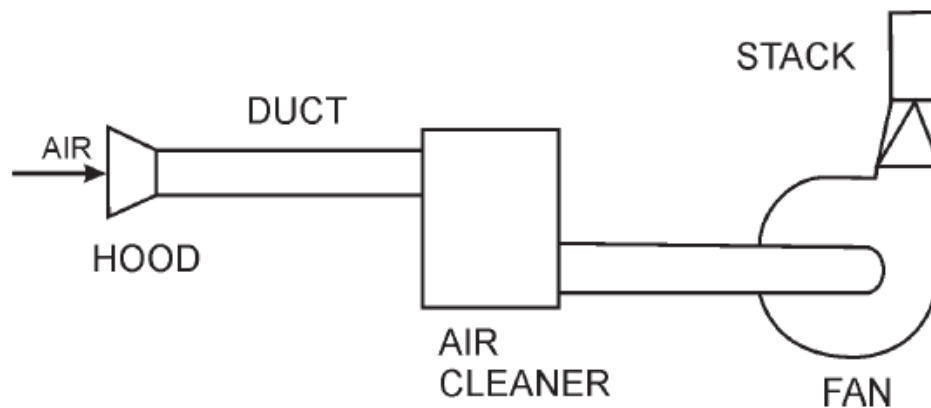


Figure 2.6 The five components of a LEV system

2.6.2.1 Hoods (9, 19, 20)

The hood is a capture device. It is designed to collect, receive and contain the contaminants to be controlled. The three common types of hoods are:

A. Enclosing hood: The enclosing hood surrounds the process where the contaminant is generated. The enclosing hood is preferred if applicable (as shown in Figure 2.7)

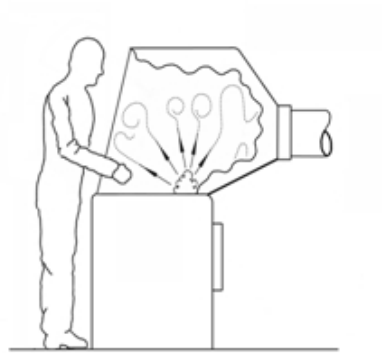


Figure 2.7 Enclosing hood

B. Receiving hood: The receiving hood is designed to collect hot rising vapor contaminant. This hood shall not be used if men can enter the contaminated air stream as air stream enters the hood. The receiving hood is referred to as a canopy hood (as shown in figure 2.8).

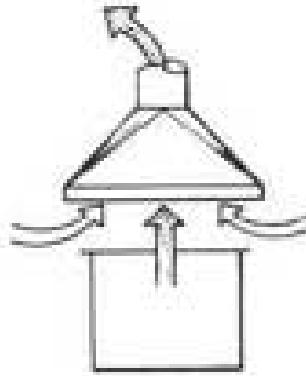


Figure 2.8 Receiving hood

C. Capturing hood: This hood is located next to a contaminant-releasing source without surrounding it. The emission source cloud is outside the hood. The hood has to generate sufficient airflow around the source to 'capture' and to draw in the contaminated air (as shown in Figure 2.9).

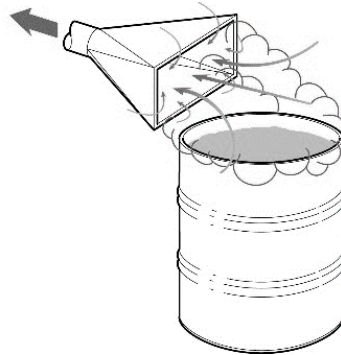


Figure 2.9 Capturing hood

2.6.2.2 Hood design factors (18)

Elimination of source of moving air is a very critical factor in reducing the required air volume and the corresponding power consumption. Important sources of moving air are:

1. Thermal air currents from hot processes
2. Motion of machinery via belt conveyors etc.
3. Material movements
4. Movements of the workers
5. Room air currents
6. Spot cooling and heating equipment

Effective control of the emission process is brought about by minimizing all moving air of the processes and then by capturing contaminated air by forcing it to flow into the exhaust hood. Flow toward the intake opening shall be sufficiently high to maintain the necessary capture velocity and to overcome opposing air currents.

Table 2.1 Range of capture velocities (21)

State of dispersion of contaminant	Example	Capture velocity (m/s)
Practically released with no velocity into calm air.	Evaporation from tanks, degreasing unit etc.	0.25 - 0.5
Released at low velocity into moderately still air.	Spray booths, welding, plating, pickling	0.5 - 1.0
Active generation into zone of rapid air motion	Spray painting in shallow booths, barrel filling unit, conveyor loading unit, crushers	1.0 - 2.5
Released at high initial velocity into zone with very rapid air motion.	Grinding, abrasive blasting, tumbling	2.5 - 10

2.6.2.3 Ducts (18)

The duct has the role of delivering the contaminated air from the hood for treatment and exhaust to the outside area in the design of the ventilation systems, it is necessary to choose the sufficiently large lowest duct air velocity to be effective in the ventilation system according to the design. If the wind velocity is too low in the duct, contaminants will accumulate in the duct. In contrast, the too large design velocity causes a loss of energy than necessary and it causes faster wear of the duct. The designer shall choose the appropriate velocity of the air accordingly. The recommendations of ACGIH for minimum air velocity in the duct are given in Table 2.2

Table 2.2 Range of minimum duct design velocities (21)

Nature of contaminant	Examples	Design velocity, m/s
Vapors, gases, smoke	All vapors, gases and smoke	5 - 10
Fumes	Welding	10 - 13
Very fine light dust	Cotton lint, wood flour	13 - 15
Dry dusts & powders	Fine rubber dust, bakelite molding powder dust, jute lint, cotton dust, shavings (light), soap dust, leather shavings	15 - 20
Average industrial dust	Grinding dust, buffing lint (dry), wool jute dust (shaker waste), coffee beans, shoe dust, granite dust, silica flour, general material handling, brick cutting, clay dust, foundry (general), limestone dust, packaging and weighing of asbestos dust in textile industries	18 - 20
Heavy dusts	Sawdust (heavy and wet), metal turnings, foundry tumbling barrels and shake-out, sand blast dust, wood blocks, hog waste, brass turnings, cast iron boring dust, lead dust	20 - 23
Heavy or moist	Lead dusts with small chips, moist cement dust, asbestos chunks from transit pipe cutting machines, buffing lint (sticky), quick-lime dust	23 and up

2.6.2.4 Fans (18)

Fans function to generate vacuum in the duct system. They shall be large enough to pull the contaminated air into the hood for the air motion from one place to another. The fan shall drive air to flow equally with the flow rate and the air velocity in the duct as designed.

There are two main types of fans: axial flow fan and centrifugal fan.

2.6.2.5 Air-cleaning device (9)

Air-cleaning device filters or trap contaminants in the air from the system before releases the air to the outside. The choice of cleaning equipment depending on several factors, for example, the clean air level requirements after removing contaminants, volume, properties of contaminants and the conditions of the air in the system. The designer shall also take account of safety from fire and explosion.

The device is divided into two main groups: air cleaning equipment for contaminants of particles, and air cleaning equipment for contaminants of gaseous chemicals and vapors. There are two types of cleaning equipment: equipment for cleaning of particulate contaminants and trap contaminants in gaseous state.

2.6.2.6 Stacks (9, 19)

The stack is the last element of the ventilation system. It is the exit of air after removal of contaminants. The purpose of installation of stack is to induce cleaner air (or air contaminants) having been drawn into the local exhaust ventilation to release outside the facility or the plant. The air emitted from the stack shall spread into sufficient distance not to cause a nuisance and impact to men or the environment nearby.

2.7 Test of ventilation systems (18)

When installing a ventilation system is made, the system shall be tested according to the design specifications. The system shall be inspected and tested for ventilation periodically by the time it has been planned. This is to be sure that the system continues to function effectively. Test of the system shall inspect the various components of the system including hoods, ducts, air cleaning devices and fans. The inspector shall measure air velocities and pressures of each component. Therefore, test of the ventilation systems shall require the following information:

1. Drawing and plans of the ventilation system with indication of the duct size, duct length, flow of air, type of fan, and other components such as fire protection systems in the ducts, air volume adjusting unit.
2. It is necessary to position points to monitor such as air velocity and pressure measuring points in different parts of the system.
3. The measurement observations shall be recorded with description of the state of the environment including factors that change from the original states.
4. If changes are made to the ventilation systems, the inspector shall test the impact associated with such change e.g. air velocities and static pressures that change from the original states.

2.7.1 Measuring of the ventilation system

2.7.1.1 Airflow measurement (22)

The most precise, most accurate and the primary measuring instrument is the standard Pitot tube. It is applied to measure the pressure due to the airflow (velocity pressure).

A. Standard Pitot pipe

It is a concentric tube with 90-degree bend. Its one end is open to allow air to enter. The inner tube is used to measure the pressure due to the velocity (velocity pressure, VP). The external pipe is used to measure the potential pressure or static pressure (static pressure, SP). The overall result is indicated as the total pressure or the aggregate pressure (total pressure, TP).

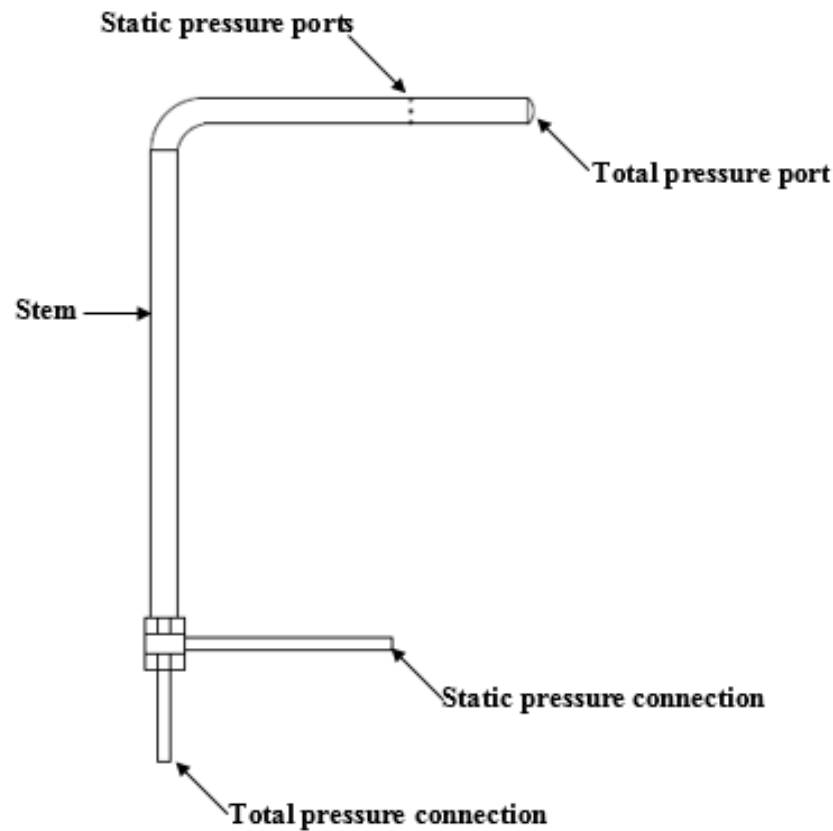


Figure 2.10 Standard Pitot tube

B. Pressure measurement in the ventilation system

The pressure measurement of the air inside the system is aimed to determine the resistance in the ventilation system, i.e. pressure loss in the ventilation system as airflows through parts of the system. The loss starts from the air intake hood, through ventilation ducts, through the contracted and expanded ducts, through the flap gates, through air pollution removing devices, and through the final release duct to the external environment of the system. Measuring of this pressure also determines the fan static pressure.

C. Summary of the inspection of the ventilation systems

(18)

In order to inspect the ventilation system, the inspector shall measure the static pressure and air velocity in the ducts at the start point of the

pollutant into the air, that is, from hood, main duct, branch ducts, air cleaning system, intake and outlet of the fan. Therefore, it is necessary to know fundamental data of the design of the ventilation system, starting from the hood to the end fans as follows.

1. Measuring of static pressure and the hood air velocity shall be positioned away from the hood at 4 - 6 times of the diameter of the duct to avoid the impact of the compressed air inflow to the intake duct that makes measurements at this location to be uncertain. This measurement should find 6 - 10 points of moving pressure on the cross section of the duct to obtain average and to calculate as the air velocity that can be converted into the flow rate of air.

2. The next positions to be measured are confluences of the branch ducts. The observed point shall be away from the congruence at least eight times of the diameter of the duct, or under criteria outlined by the U.S. Environment Protection Agency (EPA) shall be applied. This principle applies to elbows or sections with change of duct size. At this location, the air velocity, flow rate and static pressure are read.

3. Positions at the intake - outlet of air cleaning device are measured for the static pressures as compared to the designs.

4. Static pressures of fans shall be measured at the positions before and after the fan to calculate for the pressure of the fan. In addition, these observations can also be calculated into the flow rate of air, the power consumption of the fan and the position to read the static pressure as well.

2.8 Occupational safety and health management

Medical device plants today focus on cost reduction since this business group is less profitable than other businesses. Therefore, the organization is not ready to invest for infrastructure improvements. However, the organization has prepared the management system of occupational safety and health as a corporate overview. If the organization can apply this management system to different departments, it can protect safety and health of workers. This study focuses on the solution by means of the management system of occupational safety and health as an element of the hierarchy of health and safety controls.

2.8.1 Definition of safety management (23)

Administration in the academic domain is defined as determination of processes so that the activities are formalized so that the organization achieves in the objectives that have been settled.

Safety management is defined as processes of planning, organizing, managing, leadership taking and control to achieve an objective of safety with the cooperation of workers and by applying available resources with the best performance.

In practice, safety management is defined as control of the environment in the workplace. This determines the sectors to perform, and establishing methods of operation to reduce or eliminate a condition of injury and occupational diseases. This is achieved by raising wisdom of internal and external parties, and setting of functions and responsible. The aim is so that all sectors and all levels within the organization clearly understand and can implement.

Nuttawat Montewan(23) describes that the good safety management system can be characterized as follows: The operational safety is systematic and continuous by enhancing safety into the production processes. There are incentives for workers to participate in safety activities. Workers perform safety under legal requirements while employers or the top managements are critical for the resulting success in safety. These movements influence operations and indicate the activities and their adequateness.

2.8.2 Laws relating to the management of occupational health and safety

They are parts of the labor protection laws regarding the management of occupational safety and health. They are directly related to safety and occupational health of workers. The laws include the followings.

2.8.2.1 Occupational Safety, health and work environment Act, B.E. 2554 (A.D. 2011) (24)

It is the legal framework that determines mandatory roles of government agencies, employers and workers in cooperation in management and supervision of workplaces. Hygiene and safety shall be achieved according to the standards set in the Ministerial Regulations. They include rights, responsibilities and

accountabilities of employers and workers, the plan settings and operations. In addition, mandatory issues are preparation of reports and submitting to the relevant government agencies.

