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Experimental Investigation of Local Exhaust Ventilation Effectiveness at Welding Laboratory

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Abstract: The purpose of this research is to measure the LEV critical parameters according to Department of Occupational Safety and Health (DOSH) standard requirements and follow the guidelines as stated in the American Conference of Governmental Industrial Hygienists (ACGIH). According to the guidelines from DOSH, Regulation 17 stipulates that any engineering control equipment must be tested at intervals of no more than one month and must be inspected and tested by a hygiene technician at intervals of no more than twelve months. The experiment is conducted at the welding laboratory, Fakulti Kejuruteraan Mekanikal dan Pembuatan (FKMP), UTHM. The apparatus for conducting the experiment is a tachometer, a pitot tube, and an anemometer. The device is used to determine the velocity pressure, static pressure, total pressure, and speed in evaluating the effectiveness of the LEV system. For welding activities, the measurement value for face velocity and capture velocity on the hood must exceed a minimum range of 100 feet per minute (fpm) in accordance with the criteria of the standards from DOSH and ACGIH. On the ducting part, the minimum range for measuring velocity must be 2000 fpm. Based on the data obtained, the results for face velocity on all hoods are very satisfactory and above the minimum required rate of 100 fpm. However, for capture velocity results, only four out of 14 hoods achieved the minimum required rate of 100 fpm from 8-inch distances. Meanwhile, the results obtained from the hoods at 16 and 24 inches from the worktable did not achieve the minimum level required. For velocity measurements on the ducting section of the LEV system, only one of the nine data measurement points did not reach the minimum required rate of 2000 fpm. The location of the intended point is at point 1, where the results of the data taken are not satisfactory. In conclusion, the efficiency of the LEV system is not satisfactory, following the results for capture velocity and ducting section, which not achieve the standard required. However, this system still works, especially to remove welding fumes.

Keywords: Local Exhaust Ventilation, Welding Laboratory, Hazard Control

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1. Introduction

When it comes to preventing dangerous substance exposure in the workplace, there is a hierarchy of control measures that must be considered, starting with the hazard's eradication or substitution, or, if these alternatives are not viable, the hazard must be controlled using engineering means. One such engineering control measure is local exhaust ventilation (LEV). The most important engineering control for reducing worker exposures to airborne nanoparticles is local exhaust ventilation [1]. The principle of a local exhaust ventilation system is to capture a contaminant at or near the source before it is disseminated into the workroom environment. Contaminants can be in the form of dust, smoke, mist, aerosol, vapour, and gas [2]. LEV systems are designed around four essential features, which are hood, duct system, air cleaner and fan. The efficiency of an LEV system in eliminating contaminants is determined by a few factors, including the system's design, use, and maintenance [3]. The American Conference of Governmental Industrial Hygienists (ACGIH) technique should be used to design the LEV system.

In UTHM, engineering and engineering technology student especially mechanical student must learn and conduct the welding activity during their studies. The student and staff involved were exposed to the hazard generated from the welding process. In previous studies, most studies were conducted on the effectiveness of the LEV system. Among them, the findings of previous studies have proven that the effectiveness of the LEV system can be measured. The findings of the study are very important as a reference for carrying out this research.

The objective of this research is to measure the effectiveness of the LEV system while welding duties are being carried out in UTHM welding laboratory. The measurement of the LEV critical parameters is evaluated according to the DOSH standard requirements which is guidelines on occupational safety and health for design, inspection, testing, and examination of local exhaust ventilation system. Figure 1 illustrates the LEV system in welding laboratory.

