

INSPECTION, TESTING AND EXAMINATION LEV SYSTEM AT HYGIENE LABORATORY AT UITM BUKIT BESI

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ABSTRACT

Examination and testing of the LEV (LEV) system was conducted at the Hygiene laboratory of Universiti Teknologi MARA Kampus Bukit Besi to evaluate performance and compliance with safety standards. The inspection focused on a single fume hood (FH-HYGIENE) and followed guidelines from the American Conference of Governmental Industrial Hygienists (ACGIH) and Use and Standards of Exposure of Chemicals Hazardous to Health (USECHH) 2000 Regulations. Face velocities were measured at different sash heights, and duct transport velocities were assessed using instruments including a hot wire anemometer, pitot tube, digital manometer, and smoke tester kit. Results showed the fume hood had an average face velocity of 61.8 fpm at the recommended working height of 19.7 inches, below the 80-100 fpm range specified by ACGIH. Duct transport velocity was 1437 fpm, within the recommended 1000-2000 fpm range. The smoke test demonstrated excellent containment with no escape of smoke outside the hood. Comparison with the previous year's inspection revealed a significant decrease in performance, with face velocity dropping from 109 fpm to 40.2 fpm at full sash opening, and flow rate decreasing from 1008 cfm to 502 cfm. The LEV system was found to meet acceptable working conditions only at 1/3 sash opening based on ACGIH standards. Recommendations included implementing a regular maintenance schedule, limiting maximum sash opening to 19.7 inches, and conducting more frequent performance tests to address the decline in performance. This examination establishes updated measurements for ongoing monitoring of the LEV system's effectiveness in protecting worker health and safety in laboratory settings.

Keywords: ACGIH, LEV, Fume Hood, Face Velocity, USECHH 2000 Regulations.

1. INTRODUCTION

In general, laboratories use fume hoods as engineering control equipment local exhaust ventilation (LEV) systems to capture contamination sources which fall under category of smoke, vapors or gaseous. Most of the samples are derived from student analyses conducted in the laboratory. Managing worker exposure to contaminants is a crucial responsibility for employers to manage worker exposure to contaminants, a point emphasized in several key studies (Author, Year).. Employers must closely evaluate control systems that protect workers from contaminants in various jobs. This assessment ensures compliance with the Occupational Safety & Health (USECHH) Regulations 2000. It is also important to document the performance and conditions of LEV systems, as supported by recent studies (Author, Year). the conditions and performance of the LEV (LEV) system for future reviews and record-keeping, focusing on adherence to these safety regulations.

Excessive exposure to airborne chemical agents possesses the capacity to provoke severe or fatal respiratory disorders. Therefore, the fundamental roles of the (LEV) system are to proficiently capture, eliminate, and purify contaminated air before releasing only refined air into the ambient environment. Improving the operational efficiency of the system necessitated a thorough reevaluation of its operational parameters. Operators are mandated to comply with predetermined safe and standardized operating procedures (SOP) to ensure the optimal functioning of the systems consistently. Moreover, it is crucial for employers to manage any chemical risks present in the occupational setting through the application of the hierarchy of control as delineated in Regulation 15 of the (USECHH) [3], [1], [4]

Table1: Standard guidelines for inspection, examination and testing are based on DOSH recommendation.

No.	Testing	Contaminants	Standard ACGIH 23rd Edition
1	Face velocity	Smoke, vapors & gases	80-100 fpm
2	Traverse velocity	Smoke, vapors & gases	1000-2000fpm

This is periodic inspection conduct at Hygiene Laboratory, Fakulti Sains Gunaan UiTM Kampus Bukit Besi. The means of LEV System here is fume hood. A testing of all LEV system was carried out on 26th June 2024 at Hygiene 2 laboratory Level 2 UiTM Kampus Bukit Besi. Hygiene Laboratory contain one units LEV system with 1-unit fume hoods. The fume hoods were designed with individual duct system, fan and stack. The LEV System was designed to prevent or reduce hazardous smoke, vapors and gases contamination up to as far as practicable level. The methodology on this testing involved qualitative and quantitative. The qualitative test using smoke tube by visual for smoke test meanwhile for quantitative consists of face velocity test and transport velocity test [5]