2.8.2.2 Ministerial Regulation on the Prescribing of Standard for Administration and Management of Occupational Safety, health and work environment B.E. 2549 (A.D.2006) (25)

This ministerial regulation determines regulations and guidelines for the safety in the workplace. It describes training of workers, establishing of personnel acting on the safety by setting qualifications, roles, requirements and functions of the committee of occupational safety, health and work environment. It also describes requirements of the safety, health and environment department of the workplace, including mandatory reporting on accidents and occupational diseases related to the workers.

2.8.2.3 Ministerial Regulation on the Prescribing of Standard for Administration and Management of Occupational Safety, health and work environment B.E. 2553 (A.D.2010) (26)

This ministerial regulation determines more additional regulations of Ministerial Regulation on the Prescribing of Standard for Administration and Management of Occupational Safety, health and work environment B.E. 2549 (A.D.2006)

The employers having fifty employees or more shall implement management of Occupational Safety, health and work environment system.

This ministerial regulation requires the safety management systems in the work that shall contain:

1. Policy of occupational safety, health and work environment
2. Management structure on occupational safety, health and work environment
3. Plans on occupational safety, health and work environment, implementation,
4. Evaluation and review of management in occupational safety, health and work environment

5. Improvement of operations on occupational safety, health and work environment by improving and developing of the work safety management system at least once a year

2.8.2.4 Ministerial Regulation on the Prescribing of Standard for Administration and Management of Occupational Safety, health and work environment in Hazardous Chemical B.E. 2556 (A.D.2013) (27)

This Ministerial Regulation requires the work standard on the hazardous chemicals as follows. i) safety data sheet of hazardous chemicals, ii) labels and signs, iii) Safety system in which the harmful chemicals in the environment above the standards shall prevent and eliminate the air pollution by means of the local ventilation system, wet system, coverage, or other means, iv) providing of equipment for protection of personal safety, v) storage, packing and transfer of hazardous chemicals, vi) unloading, moving or transport of hazardous chemicals, vii) management and removal of hazardous chemicals, viii) control of the concentration levels of hazardous chemicals, ix) health care and control and action in the case of an emergency.

2.8.2.5 Ministerial Regulation on the Prescribing of Criteria and Method of Conducting Health Check-up of workers and Forwarding the Results of Health Check-up to Labor Inspector, B.E. 2547 (A.D.2004) (28)

This Ministerial Regulation demands that the employer provides health check-up to workers working on risk factors including i) hazardous chemicals, ii) microbe poisoning that can be a virus, bacteria, mold or biological substance, iii) radioactive substance iv) heat, coldness, vibration, atmospheric pressure, light, sound or other environment aspects with potential danger. It also describes the check-up physician qualifications, frequency for the examination, recording of results, informing and submitting the results of medical examination to the government agencies.

2.8.3 Occupational Health and Safety Management System: Thai Industrial Standard: 18001- B.E. 2554 (29)

This standard recommends the organization to define policies and objectives regarding occupational safety and health and sets the stages for

implementation as well as indication of achievements according to the criteria to cause the continual improvement cycle of management system of occupational safety and health. The conceptual framework of this standard is under the occupational safety and health management system as given in Figure 2.11.

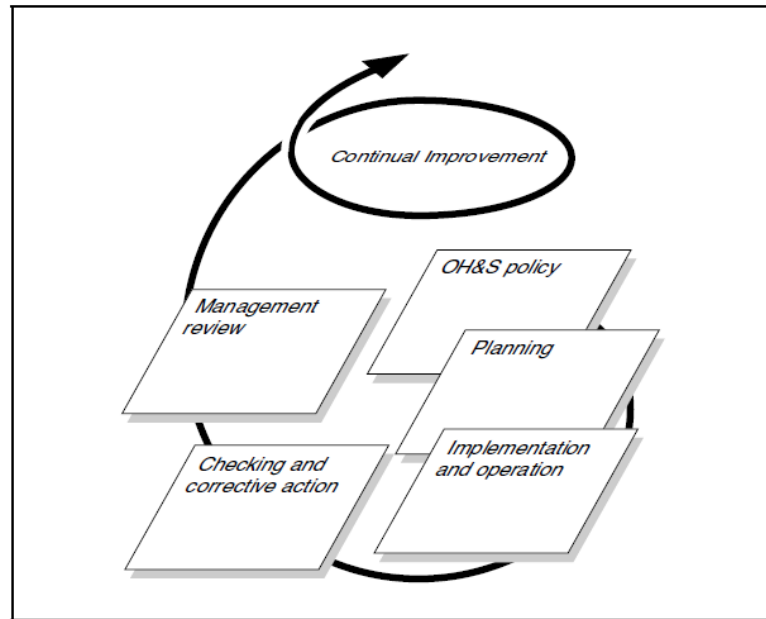


Figure 2.11 The framework of the occupational safety and health management system.

There are six main components with feedback to continual improvement as follows:

1. Review of the initial state
2. Determining of policies of occupational safety and health
3. Planning
4. Adoption and implementation
5. Monitoring and improvement
6. Management review

Review of the initial state, It is the beginning of development of the system where the organization itself shall examine its implementation of the occupational safety and health so far. The organization shall review with statutory requirements related to occupational safety and health, performance and effectiveness

of available resources which will be used for management of occupational safety and health, guidelines for the implementation of occupational safety and health already available in the organization as well as better regulations and operation the organization or other agencies have already prepared. A review of data from the initial state shall be used to determine policies and procedures, to establish the management system of occupational safety and health.

Determination of the occupational safety and health policies, the top managements of the organization shall determine the clear documented policies by signing to indicate intention to management of health and safety, by publishing the policies and to provide opportunities for worker participation for opinions and compliance with the policy. The organization shall also revise the policies periodically to ensure that the established policies are still appropriate to the organization.

Planning, this includes elements of risk assessment. The organization shall i) prepare and comply with documents of operation procedures for the hazard identification and ii) to estimate the level of risk of all events and of work environment of workers and related persons in order to determine risk control measures, laws and other regulations. The organization shall prepared and follow documents of operation procedures to identify and to follow legal requirements and other regulations the organizations shall adopt in the management of occupational safety and health. Regarding preparations on management of occupational safety and health, the organization shall prepare and comply with documents of operation procedures in preparation for management. If a new or a modified event occurs, the organizations shall modify the plans accordingly.

Adoption and implementation, it is determination of structure for accountability of people in the organization including what shall be done for safety in the workplace that includes function structure and accountability. The organization shall establish structure, responsibility and accountability of workers at all levels related to the management in occupational safety and health including preparation of publications to aware the persons concerned within the organization. The workers who perform work which affect occupational safety and health shall be qualified. The top managements shall be leaders to demonstrate accountability on occupational safety

and health and to ensure improvements in the management system of occupational safety and health periodically.

Monitoring and improvement, It is the element which ensure that the established policies, planning, and performing of various activities are successful or not. It is realizing of problems, realizing the exact cause of problems. There are sub-elements of monitoring and measurement of performance.

Management review, the top managements of the organization and the committee of occupational safety, health and work environment of the workplace as defined legally shall review the management system of occupational safety and health periodically to ensure that the management system continues to be appropriate, adequate, efficient and effective. In addition, the top managements shall analyze the actions that require addressing based on shortcomings of the system of occupational safety and health. The organization shall consider the essentiality for change in policies, preparation for management of occupational safety and health as well as other elements of the system of occupational safety and health by reviewing results of audits of the management system of occupational health and safety, circumstances changes and the intention for continual improvements.

2.9 Reviewed literatures

Saowapa Petsungkart (2007) (30) studied the relationship of the concentration of dust particle (respirable dust) with health conditions of workers and designs the ventilation system for welding in the automotive manufacturing industry. Upon retrospective study of data five years ago, Saowapa found that the concentration of respirable dust correlated with the health of the workers. The existing ventilation system of the plant had a capture velocity of 0.1 m/s, which was below the threshold of the ACGIH standard. Therefore, diffusing dust contaminated in the workplace. Saowapa designed the new ventilation system by using the bottom intake principle. This made the capture velocity of pollutant rising to 0.76 m/s. Reduction in the concentration of the respirable dust in the workspace reached 1.69 mg/m³. This design eliminated adverse health effects of the worker.

Pitsamai Chantaramai (2007) (31) studied the appropriate air velocity for intake of vapor of isopropyl alcohol (IPA) out of the chemical mixture room to be safe for the health of workers through measurements of air quality in that room. It found that the concentration of IPA was much above the standard. The workers had dizziness, irritation in eyes and the neck. It was found that the original mixture room had no local exhaust ventilation. Some of IPA vapor were drawn away by the stack and IPA vapor dispersed increasingly. Majority of the IPA vapor moved to the room floor and accumulated over time. Then, Pitsamai simulated the IPA vapor intake with different air velocity and applied the capture velocity principle. It was found that the appropriate air velocity to draw IPA vapor was 6 m/s. Pitsamai also installed a hood adjacent to the original vapor source.

Kritsana Suphachitranon (2008) (32) studied how to control the volume of kerosene vapors to a safe level. The measurements of vapor of kerosene at the operation areas in the last three years revealed that the concentration was higher than the threshold of the National Institute for Occupational Safety and Health (NIOSH) standard (100 mg/m^3) and it may affect health in the long term. Kritsana designed the ventilation system for the basin with kerosene, size 0.5×1.2 meter by applying threshold of the ACGIH (2001) standards. This design can help control the amount of vapors in the work area. It found that the slot hood type intake duct was required for installation on one side.

Srirattana Vanichadisak (2008) (33) conducted a study and improvement design of the ventilation system in a chemical plant to reduce the amount of dust and to improve the structure according to the principle of ventilation. The reason was that this room had dispersion of dust resulting from the manufacturing processes in this room. It found that air velocity in capturing dust particles caused by the manufacturing processes at the air intake hood and the velocity in the air intake duct was lower than the threshold of ACGIH standard when replacing a fan but the original structure and duct lines were maintained. However, since the duct line and the original structure result in significant power loss in the system, there was a requirement to use a larger fan size. Therefore, Srirattana designed a new duct line and the completely new system. The new designed system will reduce friction and the loss occurring in

the duct line as well as the air velocity in front of the air intake hood. The air velocity in the duct line also satisfies the standards.

Wilai Hengwiwattanachai (2009) (34) studied to find out why workers in the adhesive coating processes (spray and rub of adhesive) in the facility of a plant producing automotive parts had dizziness, headache, respiratory irritation and nausea. The analysis of the concentration of the vapor at every point was made to workers who work with the gas chromatograph. The ventilation system was also inspected. It found that the concentrations of volatile organic compounds of xylene, toluene and methyl iso-butyl ketone were lower than the threshold recommended by the laws and the Occupational Safety and Health Administration (OSHA) standards. However, when Wilai checked the local exhaust ventilation systems applicable in the two areas, it found that every ventilation systems used in the adhesive spray areas and the adhesive rub area did not adhere to the threshold of ACGIH standards. Designing and the cost estimation found that fans of the local exhaust ventilation to spray adhesive shall be improved and installed into centrifugal type with back-tilt blades, 2-HP (1.492 kW) motor. In addition, the adhesive rub area shall be improved in the duct line and the air intake hood shall be a concealed hood, which will cost minimally.

Nor Halim Hasan et al (2012) (35) studied the processes with hazardous chemicals that required the local exhaust ventilation system to separate the workers from harm at the local exhaust ventilation aiming to separate contaminants from the source. The study divided into several sections such as construction, manufacture industry and paint plant etc. It found that continuous inspection, maintenance and performance of the personal protective equipment were substantial in preventing exposure of workers to contaminants of spray work processes. In addition, the design of the ventilation system in the facility, device selection and the use of the computational fluid dynamics (CFD) affect the local exhaust ventilation while the use of the push-pull type ventilation systems was highly effective.

Sumitra Chanapa (2003) (36) conducted a comparative study of factors that made the management system of occupational safety and health effective among small-medium plants and large plants. It found that factors affecting the preparation for establishment of the system of small and medium plants and large plants to be effective and to achieved in the system were as follows. i) awareness and capability of

the representative of the management system, ii) rationale to establish the system (especially, the policy of the employer, the effects of competition and corporate image as well as corporate reputation), iii) the ability of the team, iv) communication and v) workers who participate in various activities. In contrast, the significantly differentiating factors were administration of overall safety and different support from the top managements in terms of establishing of objectives, goals, timeframe, and budgets in preparation of the management system. Indeed, the large plants offered more support than small plants.

Umarat Sirijaroonwong (2006) (37) studied the effectiveness of internal audits of the management system of occupational safety and health in cement plants according to TIS.-18001 standard. It found that the requirements of TIS.-18001 were the criteria for audit evaluation. The inadequate awareness and experience on occupational safety and health as well as assessment techniques of the auditors, the incompleteness of the audits and the inadequate management in accordance with the criteria of standards of TIS.-18004, BS 8800, ISO 19011 and TIS.-18012 may affect the effectiveness of internal audits, which lead to the uneven results of occupational safety and health.

Jindaphloy Tangjai (2008) (38) studied the safety management processes in pilot plants and found that there was the focus on safety management but not serious. There was planning on safety and establishment of preventive work plans by focusing on key issues but they were not introduced into the activities. There were written procedures on the risk just to satisfy with assessment of the standards audit committee but they were not yet implemented concretely. There were controls of safety as an overview but smaller organizations had no obvious practice. Parts of the entire workers had been trained for the safety. Direct instruction methods from the supervisors to workers were applied. In addition, workers continue to focus more on financial income, fringe benefits, convenience and comforts than safety in the workplace.

CHAPTER III

MATERIALS AND METHODS

3.1 Study design

This study is the cross-sectional study together with document research. The study aims to examine the issue of the local exhaust ventilation in the existing coating processes of one manufacturer of medical devices in order to develop guidelines on management of the local exhaust ventilation system in the coating room.

3.2 Cross-sectional study

The cross-sectional study contains steps as given below.

3.2.1 Population and samples

The samples of this study are general ventilation and the local exhaust ventilation of the adhesive coating of the coating machine CT-3, CT-4 and CT-5 in the production of medical bandage.

3.2.2 Materials

Measurement and examination of various factors that affect the local exhaust ventilation are made by means of the tools and equipment below.

1. Canon Power Shot IS A3200 camera for photographing
2. Measuring tape
3. FLUKE® Airflow Meter pressure gauge (serial number: 22580022)
4. Kanomax Anemomaster standard model 6035 multi-function thermal anemometer (serial number: 400402)

3.2.3 Data collection

Inspection of the local exhaust ventilation of the adhesive coating processes includes:

1. Examination of chemical concentrations in the work environment of three-year work period in 2012-2014.

2. Examination of the ventilation system of the coating processes from drawings and plans and from the work area.

3. Measurement of the size of the hoods and duct at the local exhaust ventilation of the coating machine CT-3, CT-4 and CT-5 with measuring tape and the data are recorded.

4. Measuring of air velocity to capture the pollutant at the hood front of the local exhaust ventilation of the coating machine CT-3, CT-4 CT-5 with Kanomax Anemomaster standard model 6035 multi-function thermal anemometer as follows:

- 4.1 Check readiness of battery condition to be free from wetness or white powder on battery terminals. When not in use, the battery shall be removed immediately.

- 4.2 Slide the switch to ON To turn on the meter.

- 4.3 Press MODE to select the unit to measure.

- 4.4 Read measurements and record the desired value.