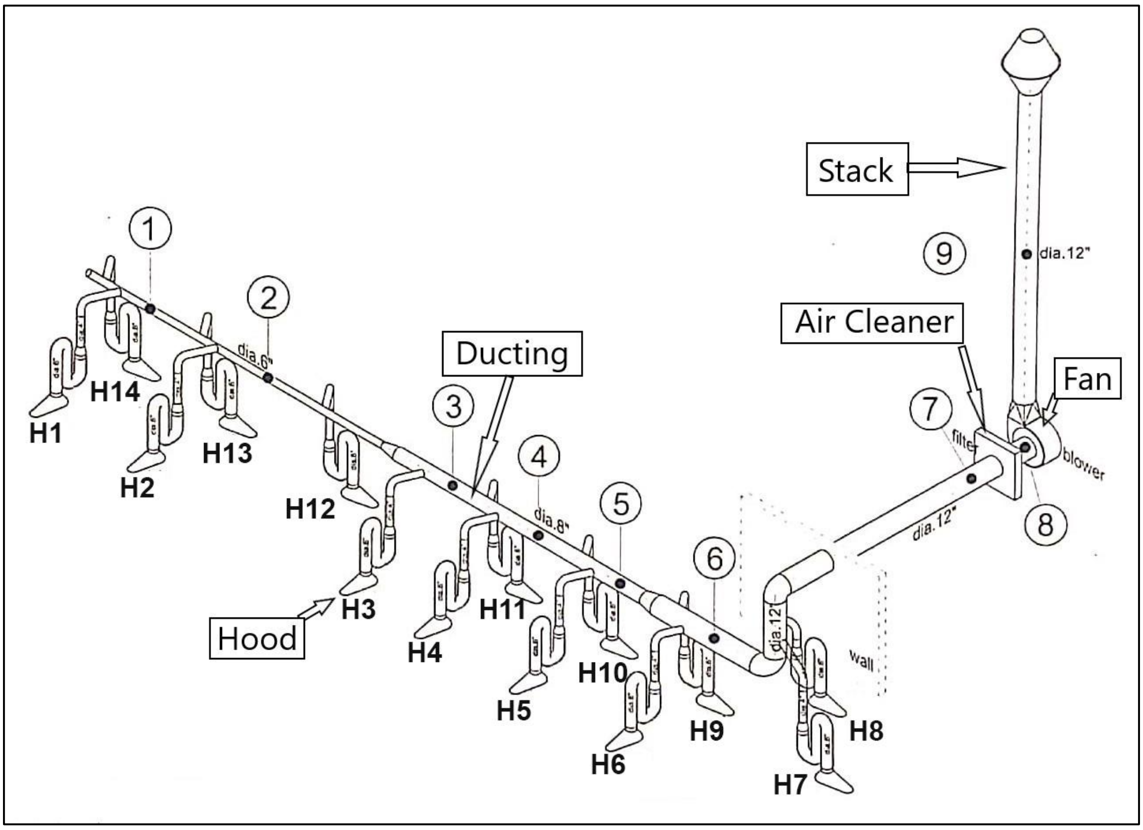

Figure 1: LEV system in welding laboratory, FKMP, UTHM

2. Materials and Methods

2.1 Materials

There are three instrument types used to collect the data critical parameters of the LEV system as follow:

- Anemometer Testo 435-4 Multi-function
- Pitot tube
- SKF laser tachometer TKRT 10

An anemometer is an instrument that measures wind speed and direction. In this experiment, the instrument used to measure the velocity of airflow in the LEV system. It is also used to measure the static pressure and velocity pressure in the ducting section of the LEV system.

A pitot tube is used to monitor the airflow in pipes, ducts, and stacks. It is connected to an anemometer by a hose. The type of pitot tube used for this experiment is pitot tube type L with an ellipsoidal head. The body of the device is made of stainless steel.

A tachometer is an instrument that measures the rotation speed of a shaft in a motor. The instrument used is a SKF digital tachometer. The rotational speed range of contact measurement is 2 to 20 000 round per minute with accuracy ±1% of reading.

2.2 Methods

The flowchart is very important as a diagram that shows how a workflow or process works. Figure 2 shows the study flow chart for completing this study.