5. Measuring static pressure and air velocity in the ducts of the local exhaust ventilation of the coating machine CT-3, CT-4 and CT-5 with FLUKE® airflow meter as follows:

- 5.1 Check readiness of battery condition to be free from wetness or white powder on battery terminals. When not in use, the battery shall be removed immediately.

- 5.2 Press POWER to turn on the power. Next, press zero for 2 seconds to reset to zero.

- 5.3 Press PRESSURE to enter the pressure mode.

- 5.4 Connect the yellow line into the Input (+) to measure the total pressure (TP) and connect the black wire to Ref (-) to measure the static pressure (SP).

5.5 While measuring, turn the Pitot tube end to face the direction of air into the pipe.

5.6 Read measurements and record the desired value.

6. Measurement of air velocity of the fan wall with Kanomax Anemomaster standard model 6035 multi-function thermal anemometer.

Its manipulating method shall be in accordance with No. 4 above.

7. Perform data analysis as in item 3.2.4 below.

3.2.4 Data analysis

This study applies the descriptive statistics for data analysis by using the average in determining the air velocity in the duct and the measured capture velocity.

3.2.4.1 Evaluation of efficiency of the ventilation system of the adhesive coating room

1. Examine appearance of the local exhaust ventilation i.e. type of hood, duct line and the type of fan.

2. Comparison of observed air velocities to the recommendation as follows:

2.1 The average measured capture velocity of pollutant compare to the recommendation of the ACGIH for the local exhaust ventilation applied with the vapor required 1 m/s.

2.2 The average measured air velocity in the duct compare to the recommendation of the ACGIH for the local exhaust ventilation applied with the vapor required 5 m/s.

3. Calculation of Volumetric flow rate in duct of the local exhaust ventilation of the coating machine CT-3, CT-4 and CT-5:

$$Q = V \times A$$

Where,

Q: Volumetric flow rate (cubic meters/second, m³/s)

V: Velocity (meters per second, m/s)

A: Area (sq. meters, m²)

4. Calculation of Volumetric flow rate at each point of the local exhaust ventilation of the coating machine CT-3, CT-4 and CT-5.

5. Calculation of the ventilation rate of coating processes:

Rate of ventilation = Supply air flow rate - Exhaust air flow rate

6. Calculation of the effective ventilation rate (Q') of coating processes.

$$Q' = (24 \times 10^6 \times SG \times ER) / MW \times C$$

Where,

Q':	Effective volumetric flow rate
SG:	Specific gravity of volatile liquid
ER:	Evaporation rate of liquid
MW:	Molecular weight of liquid
C:	Corresponding threshold limit (TLV)

7. Comparison of the ventilation rate of coating room with the effective ventilation rate.

8. Calculation of environment concentration of coating processes on the one-hour coating processes.

$$C = (M/Mw) \times (24.45/V) \times 10^6$$

Where,

C:	Concentration in environment (ppm)
M:	Chemical mass (kg)
MW:	Molecular weight
V:	Room volume (m ³)

9. Calculation of the concentration of chemicals in the working environment after ventilation with the current rate of ventilation for 1 hour if ventilation is effective.

$$C_2 = C_1 \times e^{(Q' \times (t_2 - t_1) / V)}$$

Where,

C_1 : Initial concentration of chemical gas or vapor (ppm)

C_2 : Concentration of chemical gas or vapor (ppm)

Q' : Effective volumetric flow rate (m^3 /hour).

V : Volume of room (m^3)

t_1 : Initial time

t_2 : Elapsed time

3.2.4.2 Effect measurements of concentration of chemicals in the work environment

The measurements of concentration of chemicals in the work environment for the past 3 years, in 2012-2014, are conducted at the worker (personal sample) operating the coating machine CT-3, the coating machine CT-4 and the adhesive coating machine CT-5. The data shall be calculated by using the indicator of additive mixture equation.

That is, if

$$(C_1/TLV_1) + (C_2/TLV_2) + \dots + (C_n/TLV_n) > 1$$

Where,

C = the concentration of chemicals obtained in the air from measurements

T = the concentration limits of hazardous chemicals (Threshold Limit Value-Time Weighted Average (TLV-TWA)).

In this situation, the threshold limit of the mixture is violated.

3.2.4.3 Analysis of calculations

The results of the study in item 3.2.4.1 and item 3.2.4.2 are analyzed for issues of the local exhaust ventilation of the coating processes.

3.3 Document research

3.3.1 Study process

The study is divided into three stages as follows:

3.2.1.1 Review of relevant documents

The author conducts review of relevant documents on regulatory laws and related standards of the local exhaust ventilation system as follows:

Occupational safety, health and work environment Act B.E. 2554 (A.D. 2011)

Ministerial Regulation on the prescribing of standard for administration and management of occupational safety, health and work environment, B.E. 2549 (A.D.2006)

Ministerial Regulation on the prescribing of standard for administration and management of occupational safety, health and work environment B.E. 2553 (A.D.2010)

Ministerial Regulation on the prescribing of standard for administration and management of occupational safety, health and work environment in hazardous chemicals, B.E. 2556 (A.D.2013)

Occupational health and safety management system (Thai Industrial Standard: 18001- B.E. 2554)

Ministerial Regulation on the prescribing of criteria and method of conducting health checkup of workers and forwarding the results of health check-up to labor inspector, B.E. 2547 (A.D.2004)

Standard of the American Conference of Government Industrial Hygienists (ACGIH): 2014, TLVs and BEIs

Standard of the American Conference of Government Industrial Hygienists (ACGIH): Industrial ventilation

3.2.1.2 Analysis of local exhaust ventilation of the adhesive coating processes

The author performs analysis of the current situations of the local exhaust ventilation of the adhesive coating processes:

1. Review of laws and related standards
2. Review of related research papers
3. Review of the requirements of one production plant of medical equipment
4. Collection of the information resulting from the review for analysis and development of safety management of the local exhaust ventilation of the adhesive coating processes

3.2.1.3 Development of management system standard

The author develops the management system standard on occupational safety, health and work environment

3.3.2 Analysis of information

The results and the process operation procedures shall be summarized and collected to develop the systems approach for management of the local exhaust ventilation of the adhesive coating processes.

CHAPTER IV

RESULTS

The objective of this research was to develop guidelines for management of local exhaust ventilation system in the adhesive coating processes. The experimental results were divided into three parts, as follows;

4.1 Ventilation system of the adhesive coating processes at present.

4.2 The results of chemicals concentrations measurement in the workplace at the adhesive coating processes.

4.3 Guidelines for the management of local exhaust ventilation system of the adhesive coating processes.

4.1 Ventilation system of the adhesive coating processes at present

The study found that the adhesive coating processes consist of two ventilation types, as follows;

4.1.1 Dilution Ventilation Systems (also, General Exhaust Ventilation)

using the method of ventilation by mechanical means of fans to aid circulate air movement. A total of 9 wall fans were installed. The wall fan with a dimension of 0.9 meters in width by 0.9 meters in length diluted pollutants from the production processes. Number of wall fan was shown in figure 4.2, including;

Four supply wall fans, namely; No.1, No.2, No.3, and No.4, draw clean air into the adhesive coating room. Five exhaust wall fans, namely; No.5, No.6, No.7, No.8, and No.9 ventilate the adhesive coating room. The air velocity and air flow rate of each wall fan shown in table 4.1.

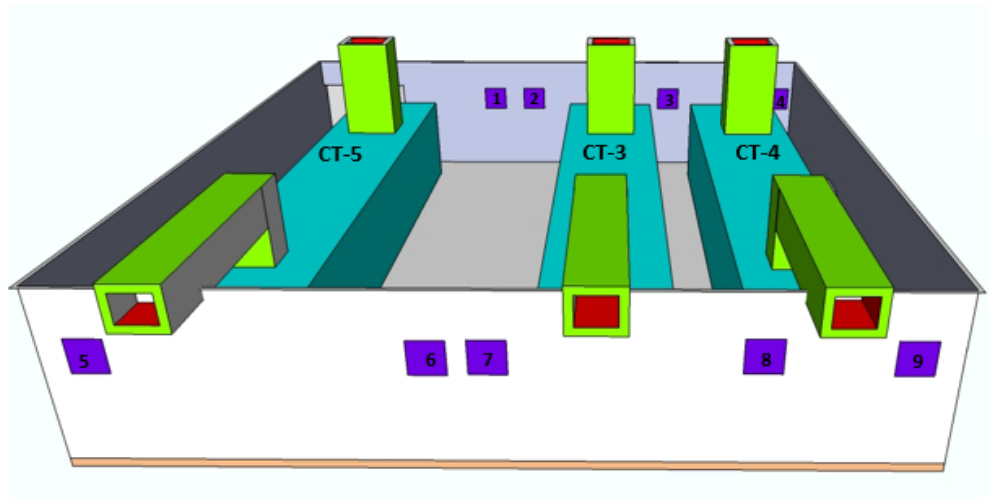


Figure 4.1 Wall fan numbers 1 to 9

Table 4.1 The average observed air velocity and the rate of airflow of the wall fans

Wall fan number	Average velocity (m/s)	Flow rate (m ³ /s)
No.1	8.12	6.58
No.2	8.27	6.70
No.3	8.60	6.97
No.4	7.64	6.19
No.5	7.34	5.95
No.6	7.67	6.21
No.7	7.85	6.36
No.8	7.54	6.11
No. 9	7.78	6.30

The total supply air flow rate of the wall fan was 26.43 m³/s which calculated from the fan No.1, No.2, No.3, and No.4. The total exhaust air flow rate of the wall fan was 30.93 m³/s which calculated from the fan No.5, No.6, No.7, No.8, and No.9.

4.1.2 Local exhaust ventilation system

The adhesive coating machine CT-3, CT-4 and CT-5 were installed with the local exhaust ventilation at the adhesive coating head near the workstation. The round duct with 0.15 meter diameter was connected to the airflow of the existing adhesive coating machines using blower in combination with the original system of the adhesive coating machines. The air was drawn into the adhesive coating system and moved along the oven. It was released at the two ventilation ducts (exhaust), as shown in figure 4.2.

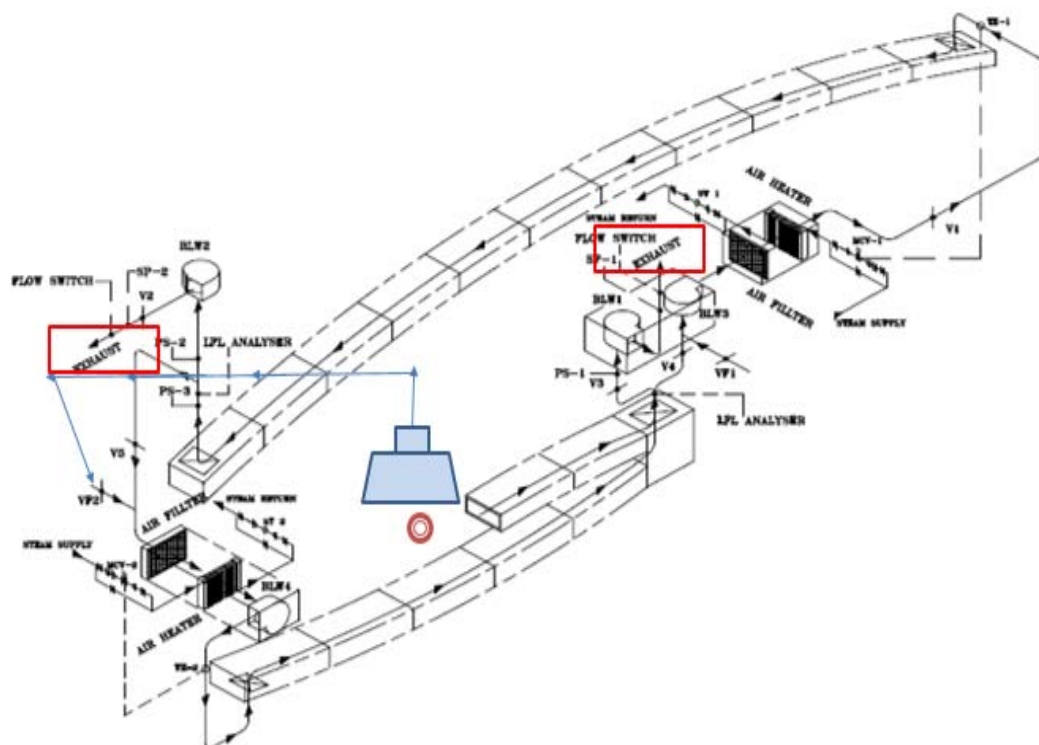


Figure 4.2 The local exhaust ventilation of the adhesive coating machine

Figure 4.2 demonstrates that each local exhaust ventilation of the adhesive coating machine was installed with a canopy hood around the top of the adhesive coating head in which the feature and size are shown in figure 4.3.

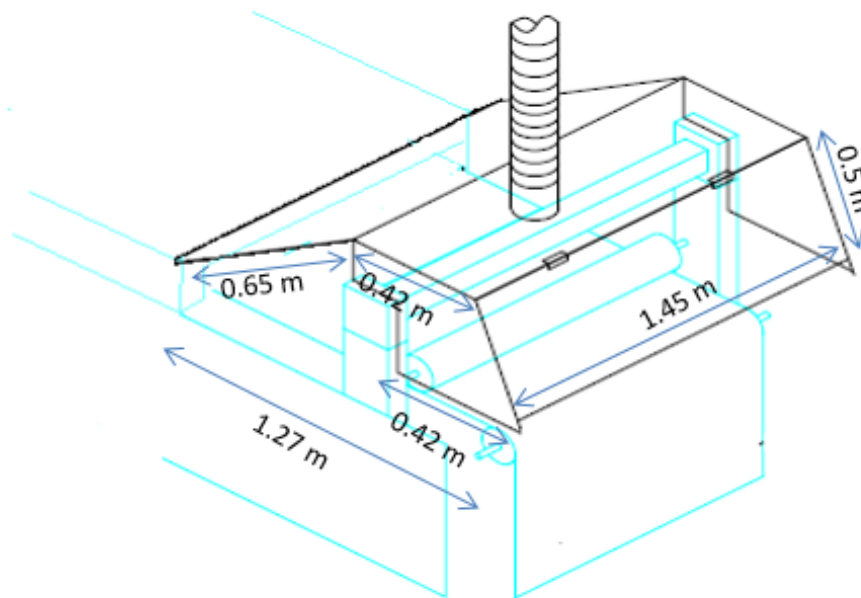


Figure 4.3 The feature and size of canopy hood around the top of adhesive coating head

Based on the direction of air flow from the study revealed that all adhesive coating machines were similar. The air flow diagram can be drawn as shown in figure 4.4. The chemical vapors were drawn into the ventilation system by the hood at point A and by at the oven point E. The air flowed from point A to point B through 0.15 meter diameter duct and combined to point C then became to point D which the air was drawn into the system to dilute the chemicals in the oven. After that the air was drawn into a 7.5-HP blower at point D in which the air flowed to join with point E at point F. At this point, the air was split into two parts in which the first part was ventilated through the stack with a 5.5-HP blower at point G, and the second part was pulled back into the system again to merge with point H, which the air was sucked at point I to enter the 7.5-HP blower.

4.1.2.1 Study results of the local exhaust ventilation system of the adhesive coating machine CT-3, CT-4, and CT-5.

1. Study results of the local exhaust ventilation system of the adhesive coating machine CT-3.

The flow rate and the duct velocity of the ventilation system of the machine CT-3 were measured at the designated point in figure 4.4 including the measurement of static pressure of each point, as shown in table 4.2.

Table 4.2 The measurement results of duct velocity, flow rate and static pressure of the ventilation system of the adhesive coating machine CT-3.

Point	Type of velocity	Type of duct	Duct size (meter)	Average velocity (m/s)	Flow rate (m ³ /s)	Static pressure (Pa)
A	Capture velocity	Hood	1.45×1.27	0.24	-	-
B	Duct	Round	0.15	8.71	0.15	-129
C	Duct	Rectangular	0.45×0.45	5.99	1.21	-59
D	Duct	Rectangular	1.3×0.35	5.89	2.68	-165
E	Duct	Rectangular	1.3×0.35	6.89	3.14	-51
F	Duct	Rectangular	1.3×0.35	10.17	4.63	-142
G	Duct	Rectangular	0.6×0.6	5.20	1.87	-79
H	Duct	Rectangular	0.45×0.45	7.06	1.43	-87
I	Duct	Rectangular	1.3×0.35	7.67	3.49	-127
J	Duct	Rectangular	0.6×0.6	5.42	1.95	-131
K	Duct	Rectangular	1.3×0.35	2.87	1.31	-106

The flow rate in the duct at each point of the adhesive coating machine CT-3 can be summarized as shown in Figure 4.5

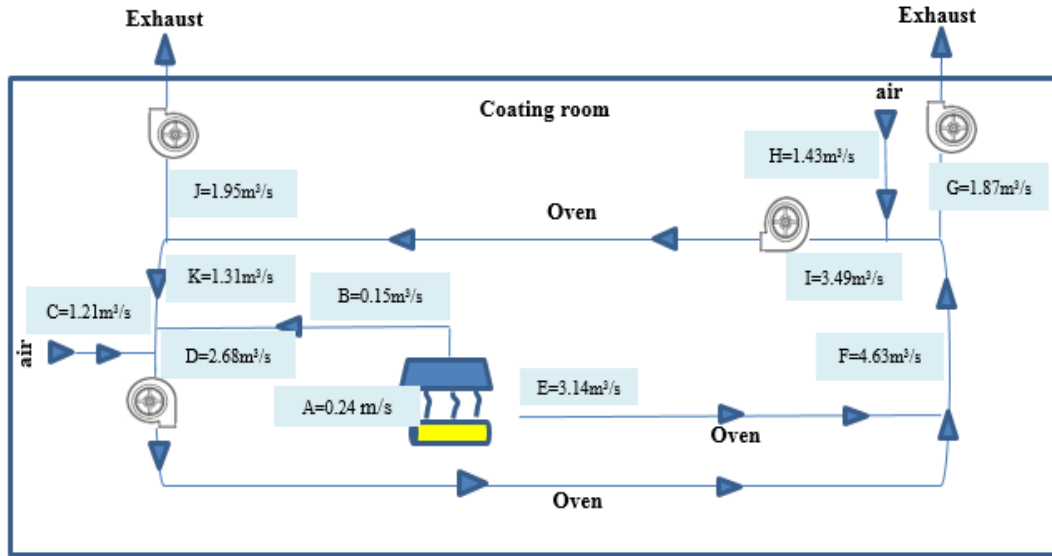


Figure 4.5 Diagram of air flow direction and airflow rate of coating machine CT-3

Figure 4.5 demonstrates the flow rate at all points of the adhesive coating machine CT-3. From the principle of volumetric flow rate of air in the duct is the same at all points, since $D = B + C + K$.

The measured flow rate at point D was $2.68 \text{ m}^3/\text{s}$ comparing to the rate of flow from points B, C, and K with a flow rate of $2.67 \text{ m}^3/\text{s}$ ($B + C + K = 0.15 + 1.21 + 1.31$). Therefore, point D had a flow rate close to points $B + C + K$.

Since $F = D + E$, Flow rate measured at point F was equal to $4.63 \text{ m}^3/\text{s}$ comparing to points D and E with a flow rate of $5.82 \text{ m}^3/\text{s}$ ($D + E = 2.68 + 3.14$). Therefore, the flow rate at point F was less than points $D + E$.

Since $I = F + H - G$, flow rate measured at point I was equal to $3.49 \text{ m}^3/\text{s}$ comparing to points $F + H - G$ with a flow rate of $4.19 \text{ m}^3/\text{s}$ ($F + H - G = 4.63 + 1.43 - 1.87$). Therefore, the flow rate at point I was less than points $F + H - G$.

Since $K = I - J$, The actual flow rate measured at K was 1.31 m^3/s comparing to points I – J with a flow rate 1.54 m^3/s ($I - J = 3.49 - 1.95$). Therefore, the flow rate at point K was less than points I - J.

Table 4.2 shows that the hood capture velocity of machine CT-3 (0.24 m/s) was below the recommendation of ACGIH. It requires the capture velocity not less than 1 m/s. The study also found that the duct velocities from B to K complied with the recommendation of the ACGIH. This requires the duct velocity not less than 5 m/s. There was only the measurement of point K (2.87 m/s) below the recommendation of the ACGIH. The static pressures of all points were negative at the blower inlet, and the exhaust ventilation rate of the stack, at points G and J was 3.82 ($1.87 + 1.95$) m^3/s .

2. Study results of the local exhaust ventilation system of the adhesive coating machine CT-4.

The flow rate and the duct velocity of the ventilation system of the machine CT-4 were measured at the designated point in figure 4.4 including the measurement of static pressure of each point, as shown in table 4.3.

Table 4.3 The measurement results of duct velocity, flow rate and static pressure of the adhesive coating machine CT-4.

Point	Type of velocity	Type of duct	Duct size (meter)	Average velocity (m/s)	Flow rate (m³/s)	Static pressure (Pa)
A	Capture velocity	Hood	1.45×1.27	0.31	-	-
B	Duct	Round	0.15	11.35	0.20	-153
C	Duct	Rectangular	0.45×0.45	7.26	1.47	-49
D	Duct	Rectangular	1.3×0.35	7.11	3.24	-190
E	Duct	Rectangular	1.3×0.35	6.45	2.94	-61
F	Duct	Rectangular	1.3×0.35	11.26	5.12	-173
G	Duct	Rectangular	0.6×0.6	5.13	1.85	-67
H	Duct	Rectangular	0.45×0.45	7.16	1.45	-79
I	Duct	Rectangular	1.3×0.35	8.69	3.95	-121
J	Duct	Rectangular	0.6×0.6	5.00	1.80	-152
K	Duct	Rectangular	1.3×0.35	3.13	1.42	-115

The flow rate in the duct at each point of the adhesive coating machine CT-4 can be summarized as shown in Figure 4.6

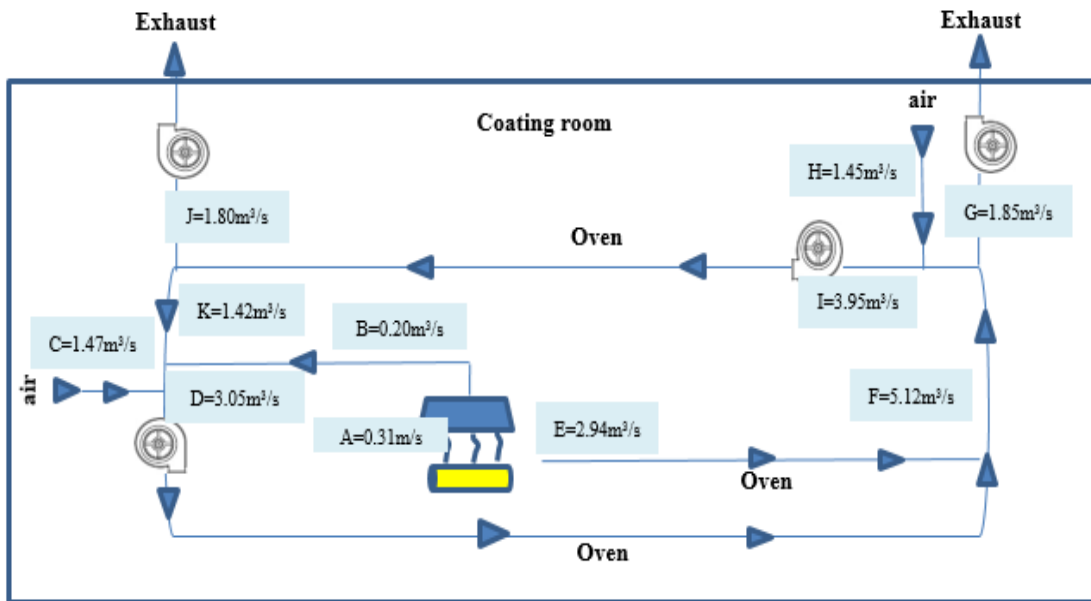


Figure 4.6 Diagram of air flow direction and airflow rate of coating machine CT-4

Figure 4.6 demonstrates the flow rate at all points of the adhesive coating machine CT-4. From the principle of volumetric flow rate of air in the duct is the same at all points, since $D = B + C + K$.

The measured flow rate at point D was $3.05 \text{ m}^3/\text{s}$ comparing to points B, C, and K with a flow rate of $3.09 \text{ m}^3/\text{s}$ ($B + C + K = 0.20 + 1.47 + 1.42$). Therefore, point D had a flow rate close to points $B + C + K$.

Since $F = D + E$, flow rate measured at point F was $5.12 \text{ m}^3/\text{s}$ comparing to points D and E with a flow rate of $5.99 \text{ m}^3/\text{s}$ ($D + E = 3.05 + 2.94$). Therefore, the flow rate at point F was less than points $D + E$.

Since $I = F + H - G$, flow rate measured at point I was $3.98 \text{ m}^3/\text{s}$ comparing to the rate of flow from points $F + H - G$ with the flow rate of $4.72 \text{ m}^3/\text{s}$ ($F + H - G = 5.12 + 1.45 - 1.85$). Therefore, the flow rate at point I was less than points $F + H - G$.

Since $K = I - J$, the actual flow rate measured at K was $1.42 \text{ m}^3/\text{s}$ comparing to points $I - J$ with the flow rate of $2.15 \text{ m}^3/\text{s}$ ($I - J = 3.95 - 1.80$). Therefore, the flow rate at point K was less than points $I - J$.

Table 4.3 shows that the hood capture velocity of machine CT 4 (0.31 m/s) was below the recommendation of the ACGIH. It requires the capture velocity not less than 1 m/s. The study also found that the duct velocities from B to K complied with the recommendation of the ACGIH. This requires the duct velocity not less than 5 m/s. There was only the measurement of point K (3.13 m/s) below the recommendation of the ACGIH. The static pressures of all points were negative at the blower inlet, and the exhaust ventilation rate of the stack at points G and J was 3.65 m³/s (1.85 + 1.80).

3. Study results of the local exhaust ventilation system of the adhesive coating machine CT-5.

The flow rate and the duct velocity of the ventilation system of the machine CT-5 were measured at the designated point in figure 4.4 including the measurement of static pressure of each point, as shown in table 4.4.

Table 4.4 The measurement results of duct velocity, flow rate and static pressure of the ventilation system of the adhesive coating machine CT-5

Point	Type of velocity	Type of duct	Duct size (meter)	Average velocity (m/s)	Flow rate (m ³ /s)	Static pressure (Pa)
A	Capture velocity	Hood	1.45×1.27	0.16	-	-
B	Duct	Round	0.15	9.30	0.16	-184
C	Duct	Rectangular	0.45×0.45	6.45	1.31	-48
D	Duct	Rectangular	1.3×0.35	6.45	2.93	-127
E	Duct	Rectangular	1.3×0.35	6.66	3.03	-79
F	Duct	Rectangular	1.3×0.35	10.91	4.96	-157
G	Duct	Rectangular	0.6×0.6	5.21	1.88	-115
H	Duct	Rectangular	0.45×0.45	6.46	1.31	-69
I	Duct	Rectangular	1.3×0.35	7.27	3.31	-128
J	Duct	Rectangular	0.6×0.6	5.17	1.86	-134
K	Duct	Rectangular	1.3×0.35	3.02	1.37	-98

The flow rate in the duct at each point of the adhesive coating machine CT-5 can be summarized as shown in Figure 4.7.

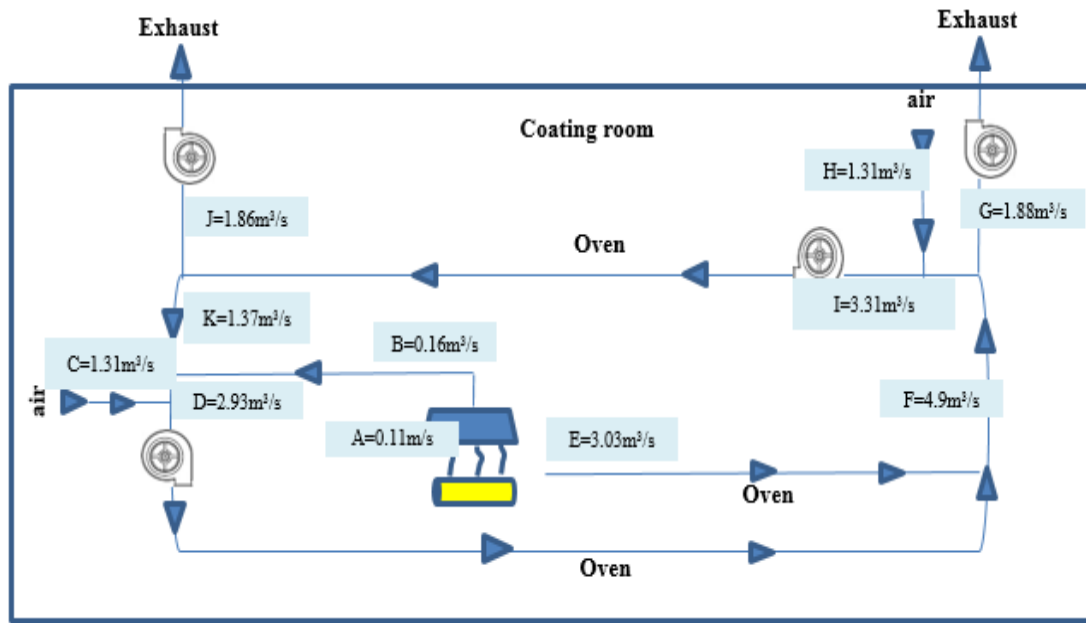


Figure 4.7 Diagram of air flow direction and airflow rate of coating machine CT-5

Figure 4.7 demonstrates the flow rate at all points of the adhesive coating machine CT-5. From the principle of volumetric flow rate of air in the duct is the same at all points, since $D = B + C + K$.

The measured flow rate at point D was $2.93 \text{ m}^3/\text{s}$ comparing to the rate of flow from points B, C, and K with a flow rate of $2.84 \text{ m}^3/\text{s}$ ($B = 0.16 + C = 1.31 + K = 1.37$). Therefore, point D had a flow rate close to points $B + C + K$.