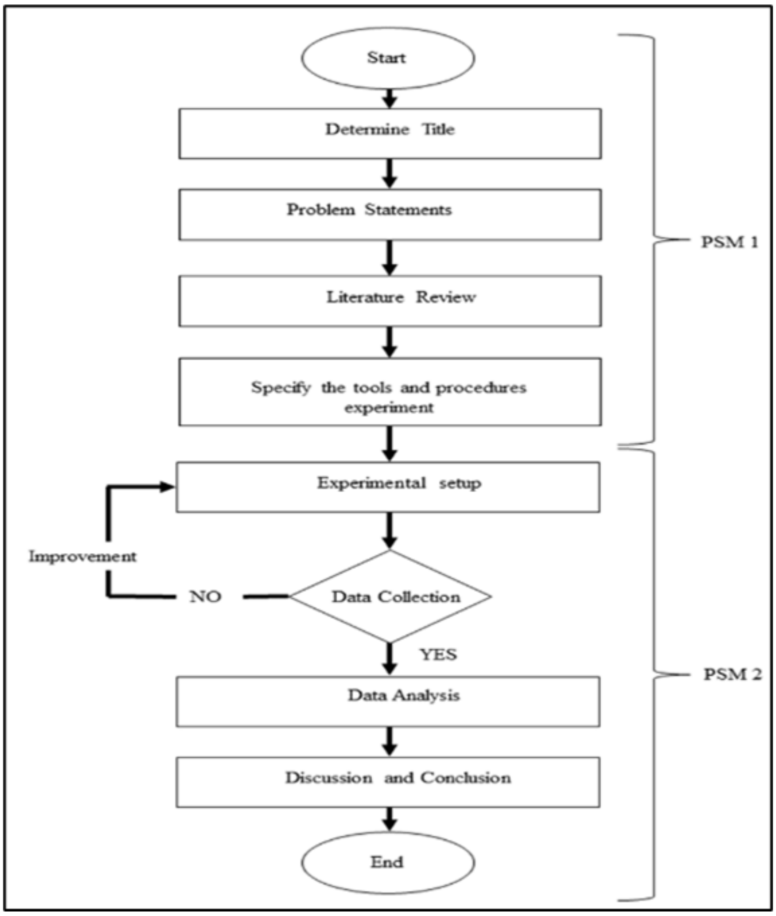

Figure 2: Process flowchart for this study

PSM 1 is the beginning of a study where it is determined what studies will be done. Meanwhile at PSM 2, experiments are conducted in the welding laboratory. The data results were analysed and included in the project report. The LEV system's performance was compared to DOSH standard requirements, which are occupational safety and health guidelines for the design, inspection, testing, and examination of local exhaust ventilation system. An analysis of the system was made based on the DOSH standard.

To carry out this experiment, several procedures have been established. Among them, a visual inspection should be done before any performance measurement of the LEV system. This step is important to analyse the overall state of the system. Any abnormalities, such as dented ducts, corrosion, abrasion, loose connections, or the general condition of fans and motors, which have the potential to reduce system performance, must be noted, and highlighted in the evaluation report.

For the implementation of the experiment, equipment such as an anemometer, a pitot tube, and a tachometer has been prepared to carry out this study. The experimental process for determining face velocity and capture velocity is measured by using anemometer equipment with a probe. This process is carried out on every hood in the LEV system.

Meanwhile, the experimental process for ducting velocity is measured using anemometer equipment connected to a pitot tube. This process is carried out to obtain the velocity in the ducting section of the LEV system. A tachometer is used to get readings for motor speed on the LEV system.

2.3 Equations

The following formula was used to determine the critical parameters in the LEV system. Equation 1 is used to convert velocity pressure to velocity. Equation 2 to determine the static pressure at the fan section. Equation 3 is used to determine the total fan pressure. Equation 4 to determine the pressure losses at the air cleaner. Equation 4 is used to determine the brake horsepower, where ME is equal to 0.65.

$$V = 1096\sqrt{\frac{Vp}{\rho}} = 4005\sqrt{Vp} \qquad Eq. 1$$

$$FSP = SP_{outlet} - SP_{inlet} - VP_{inlet} \qquad Eq. 2$$

$$FTP = FSP + VP_{outlet} \qquad Eq. 3$$

$$Pressure\ loss = SP_{inlet} - SP_{outlet} \qquad Eq. 4$$

$$BHP = \frac{(Q \times FTP)}{6356 \times ME} \qquad Eq. 5$$

Where:

V	:	Air velocity (ft/min)	SP	:	Static Pressure
Vp	:	Velocity pressure in inches of water (in.W. g)	VP	:	Velocity Pressure
ρ	:	Density of water	FSP	:	Fan Static Pressure
Q	:	Flow rate	FTP	:	Fan Total Pressure
ME	:	Mechanical efficiency	BHP	:	Brake Horsepower

3. Results and Discussion

The result covered the experimental and analysis of LEV effectiveness at welding laboratory. The investigation was conducted based on critical parameters of the LEV system.

3.1 Face velocity at hood

There are 14 different segment to perform welding activities separated by brick walls. Each welding segment is equipped with one ellipse shape hood connected to a flexible extractor arm. For face velocity readings, flow measurements are taken at each hood opening. Table 1 shows the summary of the face velocity result.

Table 1: Summary of face velocity result

Hood	Face velocity (fpm)	Flowrate, Q (cfm)	Remarks	
			Accept	Reject
H1	208.13	545	✓	
H2	278.31	727	✓	
H3	345.44	904	✓	
H4	385.88	1010	✓	
H5	471.63	1235	✓	
H6	496.88	1301	✓	
H7	529.38	1386	✓	
H8	599.13	1569	✓	
H9	564.44	1478	✓	
H10	466.44	1221	✓	
H11	381.69	999	✓	
H12	342.50	897	✓	
H13	250.75	656	✓	
H14	247.81	649	✓	

From the results tabulated in Table 1, all hoods exceeded the required face velocity of 100–200 fpm. The lowest value is on hood 1 with a reading of 208.13 fpm, while the highest value is 599.13 fpm on hood 8. Based on the data taken, the surface flow rate produced for all hoods also exceeds the required minimum rate value of 262 cfm. The lowest value is 545 cfm on hood 1, while the highest value is 1569 cfm on hood 8. Overall, the face velocity value of this system is very satisfactory and meets the minimum required range of 100 fpm.