Since $F = D + E$, flow rate measured at point F was equal to $4.96 \text{ m}^3/\text{s}$ comparing to points D and E with a flow rate of $5.96 \text{ m}^3/\text{s}$ ($D=2.93+E=3.03$). Therefore, the flow rate at point F was less than points $D + E$.

Since $I = F + H - G$, flow rate measured at point I was equal to $3.11 \text{ m}^3/\text{s}$ comparing to points $F + H - G$ with a flow rate of $4.42 \text{ m}^3/\text{s}$ ($F = 4.96 + H = 1.34 - G = 1.88$). Therefore, the flow rate at point I was less than points $F + H - G$.

Since $K = I - J$, the actual flow rate measured at K was $1.37 \text{ m}^3/\text{s}$ comparing to points $I - J$ with a flow rate of $1.45 \text{ m}^3/\text{s}$ ($I = 3.31 - J = 1.86$). Therefore, the flow rate at point K was less than points $I - J$.

Table 4.3, show that the hood capture velocity of machine CT-3 (0.16 m/s) was below recommendation of the ACGIH. It requires the capture velocity not less than 1 m/s . The study also found that the duct velocities from B to K

complied with the recommendation of ACGIH. This requires the duct velocity not less than 5 m/s. There was only, the measurement of point K (3.02 m/s) below recommendation of the ACGIH. The static pressures of all points were negative at the blower inlet, and the exhaust ventilation rate of stack, at points G and J 3.74 m³/s (1.88 + 1.86).

4.1.3 Ventilation of the adhesive coating processes

4.1.3.1 Calculation of the ventilation rate of adhesive coating processes

The supply air flow rate into the adhesive coating process was 26.43 m³/s. The total exhaust air flow rate from the adhesive coating processes was the sum of the general ventilation and local exhaust ventilation. The ventilation rate of the wall fans was 30.93 m³/s and the sum of the ventilation rate of ventilation stack of machines CT-3, CT-4, and CT-5 was 42.14 m³/s (CT 3 = 3.82 m³/s + CT 4 = 3.65 m³/s + CT 5 = 3.74 m³/s). Therefore, the exhaust air flow rate was 15.71 m³/s (42.14 m³/s - 26.43 m³/s) more than the supply air flow rate into the system.

4.1.3.2 Calculation of the effective ventilation rate (Q') of the coating processes

The adhesive coating processes using 315 liters / hour of dearomatized hydrocarbon and the composition of this chemical shown in table 4.5. The volume of the adhesive coating room was 5,552.56 m³.

Table 4.5 Chemical properties of dearomatized hydrocarbons

Chemical name	CAS No.	% Concentration	Molecular weight	Specific gravity	ACGIH TLV-TWA (ppm)
Cyclohexane	110-82-7	35	84.16	0.779	100
Heptane	Mixture	40	100.2	0.681	400
Methyl cyclohexane	108-87-2	15	98.18	0.769	400
n-hexane	110-54-3	10	86.17	0.659	50

The effective ventilation rate (Q') of the coating process was determined from the equation:

$$Q' = (24 * 106 * SG * ER) / MW * C.$$

Where ,

Q':	Effective volumetric flow rate
SG:	Specific gravity of volatile liquid
ER:	Evaporation rate of liquid
MW:	Molecular weight of liquid
C:	Corresponding threshold limit (TLV)

Calculation results were shown in table 4.6.

Table 4.6 The results of the effective ventilation rate(Q') of dearomatized hydrocarbon

Chemical name	Effective ventilation rate (m ³ /hr)
Cyclohexane	13,328.89
Heptane	2,446.71
Methyl cyclohexane	2,819.72
n-hexane	22,025.30

The ventilation rate of the chemical compound can be calculated from the rate of ventilation of each chemical altogether. It was 40620.62 m³/hr or 11.28 m³/s.

4.1.3.3 The ventilation rate of the adhesive coating room and the effective ventilation rate in comparison.

Based on the calculated results, it was found that ventilation rate of the adhesive coating room at present was 15.71 m³/s which was higher than the effective ventilation rate (Q') of 11.28 m³/s.

4.1.3.4 Calculation of atmospheric concentration of the adhesive coating processes from one hour of adhesive coating.

The data from table 4.5 can be calculated to determine the atmospheric concentration of the adhesive coating processes for one-hour of adhesive coating, by using the formula as follows;

$$C = (M/M_w) \times (24.45/V) \times 10^6.$$

Where,

- C: Atmospheric Concentration (ppm)
M: Chemical mass (kg)
MW: Molecular weight
V: Room volume (m³)

Table 4.7 Results of atmospheric concentration of the adhesive coating processes for one hour of adhesive coating.

Chemical name	Concentration in workplace (ppm)
Cyclohexane	4493.62
Heptane	3770.82
Methyl cyclohexane	1629.64
n-hexane	1060.78

4.1.3.5 Calculation of the concentration of the remaining chemicals after ventilating air out of the adhesive coating room for one hour in case of ventilation system was effective.

It can be calculated to find the concentration of the remaining chemicals in the room after ventilating air out of the adhesive coating room for one hour by using the value of ventilation rate at present that was 42.14 m³/s or 151,704 m³/hr. This can be expressed in equation form, as follows;

$$C_2 = C_1 \times e^{-(Q \times (t_2 - t_1) / V)}$$

Where,

- C_1 : Initial concentration of chemical gas or vapor (ppm)
 C_2 : Concentration of chemical gas or vapor (ppm)
 Q : Effective volumetric flow rate (m³/hour)
 V : Volume of room (m³)
 t_1 : Initial time
 t_2 : Elapsed time

Table 4.8 Calculation results of the concentration of chemicals in the working atmosphere after one-hour of ventilating air out of the room in case of ventilation system was effective.

Chemical name	Concentration in environment (ppm)
Cyclohexane	6.12×10^{-9}
Heptane	5.14×10^{-9}
Methyl cyclohexane	2.22×10^{-9}
n-hexane	1.45×10^{-9}

4.2 The results of chemicals concentrations measurement in the workplace at the adhesive coating processes

The Measurement results of air quality of chemicals in the working atmosphere of the adhesive coating process by examining the resulting data of air quality in the workplace. The sampling data were collected twice a year (every 6 months) which dated back for the past three years since 2012-2014 AD. During the period, there was no change in production process and ventilation system, as shown in table 4.10 to 4.15.

The measurement of air quality was done by collecting the sample during eight-hour work period (one work shift) using the passive personal sample device called 3MTM Organic Vapor Monitors-3500. It was on the employees working around

the adhesive coating head of every machine (CT-3, CT-4, and CT-5) at breathing zone. The concentration of the chemicals were analyzed and calculated the amount of chemicals.

The adhesive coating processes were operated at 24-hour basis. Total workers were 17 persons with three work locations. There were two workers per shift working at the adhesive coating head of each adhesive coating machine over eight hours long.

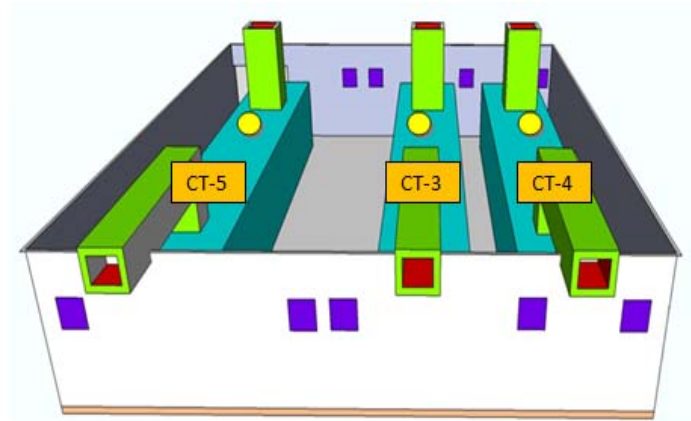


Figure 4.8 The circle was where the workers work around the adhesive coating head

The workers were exposed to dearomatized hydrocarbon which was used as solvent in the adhesive mixture in the processes of fabric coating. The additive mixture calculations were shown in table 4.9 to 4.15.

Table 4.9 The concentration threshold limit values of dearomatized hydrocarbon in the working atmosphere of the adhesive coating room.

Chemical name	CAS No.	TLV-TWA (ACGIH) (ppm)
Cyclohexane	110-82-7	100
Heptane	Mixture	400
Methyl cyclohexane	108-87-2	400
n-hexane	110-54-3	50

Table 4.10 The calculation results of additive mixture of chemicals in the working atmosphere during the first half of 2012 AD.

Machine	Chemicals	Concentration of organic vapor (ppm)	Calculated indicator of additive mixture
CT-3	Cyclohexane	21.55	1.02
	Methyl cyclohexane	15.78	
	n-hexane	27.26	
	Heptane and Isomer	89.45	
CT-4	Cyclohexane	36.14	1.13
	Methyl cyclohexane	18.29	
	n-hexane	23.78	
	Heptane and isomer	98.36	
CT-5	Cyclohexane	29.12	1.03
	Methyl cyclohexane	23.44	
	n-hexane	29.56	
	Heptane and isomer	37.12	

Table 4.11 The calculation results of additive mixture of chemicals in the working atmosphere during the second half of 2012 AD.

Machine	Chemicals	Concentration of organic vapor (ppm)	Calculated indicator of additive mixture
CT-3	Cyclohexane	39.42	1.09
	Methyl cyclohexane	46.21	
	n-hexane	21.26	
	Heptane and isomer	61.33	
CT-4	Cyclohexane	23.59	0.92
	Methyl cyclohexane	32.62	
	n-hexane	19.78	
	Heptane and isomer	84.02	
CT-5	Cyclohexane	17.78	0.96
	Methyl cyclohexane	40.82	
	n-hexane	26.92	
	Heptane and isomer	55.21	

Table 4.12 The calculation results of additive mixture of chemicals in the working atmosphere during the first half of 2013 AD.

Machine	Chemicals	Concentration of organic vapor (ppm)	Calculated indicator of additive mixture
CT-3	Cyclohexane	18.12	0.90
	Methyl cyclohexane	17.12	
	n-hexane	23.23	
	Heptane and isomer	84.67	
CT-4	Cyclohexane	29.56	1.03
	Methyl cyclohexane	29.30	
	n-hexane	20.49	
	Heptane and isomer	101.99	
CT-5	Cyclohexane	37.89	1.15
	Methyl cyclohexane	19.45	
	n-hexane	27.48	
	Heptane and isomer	69.32	

Table 4.13 The calculation results of additive mixture of chemicals in the working atmosphere during the second half of 2013 AD.

Machine	Chemicals	Concentration of organic vapor (ppm)	Calculated indicator of additive mixture
CT-3	Cyclohexane	12.59	1.12
	Methyl cyclohexane	47.23	
	n-hexane	29.09	
	Heptane and isomer	118.05	
CT-4	Cyclohexane	37.93	1.09
	Methyl cyclohexane	58.67	
	n-hexane	21.49	
	Heptane and isomer	53.85	
CT-5	Cyclohexane	20.20	1.17
	Methyl cyclohexane	42.43	
	n-hexane	33.26	
	Heptane and isomer	78.04	

Table 4.14 The calculation results of additive mixture of chemicals in the working atmosphere during the first half of 2014 AD.

Machine	Chemicals	Concentration of organic vapor (ppm)	Calculated indicator of additive mixture
CT-3	Cyclohexane	15.34	1.03
	Methyl cyclohexane	23.13	
	n-hexane	27.98	
	Heptane and isomer	105.12	
CT-4	Cyclohexane	24.56	1.21
	Methyl cyclohexane	19.11	
	n-hexane	26.23	
	Heptane and isomer	76.67	
CT-5	Cyclohexane	29.56	1.28
	Methyl cyclohexane	34.68	
	n-hexane	32.7	
	Heptane and isomer	99.65	

Table 4.15 The calculation results of additive mixture of chemicals in the working atmosphere during the second half of 2014 AD.

Machine	Chemicals	Concentration of organic vapor (ppm)	Calculated indicator of additive mixture
CT-3	Cyclohexane	32.34	1.06
	Methyl cyclohexane	62.36	
	n-hexane	19.86	
	Heptane and isomer	73.50	
CT-4	Cyclohexane	18.03	1.16
	Methyl cyclohexane	47.29	
	n-hexane	31.79	
	Heptane and isomer	90.21	
CT-5	Cyclohexane	37.54	1.11
	Methyl cyclohexane	32.90	
	n-hexane	24.72	
	Heptane and isomer	63.88	

Based on the study results on the concentration of chemicals in the working atmosphere in the adhesive coating process dated back for the past 3 years since 2012 – 2014 AD., it was found that if the concentration limits of each chemical

substance in the atmosphere was not exceed the recommendation of the ACGIH, in comparable, throughout the past three years, as shown in table 4.10 to table 4.15.

Cyclohexane, methyl cyclohexane, n-hexane and heptane resulted in neurotoxicity to health at the same target organs, the additive effect form, which was affecting the central nervous system by having two chemicals, entered the body, and then a combined affect occurred. It was equivalent to adding two toxic chemicals together. When computing additive mixture calculation, if it was greater than 1, it indicated that the value was exceeding the standard as shown in figure 4.9.

Based on the additive mixture calculation, it was found that the concentrations of chemicals in the atmosphere, each measuring time, the value was in the range of 0.9 to 1.28. Consequently, the health effects were at high levels.

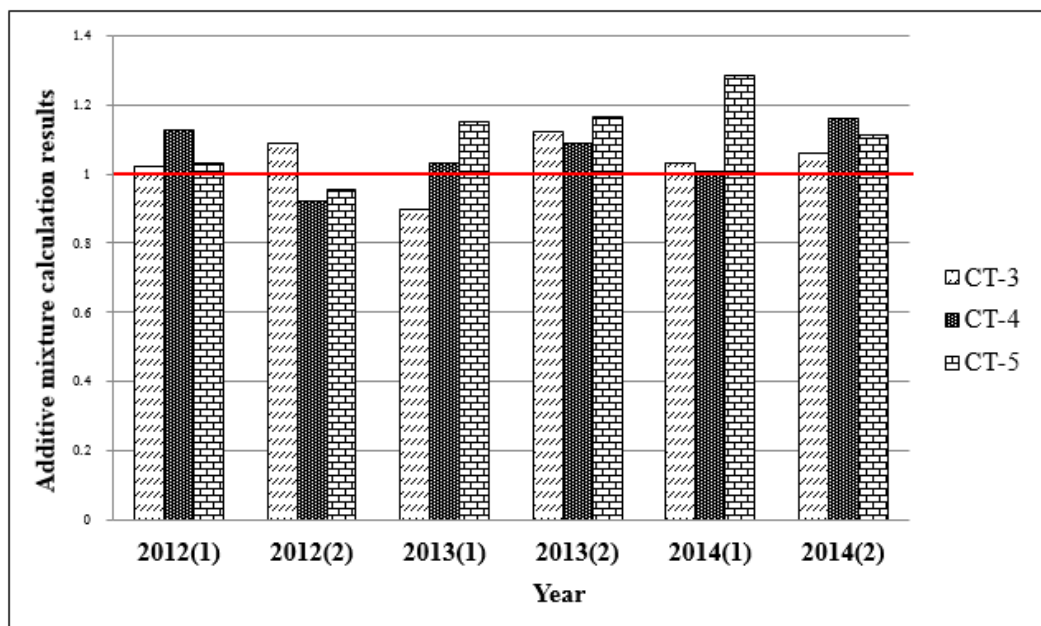


Figure 4.9 The calculated indicators of additive mixture

4.3 Guidelines for the management of local exhaust ventilation system of the adhesive coating processes.

The problem of ventilation of the adhesive coating processes was not able to ventilate effectively, thus the concentration of chemicals in the atmosphere exceeded the standards, therefore, the preparation of guidelines for the management of local exhaust ventilation were taken into consideration. By reviewing the documents used as a guide to system management standards on safety, occupational health, and workplace environment. The documents reviewed were, including; the Occupational Safety, Health and Work Environment Act B.E. 2554, the Regulations set standards for the administration and management of Occupational Safety, Health and Work Environment B.E. 2549, the Standard of Occupational Health and Safety Management Systems (TIS. 18001-2554), and the Ministerial Regulation on the Prescribing of Standard for Administration and Management of Occupational Health, Safety and Work Environment B.E. 2553 (edition 2).

The study found that this organization has no concrete guidelines on management of the local exhaust ventilation. There were no documented standards. There were no defined duties and responsibilities under the corporate structure, no work plans, no monitoring, and no operation of the management system review of occupational health and safety. Therefore, this study proposed guidelines for management of the local exhaust ventilation in the adhesive coating processes to ensure the implementation of the efficient local exhaust ventilation. It was anticipated that these guidelines could reduce the risk of the excessive concentration of chemicals in the work environment not to exceed the threshold, and to reduce the risk of fire and explosion in the coating process. These practices can be conducted by restricting the concentration of organic vapors in the work environment to less than 10% of the lower explosive limit (LEL). In this regard, the organization should provide the followings:

4.3.1 Standardization

1) Set the standard concentration of the chemicals in the workplace atmosphere.

Table 4.16 Set the concentration limits of the chemicals in the workplace atmosphere for the eight-hour work shift.

Chemical name	CAS No.	TLV-TWA (ACGIH) (ppm)
Cyclohexane	110-82-7	100
Heptane	Mixture	400
Methyl cyclohexane	108-87-2	400
n-hexane	110-54-3	50

2) Set the lower explosive limit (LEL)

In the adhesive coating processes, the concentration of chemicals in the atmosphere should not exceed 10% of the lower explosive limit (LEL) during the work hours.

3. Set a limit for the concentration of chemicals in the working atmosphere for 8-hour, and chemical mixture must not to exceed 1. It can be calculated according to the formula as follows;

$$(C_1/TLV_1) + (C_2/TLV_2) + \dots (C_n/TLV_n) \leq 1$$

Where,

C = the concentration of chemicals obtained in the air from measurements

T = the concentration limits of hazardous chemicals (Threshold Limit Value-Time Weighted Average (TLV-TWA)).

In case the result was greater than 1, it indicated that the concentration exceeded the concentration limits of hazardous chemicals mixtures of additive effect.

When the concentration of chemicals in the atmosphere exceeded the action level, which was 50% of the TLV-TWA of each chemical, or when the calculated additive mixture concentration was greater than 1, workers were required to wear the half-face piece respirator with organic vapor cartridges.

4) Proposed qualifications of the training instructors

The training instructors should be qualified for any of the following;

A. He / she must have work experience on related to the topic of the instruction for at least three years, or has worked directly in knowledge development or safety standards for at least three years Basically, the instructor must have experience as a lecturer in work safety for at least one year. The instructor must be knowledgeable and has work experience related to the topic of the instruction for at least one year, or has worked directly in knowledge development or occupational health and safety standards for at least one year.

B. He / she was a lecturer in the institute of higher education who graduated at least a bachelor degree on occupational health or equivalent by teaching in occupational health and safety as well as has taught on the subject for at least three years.

5) Specify of capture velocity and duct velocity for the local exhaust ventilation in the adhesive coating processes for capture velocity was 1 m/s and duct velocity was 5 m/s.

6) Schedule health checkup for employees.

Schedule health checkup for employees who work in the adhesive coating room and have been exposed to chemicals of n-Hexane by licensed medical doctor in occupational medicine, or who has been trained in occupational medicine. The mandatory check-up items should be as follows;

A. Electromyography (EMG), the rate of nerve conduction showed a decline, it was an indicator of peripheral neuropathy.

B. Eye examination for vision disorders and probable optic nerve disorders.

C. Examination of 2, 5-hexanedione in urine at the end of each work shift (the normal value of urine was not over 5 mg/g creatinine).

The minimum mandatory health check-up of workers should be at least once a year, and the check-up should be made within 30 days for new workers or workers who change to risky task.

4.3.2 Responsibility and accountability

4.3.2.1 The management system organization chart for the local exhaust ventilation is shown in figure 4.10.

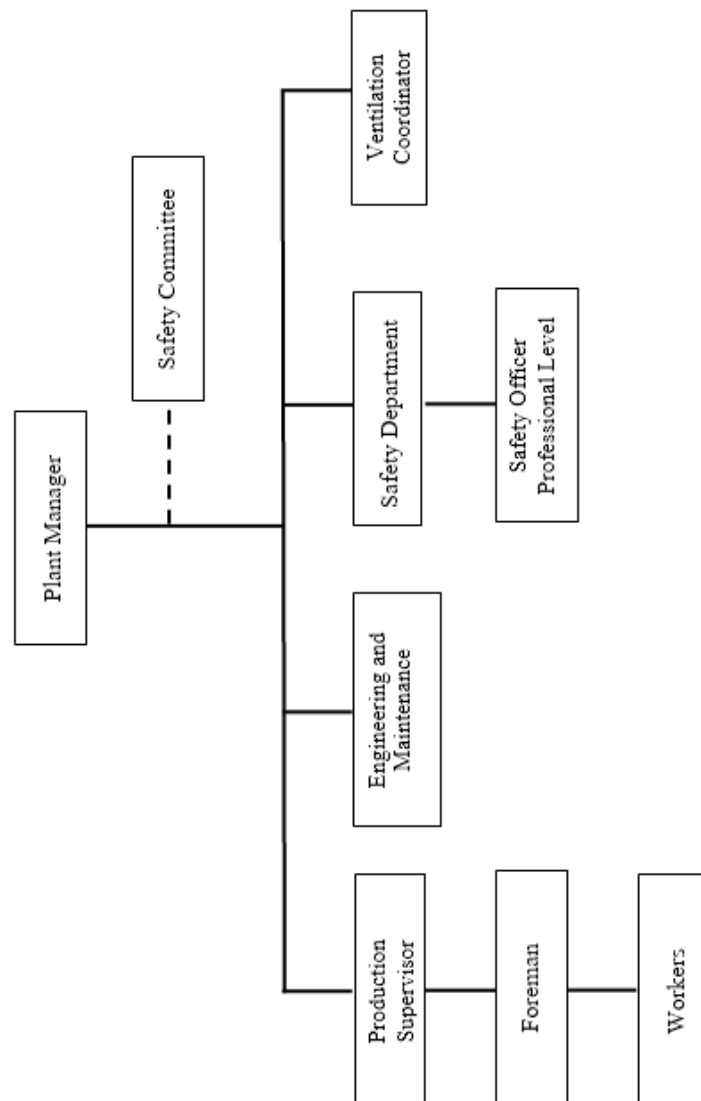


Figure 4.10 Management structure organizational chart.

A. Plant Manager

Qualifications:

1. Safety officer at managerial level.
2. Chairman of the committee of occupational health, safety and work environment

Responsibilities:

1. Supervise the implementation of the management system of the local exhaust ventilation.
2. Promote and support all workers to participate in the implementation of the management system of the local exhaust ventilation.
3. Supervise, monitor and control all levels of the underling safety officers in the workplace.
4. Determine goals and objectives of the management system of the local exhaust ventilation.
5. Allocate budgets for the implementation of management system of the local exhaust ventilation.
6. Review the program for installation and improvement of the local exhaust ventilation of the adhesive coating processes at the production supervisor requested.

B. Committee of occupational safety, health and environment of the local exhaust ventilation

Responsibilities:

1. Participate in review of planning, installing, and improving the local exhaust ventilation of the adhesive coating processes.
2. Report and propose measures or guidelines to improve or modify as required by laws on work safety and safety standards of the local exhaust ventilation.
3. Review regulations and manuals as well as work standards of the local exhaust ventilation system.
4. Monitor the operation of the local exhaust ventilation at least once a month.
5. Review projects or training plans of work safety of the local exhaust ventilation system.

6. When supervisor identify anomalies of the local exhaust ventilation, participated in prevention and solution.

7. Monitor the measuring results of chemicals concentration in the working atmosphere of the adhesive coating processes. It should not exceed the threshold requirements.

8. Monitor the health check-up of workers in the adhesive coating processes.

9. Monitor the implementation for improvement of the local exhaust ventilation system if an abnormality was found.

10. Monitor the measuring results of capability of the local exhaust ventilation system, for instance;

-capture velocity is 1 m/s.

-duct velocity is 5 m/s.

C. Production supervisor

Qualifications

1. Safety officer at managerial level.
2. He / she has an education background at least bachelor degree or higher in engineering or science or equivalent.
3. He / she have work experience with production processes at least 10 years.

Responsibilities:

1. Supervise, and direct the underling safety officers in supervising level.
2. Propose installation and improvement planning for local exhaust ventilation of the adhesive coating processes to the plant manager.
3. Promote, support and follow-up the training plan, inspection plan, maintenance plan and health check-up plan for workers.
4. Supervise, direct and follow-up to correct the defectiveness of the local exhaust ventilation according to the report or upon the recommendation of supervisors, ventilation coordinator, safety officers, and safety committee.
5. Report the defect of local exhaust ventilation to the plant manager.

D. Foreman

Qualifications:

1. The safety officer in supervisory level.
2. He / she earned at least high school diploma.
3. He / she have worked in the adhesive coating processes for at least five years.

Responsibilities:

1 Inspect the conditions of local exhaust ventilation before starting daily operations, including;

1.1 Inspect the conditions of the local exhaust ventilation i.e. hoods and ducts to be ready to use without damaged, broken, collapsed or bended.

1.2 Inspect all wall fans to ensure that they are function.

1.3 Inspect all doors of the adhesive coating room to ensure that they are tightly shut during the process of coating.

1.4 Inspect the difference pressure of the adhesive coating room. It should be negative during the process of coating, which is between 14 – 18 Pascal.

1.5 Inspect all chemical containers to ensure that the lids are tightly sealed.

1.6 Inspect all the LEL meters to ensure their function normally and do not have any modification.

1.7 Inspect dampers to ensure that they are always at the highest level.

1.8 Inspect the LEL detector to ensure that it run normally by observing the LED at the control panel of the LEL gauge that it should be at the normal state. The meaning of each LED color is as follows;

Green LED means normal operation.

Red LED means sensors detect the chemical vapors above the set point. The operator must shut down the machines.

Yellow LED means the sensor fail. The reading is lower than 6% LEL.

Blue LED means the system fail. The system is not able to draw chemical vapors and the sensor fails.

Blue LED means the system fails – no vapor is drawing to the sensor and the sensor fails.

2. Chemical protective masks should be provided for workers to wear at the entire work shift when measuring results of chemicals concentration in the atmosphere exceed 50% of the acceptable levels.

3. Provide health check-up for workers based on risk factors once a year.

4. Calibrate sensors of LEL gauges of the adhesive coating machine every six months.

5. If irregularities are found in the local exhaust ventilation, the foreman should report to the ventilation coordinator and notify the safety officer at professional level to report to the safety department immediately.

6. Investigate the cause of malfunction of the local exhaust ventilation together with the safety officer at professional level and the ventilation coordinator. Then, report and recommend guidelines on solutions to the production supervisor.

7. Notify the results of medical examinations to workers as required by regulation.

7.1 If result show disorders, must inform the worker within three days after receiving the result of medical examination.

7.2 If result show normal, must inform the worker within seven days after receiving the result of medical examination.

E. Adhesive coating workers

Qualifications:

1. There is no illness of respiratory system or diseases associated with the central nervous system.

2. Age 20 years or over.

3. High school diploma or equivalent.

Responsibilities:

1. All workers must report unsafe working conditions when the local exhaust ventilation does not function or when there are abnormalities, such as irregular loud noise or strong chemicals odor, and so forth.

2. All workers must not modify LEL gauge system to disable the normal function.

3. If there is any suggestion pertaining to the local exhaust ventilation, it should be proposed to the foreman.

4. All workers must wear personal protective device provided by the foreman.

5. The worker must be trained as required on these subjects, including; safety work with hazardous chemicals, the use of ventilation system properly, safety work with machinery, training on work manual pertaining to ventilation system, and the use of personal protective device.

6. If there are any of these health symptoms for instance headache, numbness, dizziness, vertigo, numbness and weakness of limbs, the workers must notify a supervisor immediately.

F. Engineering and maintenance technician

Qualifications:

1. Has high vocational certificate in engineering technique.
2. Has work experience on ventilation system maintenance for at least two years.
3. Passed the tests and trainings under the requirements of the organization.

Responsibilities:

1. Maintain, repair, and inspect local exhaust ventilation system including the preparation of reports to the ventilation coordinator as specified in table 4.25.
2. Measure the capability of local exhaust ventilation system as specified including the preparation of reports to the ventilation coordinator as specified in table 4.24.
3. Must be trained on using the local exhaust ventilation system properly and inspection of local exhaust ventilation system as well as local exhaust ventilation system maintenance.
4. Direct, control, and supervise the contractors.

G. Ventilation Coordinator

Qualifications:

1. Has at least bachelor degree in mechanical engineering or electric engineering.
2. Has work experience in maintenance of ventilation systems for at least five years.
3. Passed the tests and trainings according to the requirements of the organization.

Responsibilities:

1. Develop the instruction manuals of the local exhaust ventilation and update the manuals regularly.
2. Develop and coordinate to prepare the inventory of the local exhaust ventilation.
3. Design or supervise the design in the case of existing ventilation system needed to be improved or new ventilation system needed to be installed to meet the standard of minimum capture velocity is 1 m/s and minimum duct velocity is 5 m/s
4. Assess the risks and identify the dangers associated with the local exhaust ventilation by working together with the safety officer at professional level and the foreman.
5. Supervise and direct the maintenance program or maintained the local exhaust ventilation system.
6. Train the workers to use the ventilation systems properly as well as the inspection and maintenance of ventilation system.
7. When malfunction of the local exhaust ventilation is found, investigate the cause by working together with the safety officer at professional level and the foreman.

H. Occupational Safety, Health and Environment Department

Responsibilities:

1. Prepare manuals and safety standards pertaining to the local exhaust ventilation system.
2. Promote, support educational activities and the implementation of the local exhaust ventilation system.
3. Basic knowledge training and regulations on work safety with the local exhaust ventilation system are given to the new workers first, as well as the workers whose new job duties are different from the previous one, and may be risky.
4. Appoint auditors for system management on the local exhaust ventilation system.
5. Monitor the performance of the system management on the local exhaust ventilation system and prepare monthly report to the plant manager and committee.