3.2 Capture velocity at hood

The value of the capture velocity results was taken based on 3 different capture distances on the worktable from the face hood. Figure 3 shows the result of capture velocity.

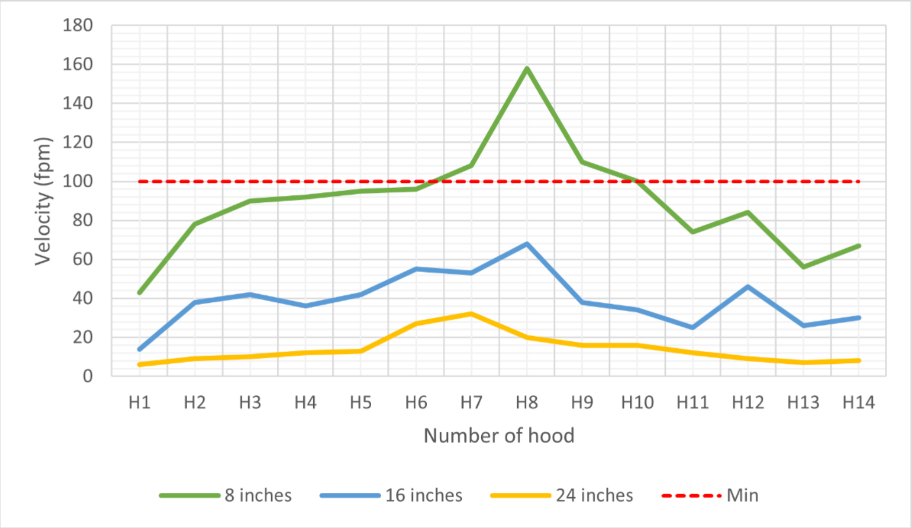

Figure 3: Graph of capture velocity

Based on the capture velocity results made on each hood, only 4 of the 14 hoods passed the minimum required rate of 100 fpm. H7, H8, H9, and H10 are the four hoods that pass the minimum rate from an 8-inch distance. Meanwhile, all readings from 16 inches and 24 inches taken on each hood did not exceed the minimum required. This is due to the distance factor in the capture results for polluted air, where the further the measurement distance is taken, the less effective it is to obtain the minimum required rate. As conclusion, the capture velocity results are not satisfactory because only 4 out of the 14 hoods has pass the minimum range required. The effectiveness in capturing contaminated material no larger than 8 inches.

3.3 Ducting section

The ducting works as a transport mechanism for pollutants and is filtered according to the filtration process before being released into the environment. The pressure in the duct must exceed the minimum transport velocity required so that the contaminant can be drawn in and separated from the workplace. The minimum transport velocity required are 2000 fpm. There are 9 measurement points that have been made at the location selected for data collection. Each point has two perpendicular holes at 90 degrees that have been drilled to allow the pitot tube to be inserted into the duct. Table 2 shows the summary of data on ducting system.

Table 2: Summary of data on ducting system

Point	Velocity, V (fpm)	Flowrate, Q (cfm)	Remarks	
			Accept	Reject
1	1178	230.89		✓
2	2411	47256	✓	
3	2582	901.12	✓	
4	3370	1176.13	✓	
5	4942	1724.76	✓	
6	2735	2146.98	✓	
7	3193	2506.51	✓	
8	3617	2839.35	✓	
9	3175	2492.38	✓	

There are only one of the nine data measurement points did not pass the minimum standard required based on ACGIH guidelines. The location of the intended point is at point 1, where the results of the data taken are not satisfactory. This occurs because point 1 in the system is farther from the fan and encounters more resistance than other points.

In general, this system is efficient in transferring contaminants from the hood to the stack element through the ducting system. However, action should be taken to resolve the unsatisfactory airflow at point 1. To overcome this, maintenance needs to be done inside the ducting section. Dust that sticks to the inside of the pipe needs to be cleaned so that the air flow is more effective.