I. The safety officer at professional level

Responsibilities:

1. Investigate and recommend the employer to comply with the laws pertaining to the local exhaust ventilation system as well as analyze the local exhaust ventilation system to identify the hazard including specify the preventive measures or work safety procedures.
2. Supervise the workers to wear the half face piece respirator with organic vapor cartridge if the concentration of chemicals in the atmosphere exceeds the “action level,” or when additive mixture calculation is greater than 1.
3. Conduct fit test to the workers for those who need to wear gas mask.
4. Measure the chemicals concentration in the work atmosphere every six months and evaluate work environment and report the results to the production supervisor as soon as the results are revealed.
5. Collaborate with the foreman and the ventilation coordinator to investigate the cause of local exhaust ventilation system that is not able to function, and analyze the accidents, illnesses or troubles and annoyance due to the work and report the results.

6. Gather statistics data, analyze, report and make a recommendation on the local exhaust ventilation system.

7. Training given on the subjects of work safety with hazardous chemicals, occupational health, safety and work environment, work safety with machinery operation, and the use of personal protection equipment (PPE) to workers.

4.3.2.1 Reporting system of the local exhaust ventilation troubleshoot

If the worker finds an abnormality of the local exhaust ventilation: In the event that workers found an abnormality of the local exhaust ventilation system;

1. The workers report an abnormality to the foreman.
2. The foreman notify the abnormality and problems to the ventilation coordinator and the safety officer at professional level as well as the safety department and working together to analyze the causes.
3. In case of repair or modification of the local exhaust ventilation system, the ventilation coordinator must notify the engineering and maintenance department to repair or to modify the local exhaust ventilation system to come back to normal.
4. The foreman must notify anomalies and solution guidelines to the production supervisor. The production supervisor is then notified the plant manager.
5. The foreman must announce to the safety committee meeting in order to determine the preventive measures.

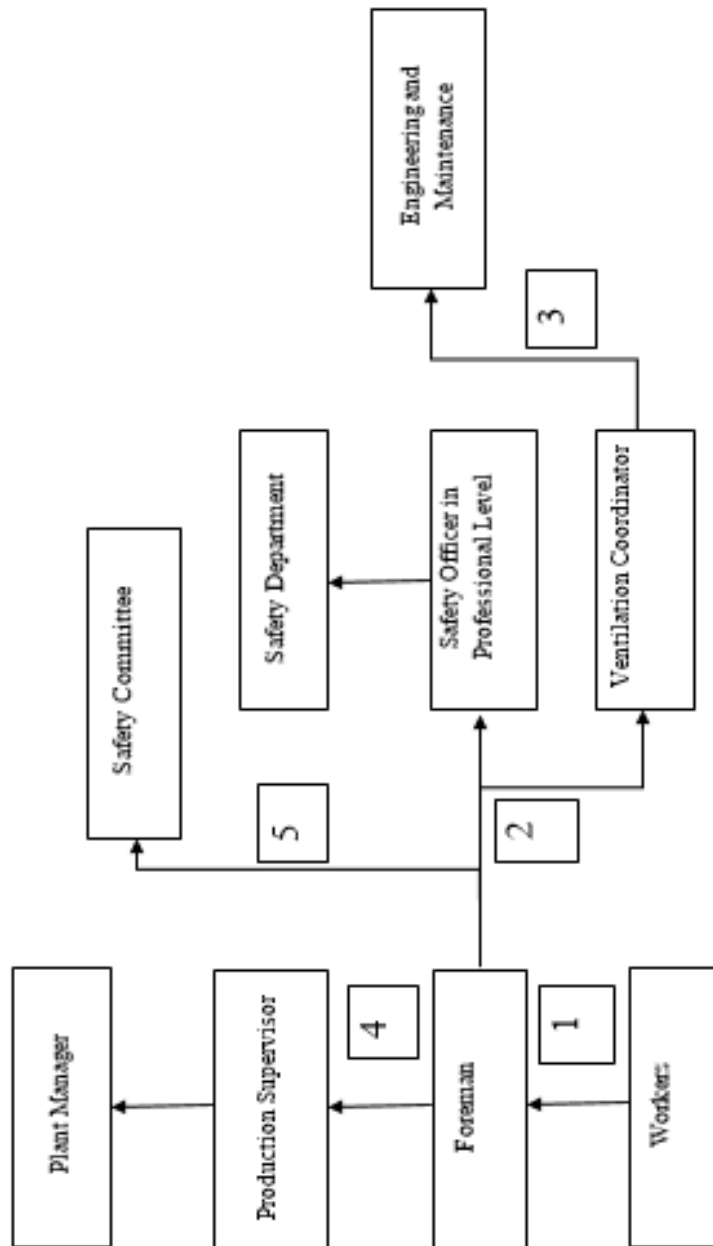


Figure 4.11 Reporting system of organizational flow

4.3.3 Action plans

To ensure that the ventilation system of the adhesive coating processes conform to the standards, the action plans are purposed to the organization to implement, as shown in table 4.23 to 4.25.

Table 4.17 Training plans

No.	Activity	Training period	Responsible person	Participant	Frequency
1	Work safely on hazardous chemicals	2 hrs.	Safety officer in professional level	All workers	1 time/year
2	Standard application of the ventilation system	3 hrs.	Ventilation coordinator	All workers and maintenance technicians	1 time/year
3	Inspection and maintenance of ventilation system	3 hrs.	Ventilation coordinator	Maintenance technicians	1 time/year
4	Occupational Safety, Health and work environment	6 hrs.	Safety officer in professional level	New workers	
5	Safety in working with machinery	1 hr.	Safety officer in professional level	All workers	1 time/year
6	Training on using of ventilation systems manuals	3 hrs.	Foreman	All workers	1 time/year
7	Application of personal protection equipment (PPE)	1 hr.	Safety officer in professional level	All workers	1 time/year

Table 4.18 Inspection plans

No.	Activity	Responsible person	Frequency
1	Hood - Hood front velocity - Pollutant capture velocity - Hood static pressure	Maintenance Technicians and Ventilation Coordinator	Every 3 months
2	Ducts - Duct velocity - Duct static pressure	Maintenance Technicians and Ventilation Coordinator	Every 3 months
3	Fans - Static pressure - Rotation	Maintenance Technicians and Ventilation Coordinator	Every 3 months
4	Stacks - Air velocity in stack	Maintenance Technicians and Ventilation Coordinator	Every 3 months
5	Wall fans - Fan air velocity	Maintenance Technicians and Ventilation Coordinator	Every 3 months
6	Investigation of air quality monitoring data	The safety officer in professional level	Every 6 months

Table 4.19 Maintenance plans

No.	Activity	Responsible person	Frequency
1	Inspection for damage or defective such as collapsed ducts, broken fans	Maintenance Technicians	1 time/week
2	Cleaning of wall fans	Maintenance Technicians	2 times/month
3	Inspection of motor grease and bearing	Maintenance Technicians	Every 3 months
4	Inspection of motor belt tension	Maintenance Technicians	Every 3 months
5	Inspection of the insulation of motor coil winding	Maintenance Technicians	Every 3 months
6	Inspection of switches of fans	Maintenance Technicians	1 time/month
7	Cleaning of fresh air filters	Maintenance Technicians	1 time/month
8	Inspection of dampers for regular functions	Maintenance Technicians	2 times/month
9	Inspection for leakage of the local exhaust ventilation with soap water	Maintenance Technicians	Every 3 months
10	Inspection of the oven door lid and oven seal	Maintenance Technicians	1 time/month
11	Inspection of LEL meters	Maintenance Technicians	2 times/month
12	Inspection of fabric belt conveyor	Maintenance Technicians	Every 3 months

4.3.4 Audits

The organization must be prepared to audit periodically to observe to that the systems and components of the management system is adequate and effective in protecting the safety and health of workers to prevent occupational diseases, by taking the action as follows;

1. The committee of occupational safety, health and work environment appoint auditors of the management system for the local exhaust ventilation system of the adhesive coating processes, including;

- 1.1 External experts

- 1.2 Corporate safety and industrial hygiene officer

2. The auditor must examine the system every six months and report audit results to the plant manager to acknowledge by reporting only the defects that are found.

3. The auditor must notify the date, time and audit issues to inspection agency before conducting an investigation.

4. The auditor must evaluate various components of the management system of the local exhaust ventilation system, as follows;

- 4.1 Inspection records.

- 4.2 Training records.

- 4.3 Maintenance records

- 4.4 Inspect and monitor the working conditions.

- 4.5 Interview with relevant workers.

5. The corrective action request and the preventive action request (CAR / PAR).

The auditor must review audited data and evidences to verify actual situations. In the event that the practice does not complying with regulatory required for the various components of the local exhaust ventilation system in the adhesive coating processes, the auditor must issue a request for the corrective action requests and preventive action requests (CAR/PAR).

6. The auditor must conclude the audit results that the various components of the system meet the requirements of the local exhaust ventilation system in the adhesive coating processes.

7. The auditor must report the audit results to the plant manager.

8. If defects are found, the auditor must propose the solution guidelines to foreman to be reviewed and obtained approval from the plant manager including designate a responsible person as well as the date and completion time.

9. The plant manager announce audit results to the management review meeting to review the system management of the local exhaust ventilation system in the adhesive coating processes.

4.3.5 Management review of the occupational safety and health system

1) The management must arrange the meeting with the occupational health, safety and work environment committee every six months.

2) The chairman may invite the other people involved to attend the meeting as appropriate.

3. Preparation for meeting.

4. The agenda for the meeting, including;

- Agenda 1: The chairman announce issues to the meeting.

- Agenda 2: The chairman approve the previous meeting.

- Agenda 3: Bring the issues on the management system of the local exhaust ventilation system to be discussed on the meeting, as follows;

4.1. Review that the management system of the local exhaust ventilation system meet the objectives of operations as planned or not.

4.2. Assess whether the management system of the local exhaust ventilation system meet overall requirements of the organization, workers and complied with the relevant laws or not.

4.3. Assess the necessity to change the management system of the local exhaust ventilation system.

4.4 Assess the audit results on the implementation and measuring results of the performance.

4.5. Provide the necessary measures to correct the defects early enough.

4.6. Provide a channel for reflecting feedbacks, including priority for useful planning and continuity improving.

4.7. Evaluate the progress of the management system of the local exhaust ventilation system and the progress of activities in correcting the defects.

4.8. Evaluate the effectiveness of the pursuit in resulting reviews of previous management.

4.9. Complaints and recommendations for improvements.

- Agenda 4: Other related issues.

5. Notification of the agenda must be made to the participants at least 3 days in advance.

6. The meeting must be proceeding along the agenda by the chairman. The chairman assigns a person to inform or to provide documents and information to the participants in order to be recognized or discussed. If there is a consensus to take action, it is necessary to define date and completion time along with the responsible persons and persons who follow-up the implementation results.

7. The meeting record of the must be documented, and a copy submitted to each participant and those involve within one week. The original meeting record must be stored at the administration department for at least three years.

8. Follow-up the meeting if it is urgent. If it is not, the implementation follow-up should be conducted in the next meeting.

CHAPTER V

DISCUSSION

The results of the study on the guidelines for the local exhaust ventilation management of coating processes in the existing medicated manufacturing, which included the cross-sectional study as well as document research, can be summarized as follows.

5.1 The existing ventilation system in the adhesive coating room

The study was done at the existing ventilation system in the coating room included the general exhaust ventilation system in combination with the local exhaust ventilation.

5.1.1 The general exhaust ventilation system

It is a mechanical ventilation by means of the wall fans to diluted pollutant residues inside the coating room. By calculating ventilation capacity of the wall fans, The total supply air flow rate of the wall fan (supply airflow rate) was 26.43 m³/s and the total exhaust air flow rate of the wall fans (exhaust airflow rate) was 30.93 m³/s.

5.1.2 Local exhaust ventilation

The coating machine CT-3, CT-4 and CT-5 were installed with the local exhaust ventilation around the adhesive coating head near the work station. The hood was attached to the existing system of coating machine CT-3, CT-4 and CT-5 by using the existing blower of the coating machine. The capture velocities of the hood front were measured as followed; CT-3 was 0.24 m/s, CT-4 was 0.31 m/s and CT-5 was 0.16 m/s. These were below the recommendation of the ACGIH in all of the three machines. It requires the capture velocity not less than 1 m/s (21). The study also found that the duct velocities from B to K of each coating machine complied with the

recommendation of the ACGIH. This requires the duct velocity not less than 5 m/s (21). There was only the measurement of point K below the recommendation of the ACGIH. The duct velocities measurement values at point K of CT-3, CT-4 and CT-5 were 2.87 m/s, 3.13 m/s and 3.02 m/s respectively. This finding consistent with the study of Saowapa Petsungkart (30). It was actually found that the ventilation systems with the capture velocity of respirable dust was less than the recommendation of the ACGIH. This was also in accordance with the study of Srirattana Vanichadisak (33). That was, the capture velocity of dust particles resulting from the manufacturing processes in front of the air channel and the air duct velocity was lower than the recommendation of ACGIH.

Regarding the health problems of workers in the coating room, the capture velocity of pollutants at the hood front and the duct velocity were lower than the recommendation of the ACGIH. This corresponds with the study by Wilai Hengwiwattanachai (34). That was the reason why the workers in the coating processes (adhesive spray and adhesive rubbing) in the facilities of the automotive parts production had health problems including dizziness, headache, respiratory irritation, and nausea due to the concentrations of volatile organic compounds of xylene, toluene, and methyl iso-butyl ketone that were below the threshold specified by laws and OSHA standards. In fact, when inspection of the local exhaust ventilation in the adhesive spray and adhesive rubbing areas was conducted, it was found that all ventilation systems of the processes did not meet with the recommendation of ACGIH.

With reference to the principle of equal volumetric flow of air in the duct at all points (17), it was actually found that the volumetric flow rate in ducts of the coating machines were not equal in which all the branch ducts combined their air velocities flow rate did not equal to the main duct. This indicated as the phenomenon of air leakage from the adhesive coating oven to the coating room. This results in dispersion of the chemicals in the workplace.

The supply air flow rate into the adhesive coating processes was 26.43 m³/s. The total exhaust air flow rate from the adhesive coating processes was 42.14 m³/s. When combined ventilation rate from the general exhaust ventilation systems and the local exhaust ventilation, therefore, the exhaust air flow rate was 15.71 m³/s more than the supply air flow rate into the system which led to the coating room

pressure was negative all the time. In fact, the concentrations of chemicals in the environment was still higher than the recommendation of ACGIH. Moreover, most of chemicals dropped on to the floor and when the time pass it will be accumulated on the floor. This air mass cannot be released to the external environment.

When verified that the direction of the wall fans was improper and caused pollutants to accumulate in the coating room. In addition, the wall fans were not efficient enough since there was no air circulation in the middle area of the coating room. As a result, the air did not flow as desired. The capture velocity and duct velocity in certain duct points of the coating machine did not meet with the recommendation of the ACGIH.

Air leakage might came out of the coating oven. By calculating based on the principle of equal volumetric flow rate of the air in the duct at all points (17),it was found that the chemicals were also released into the external atmosphere as well. This finding may cause the concentration of chemicals in the workplace exceeded the recommendation of the ACGIH based on the additive mixture calculation.

5.2 The results of chemicals concentrations measurement in workplace at the adhesive coating process

Based on the study results on the concentration of chemicals in the working atmosphere in the adhesive coating process dated back for the past 3 years since 2012 – 2014 AD., it was found that if the concentration limits of each chemical substance in the atmosphere was not exceed the recommendation of the ACGIH. These chemicals consist of cyclohexane, heptane, methyl cyclohexane and n-hexane.

The observed data were previously not analyzed by using mixture additive effect to calculate the sum of toxicity to organs altogether. When calculated by using this formula, the results of this calculation mostly were greater than one. It indicated that the thresholds were violated, according to the recommendation of the ACGIH (8). This fact was consistent with complaints of workers on occupational health issues e.g. headaches, dizziness, numbness at limbs and irritation of eyes. These were symptoms of the central nervous system that were consistent with the study of Pitsamai Chantaramai (31) who found that the concentration of IPA in the air was much above

the thresholds. The concentration made workers to experience dizziness, eyes and neck irritation. This was also confirmed by the study of Kritsana Suphachitranon (32) on measurements of the amount of vapors of kerosene in the operational areas during the past three years. It was found that the concentration was higher than the NIOSH standards (100 mg/m^3). It was then reasonably anticipated to adverse health effects.

5.3 Guidelines for the management of local exhaust ventilation system of the adhesive coating process

Since ventilation of the coating processes was not efficient, concentration of chemicals in the workplace exceeded the recommendation of the ACGIH. The organization must review guidelines on the management system of the local exhaust ventilation system in order that pollutants does not exceed the recommendation of the ACGIH (TLV-TWA). These practices can be conducted by restricting the concentration of organic vapors in the work environment to less than 10% of the lower explosive limit (LEL). Therefore, the preparation of guidelines for the management of local exhaust ventilation were taken into consideration by integrated into the management system of occupational safety and health. This approach was consistent with the study of Nuttawat Montewan(23) stated that the operational safety was systematic and continuous by enhancing safety into the production processes. There were incentives for workers to participate in safety activities. Workers performed safety under legal requirements while employers or the top management was a key factor to the resulting success in safety. These movements influence operations and indicate the activities and their adequateness.

In this regard, the organization should provide the followings:

- 1. Determine the standards:** This shall be conducted based on the analysis of the problems encountered regarding the concentration of chemicals in the workplace that violate the recommendation of the ACGIH. In addition, the ventilation system was actually inefficient since the organization has not set a clear standard. Therefore, the organization should implement guidelines as follows:

1.1 Determination of the standard concentration limits of the chemicals in the workplace atmosphere.

1.2 Determination of the lower explosive limit (LEL).

1.3 Determination of the indicator of the concentration limits of chemical mixture in the 8-hour workplace not to exceed 1.

1.4 Proposed qualifications of the training instructors.

1.5 Determination of capture velocity and duct velocity for the local exhaust ventilation in the adhesive coating processes.

1.6 Schedule health checkup for employees.

2. Determination of responsibility and accountability: It was found that the organization had defined responsibilities that were inconsistent with the management system of occupational safety and health. Responsibilities were merely determined for basic set of functions only. This led to the management system of the local exhaust ventilation that was inefficient and contrast to the study of Sumitra Chanapa (36) which confirmed that factors affecting the efficient preparation of the management system of occupational safety, health and work environment was the knowledgeable and ability of person who act as a representative for management system.

By reviewing the overview, the organization has to establish responsibilities and accountabilities to ensure compliance with the management system of occupational safety, health and work environment based on the Ministerial Regulation on the Prescribing of Standard for Administration and Management of Occupational Safety, Health and Work Environment B.E. 2549 (A.D.2006) (25). In fact, the organization in question had already implemented but it never integrated the responsibilities and accountabilities into the management system of the local exhaust ventilation in the coating processes.

3. Determination of action plans: Currently the action plans were purposed to the organization to implement. There was only an overview plan of the organization but each action plan was not clearly defined including lack of definite timing and responsible persons. To ensure that the ventilation system of the adhesive coating process conforms to the standards, therefore, the action plans should be purposed, as follow;

3.1 Training plans

3.2 Inspection plans

3.3 Maintenance plans

These plans were consistent with the study of Nor Halim Hasan et al (35). They found that the continual monitoring, maintenance and effectiveness of personal protective equipment were substantial in prevention of exposure of workers to hazardous chemicals.

4. Auditing: It was found that the organization had a management system for occupational safety and health, which was not yet complete. The safety audit was conducted but the only auditors from the plant manager and the safety officer in professional level. When a defect was found, the safety officer in professional level notified to the person concerned to make a change. The actual safety audit was only monitoring of work areas without auditing of the various elements of the management system of the local exhaust ventilation. Therefore, problems were not discovered and the errors were not rectified. In order to adhere to management system guidelines, the organization should appoint the auditors who were not a beneficiary. The auditors should evaluate the various elements of the management system of the local exhaust ventilation. When non-conformance was discovered, the request form to perform corrective action and preventive action (CAR/PAR) should be issued. In addition, the audited sector should propose resolution of the non-conformance to the foreman to review and to obtain the approval of the plant manager. The responsible person and completion time and date should be specified as well. This is consistent with the study of Umarat Sirijaroonwong (37). found that i) the inadequate awareness and experience on occupational safety and health, ii) inadequate technical assessment of the auditors, iii) the incompleteness of the audit and iv) the inadequate management based on the specified criteria affected effectiveness of the internal audits. These led to the uneven results of performances in activities of occupational safety and health.

5. Management review of occupational safety and health: It was found that the organization had not included the local exhaust ventilation with the management system of occupational safety and health. Therefore, the organization had never reviewed the management system of the occupational safety and health. The

organization only reported about problems during the meeting of the safety committee. Therefore, the author suggests that the management review of top managements should be conducted. This was inconsistent with the study of Jindaphloy Tangjai(38). It found that i) the top management had to understand safety tasks, ii) have to be responsible, iii) had leadership in safety tasks, iv)clarify their intention and commitment to support the safety tasks seriously. These actions guided everyone in the respective organization to follow and to stimulate cooperation of workers at all levels without an excessive burden to a single sector. This should also achieve in the safety policy according to the objectives that consistent with the study of Nuttawat Montewan (23) in which the top management was a key person of the organization to create an atmosphere of cooperation and operational collaboration, to had good communication in order to formulate the teamwork spirits; everyone in the organization had the shared norms of values, inspiration, goal and expectations together. In addition, there were incentives for workers to participate in safety activities.

CHAPTER VI

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

6.1.1 The existing local exhaust ventilation of the coating processes

The ventilation system in the existing coating room combined the general exhaust ventilation system with the local exhaust ventilation.

6.1.1.1 General exhaust ventilation system

The total supply air flowrate of wall fans (supply airflow rate) was 26.43 m³/s. The total exhaust air flow rate of the wall fans (exhaust airflow rate) was 30.93 m³/s. Therefore, the total exhaust air flow rate was larger than the total supply air flow rate into the system 4.5 m³/s which led to static pressures of coating room was negative all the time.

6.1.2.2 Local exhaust ventilation system

The capture velocities of the hood front of the coating machines CT-3, CT-4 and CT-5 were 0.24 m/s, 0.31 m/s and 0.16 m/s, respectively. These were below the recommendation of the ACGIH in all of the three machines. It requires the capture velocity not less than 1 m/s.

The study also found that the duct velocities from B to K of each coating machine complied with the recommendation of the ACGIH. This requires the duct velocity not less than 5 m/s (21). There was only the measurement of point K below the recommendation of the ACGIH. The duct velocities measurement values at point K of CT-3, CT-4 and CT-5 were 2.87 m/s, 3.13 m/s and 3.02 m/s respectively. The volumetric flow rates in ducts of the coating machine CT-3, CT4 and CT-5 were unequal. The branch duct flow rates were summed and became unequal with the flow rate of the main duct. This finding indicated that the air might leak from the adhesive coating oven to the adhesive coating room caused the dispersion of chemicals into the workplace atmosphere.

6.1.3.3 Ventilation system of the coating processes

The supply air flow rate into the adhesive coating process was 26.43 m³/s. The total exhaust air flow rate from the adhesive coating processes was 42.14 m³/s when combined ventilation rate from the general exhaust ventilation systems and the local exhaust ventilation. Therefore, the exhaust air flow rate was 15.71 m³/s more than the supply air flow rate into the system which led to the coating room pressure was negative all the time.

When the effective ventilation rate for the adhesive coating room was calculated, it was obvious that the required ventilation rate was 11.28 m³/s, which was below the existing ventilation rate. If the existing ventilation was actually efficient, the concentration of chemicals in the environment should be below the recommendation of the ACGIH. In fact, the study conducted observation on concentrations of chemicals in the atmosphere which consisted of cyclohexane, heptane, methyl cyclohexane and n-hexane during 2012 to 2014. When the additive mixture calculation was calculated, it was found that the values in the range between 0.9 and 1.28, which actually had impact on the health of workers seriously.

6.1.2 Management of the existing local exhaust ventilation

The organization had no concrete guidelines on management of the local exhaust ventilation system. There were no documents standard, no responsibilities and accountabilities in accordance with the structure of the organization, no work plans, no monitoring and no operation of the management system review of occupational safety and health. Thus, this study proposed guidelines for management of the local exhaust ventilation in the coating processes to ensure the implementation of the effective local exhaust ventilation system the organization should provide the followings: standardization, designation of responsibilities and accountabilities according to the structure of the organization, determination of operation plans, auditing plans and conducting of management review of the management system of occupational safety and health as led by the top managements.

6.2 Recommendation

6.2.1 Recommendation from the findings of this study

6.2.1.1 The organization should apply the management system of occupational safety and health to all sectors of the organization by setting action plans. Every activity and every sector should be integrated into the management system of occupational safety and health.

6.2.1.2 The top managements are the most critical. They should seriously give priority to any activity of the occupational safety and health by supporting and monitoring the implementation, by taking lead in safety, by committing clear intention to actualize the philosophy of “safety comes first”.

6.2.1.3 Every worker in the organization should seriously adhere to the management systems approach of occupational safety and health of the organization seriously, and should fully perform their duties fully under assigned responsibilities.

6.2.2 Recommendation for the further study

6.2.2.1 Further studies should include design a new design of local exhaust ventilation of the coating room to enhance the effective ventilation rate from the coating process successfully.

6.2.2.2 Further study should study more about safety management as a whole the organization, including all aspect of the process.

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APPENDICES

APPENDIX A

METERIAL AND EQUIPMENT IN THIS STUDY



Figure A-1 FLUKE® Airflow Meter pressure gauge



Figure A-2 Kanomax Anemomaster Standard Model 6035
Multi-function thermal anemometer

APPENDIX B
THE AVERAGE OBSERVED AIR VELOCITY
OF COATING MACHINE

Table B-1 The average observed air velocity of coating machine CT-3

Point	Type of velocity	V1	V2	V3	V4	V5	V6	Average velocity (m/s)
A	capture velocity	0.19	0.27	0.29	0.25	0.21	0.23	0.24
B	Duct	7.87	8.97	9.24	9.17	8.14	8.89	8.71
C	Duct	5.93	6.11	6.27	6.34	5.87	5.42	5.99
D	Duct	5.98	5.32	6.13	6.04	5.86	5.98	5.89
E	Duct	6.76	6.34	7.42	7.43	6.76	6.65	6.89
F	Duct	9.76	10.27	10.51	10.46	10.09	9.95	10.17
G	Duct	5.01	4.94	5.64	5.32	5.21	5.08	5.20
H	Duct	6.76	6.88	7.23	7.44	7.18	6.84	7.06
I	Duct	7.88	7.53	8.11	7.98	7.65	6.89	7.67
J	Duct	5.34	5.69	5.32	5.44	5.49	5.22	5.42
K	Duct	2.11	3.09	3.11	3.26	3.21	2.46	2.87

Table B-2 The average observed air velocity of coating machine CT-4

Point	Type of velocity	V1	V2	V3	V4	V5	V6	Average velocity (m/s)
A	capture velocity	0.3	0.28	0.4	0.33	0.26	0.29	0.31
B	Duct	11.41	11.39	11.98	11.22	11.68	10.43	11.35
C	Duct	6.77	7.45	7.78	7.43	7.52	6.62	7.26
D	Duct	6.55	6.67	6.98	6.34	6.79	6.85	6.70
E	Duct	5.98	6.43	6.58	6.75	6.45	6.53	6.45
F	Duct	11.03	11.24	11.46	11.35	11.52	10.95	11.26
G	Duct	5.06	5.18	5.23	5.31	5.04	4.96	5.13
H	Duct	6.99	6.96	7.69	7.53	7.04	6.74	7.16
I	Duct	7.93	8.53	9.11	8.97	8.82	8.76	8.69
J	Duct	4.82	5.01	5.1	5.08	4.96	5.03	5.00
K	Duct	2.98	2.84	3.31	3.35	3.23	3.06	3.13

Table B-3 The average observed air velocity of coating machine CT-5

Point	Type of velocity	V1	V2	V3	V4	V5	V6	Average velocity (m/s)
A	capture velocity	0.11	0.13	0.21	0.24	0.15	0.13	0.16
B	Duct	9.05	9.11	9.95	9.21	9.42	9.08	9.30
C	Duct	5.89	6.87	6.79	6.66	6.48	6.03	6.45
D	Duct	5.82	5.96	7.35	7.24	6.83	5.48	6.45
E	Duct	5.21	6.46	7.56	7.76	6.64	6.33	6.66
F	Duct	10.33	10.74	11.13	11.88	10.63	10.76	10.91
G	Duct	5.14	5.11	5.45	5.32	5.23	5.02	5.21
H	Duct	5.93	6.83	6.87	7.21	6.74	5.18	6.46
I	Duct	7.32	7.44	7.67	7.33	6.99	6.85	7.27
J	Duct	5.06	5.14	5.17	5.29	5.23	5.12	5.17
K	Duct	2.87	2.93	3.23	3.15	2.95	2.97	3.02

APPENDIX D
CERTIFICATE OF APPROVAL ETHICAL
TITLE CHANGE



Approval of Amendment
Ethical Review Committee for Human Research
Faculty of Public Health, Mahidol University

Protocol Title : GUILDLINE FOR LOCAL EXHAUST VENTILATION MANAGEMENT OF COATING PROCESS IN MEDICATED MANUFACTURING

Protocol No. : 161/2558

Principal Investigator : Miss Kanokwan Kongsamlee

Type of Document : Protocol Amendment

Protocol Title Change to GUIDELINE FOR LOCAL EXHAUST VENTILATION MANAGEMENT OF COATING PROCESS IN MEDICATED MANUFACTURING

Date of Approval : 31 March 2016

The aforementioned project have been reviewed and approved according to the Declaration of Helsinki by Ethical Review Committee for Human Research, Faculty of Public Health, Mahidol University.

Handwritten signature of S. Nanthamongkolchai.

(Assoc. Prof. Dr. Sutham Nanthamongkolchai)
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