3.4 Air cleaner

To prevent necessary undesirable particles from being released into the environment, the air cleaner is an essential filtration mechanism. As the system might clog and cause the pressure to drop, it needs to be routinely monitored for performance. The static pressure difference between the air cleaner's inlet and outlet must be within the range of permitted tolerance which is ±10% of the reference value. The data collected for the air cleaner system is shown in Table 3.

Table 3: Summary of air cleaner result

Point	Duct Area (ft^2)	VP (in.wg)	SP (in.wg)	Velocity (fpm)	Flow rate, Q (cfm)
Inlet	0.785	0.6355	-2.831	3192.72	2506.29
Outlet	0.785	0.8155	-6.5405	3616.72	2839.13

In conclusion, filter pressure drop is directly proportional to filter air flow rate. The higher the pressure drop the tighter the filter is against the airflow. Air flowing through the filter is easier if the pressure drop value is lower.

3.5 Fan and motor

The fan works to produce the necessary pressure in the ducting system so that the contaminants can be extracted and released into the air. The type of fan used in this system is a centrifugal fan. Meanwhile, the motor used is a TECO model with a design power of 7.5 HP. It is connected to the fan shaft using a belt drive. Table 4 shows the summary of fan and motor performance.

Table 4: Summary of fan and motor performance

Description	Speed (rpm)	FSP (in.wg)	FTP (in.wg)	BHP (HP)	Flowrate, Q (cfm)
Design data	N/A	N/A	N/A	7.5	N/A
Previous data	1465	7.880	8.303	5.8	2644
Tested	1465	6.8935	7.522	4.85	2665.79

The fan and motor operate well and can remove contaminants resulting from welding activities in the laboratory and released them into the air environment. However, maintenance should be done mainly on the motor cover and the rusted steel base structure.

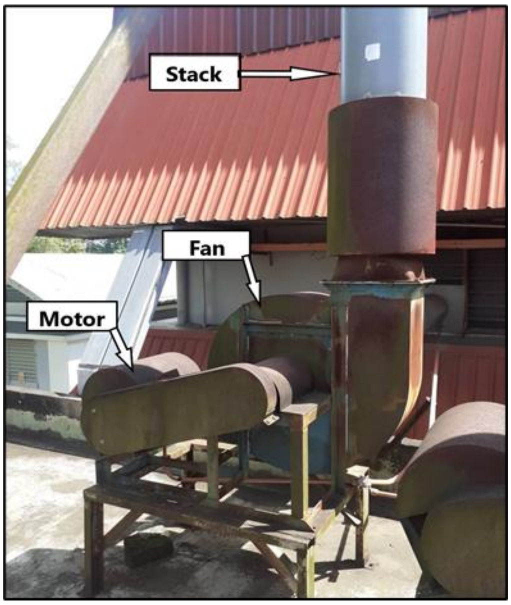

Figure 4: Rusted surface on the fan and motor cover

3.6 Stack

The exhaust stack is very important to ensure that workers are safe from welding fumes while working in enclosed areas. The results obtained show an increase in the efficiency of this system compared to the previous data. Table 5 shows the summary of exhaust stack performance.

Table 5: Summary of exhaust stack performance

Description	VP (fpm)	SP (fpm)	Velocity, V (fpm)	Flowrate, Q (cfm)
Previous data	0.423	0.781	2604.79	2046.062
Tested	0.6285	1.1685	3175.08	2492.44

Overall, the test results prove that the exhaust stack works very well in this LEV system. The recorded static pressure is a positive value, indicating that it has a pressure higher than the atmospheric pressure and is capable of releasing pollutants into the environment. However, maintenance should be done on the rusted parts, as shown in Figure 5 to ensure that this system can be used continuously.

Figure 5: Condition of exhaust stack due to oxidation process

4. Conclusion

From this experiment, the objective to measure the LEV critical parameters according to DOSH standard requirement has been implemented. Additionally, tests were made to evaluate the LEV effectiveness in ensuring the engineering control for welding process. Overall, the efficiency of the LEV system is not satisfactory, following the results for capture velocity and ducting section, which not achieve the standard required. However, this system still works, especially to remove welding fumes. The results for the face velocity on all hoods are very satisfactory and reach the minimum required rate of 100 fpm. However, for capture velocity results, only four out of 14 hoods reached the minimum required rate of 100 fpm from 8 inches. Meanwhile, the results obtained from 16 inches and 24 inches did not reach the minimum required. For velocity data at ducting section, only one of the nine data measurements points do not meet the minimum required range of 2000 fpm. The location of the intended point is at point 1, where the results of the data taken are not satisfactory. Thorough inspection and maintenance are required to ensure the performance of moving parts components such as motors, fans, and belts.

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