To evaluate the efficacy and efficiency of the LEV system, it is vital to ensure that the systems are scrupulously designed. Furthermore, the implementation of regular preventive maintenance in conjunction with visual inspections holds equal importance to ascertain that the LEV systems consistently function in alignment with the established design specifications. Nonetheless, laboratory staff are still strongly urged to utilize appropriate personal protective equipment (PPE) such as face masks, safety footwear, gloves and goggles as advocated by safety officers during their operations, in accordance with Regulation 13 of the (USECHH). Specifically, Regulation 13 of the (USECHH) Regulations 2000 states: "Every employer shall provide suitable personal protective equipment to his employees who are exposed to chemicals hazardous to health and shall ensure that such equipment is worn or used by the employees." [6]. This regulation emphasizes the responsibility of employers to provide appropriate PPE to employees who are exposed to hazardous chemicals and to ensure that the employees wear and use the provided protective equipment while carrying out their work duties. By following this regulation, employers can help protect the health and safety of their workers in environments where hazardous chemicals exist [7].

Housekeeping holds significant importance in maintaining a safe working environment, as supported by safety guidelines [1], within the occupational environment. Any instances of chemical spillage must be promptly addressed and rectified. It is imperative to secure all unused chemical containers and close machine doors to mitigate the accumulation of airborne pollutants in the surrounding atmosphere. Every (LEV) system that has been installed within the facility is to be maintained regularly and must remain operational at all times during the functioning of the machinery or plant. Ultimately, while the onus of ensuring the accuracy and fairness of the report primarily rests upon the hygiene technician, the collaborative efforts and mutual understanding of all stakeholders are essential for achieving the overarching objective of safeguarding worker health. The Occupational Safety and Health Act of 2022 delineates the requisite responsibilities of employers to ensure the safety, health, and welfare of their workers. Enhancements to the fume hood system are necessary if they do not comply with the standards set forth by the (ACGIH) and the (USECHH) Regulation of 2000.

The primary aim of the inspection is to ascertain the quantitative assessment of static pressure, velocity pressure, and total pressure within LEV (LEV) systems. Moreover, the processes of inspecting, testing, and evaluating performance serve to elucidate the operational capacity of LEV systems. In instances of damage or potential enhancements, all modifications must receive endorsement and evaluation by a licensed professional engineer. The principal objective of this research endeavor is to assess the efficacy of the LEV (LEV) System within the Hygiene Laboratory. To fulfill this overarching objective, three specific subobjectives have been articulated:

- i. To conduct qualitative and quantitative periodic inspection, testing and examination on LEV system on performance and operating conditions of LEV Systems as well as its associated component
- ii. To verify compliance by comparing it with previous measurements or required face and traverse velocities as recommended under Industrial Ventilation: A Manual of Recommended Practice 23rd Edition by (ACGIH) and USECHH 2000 Regulations.
- iii. To recommend improvement in LEV Systems for compliance with USECHH 2000 Regulations.

The study was conducted to comply with Malaysian regulations, specifically the (USECHH) Regulations 2000 under the Occupational Safety and Health Act 1994. It involves periodic inspection, testing, and examination of the (LEV) system at Encompass Laboratory to ensure it meets safety standards. The primary goal of the study, as highlighted by previous research [8], is to evaluate the performance of the laboratory fume hood in providing protection for workers from exposure to hazardous chemicals. It assesses whether the LEV system effectively captures and removes contaminants, preventing their release into the laboratory environment.

By comparing current performance data with baseline, the study allows tracking the LEV system's performance over time, enabling early detection of any degradation in performance. For system Performance Evaluation, the study thoroughly examines various components of the LEV system, including the fume hood, ducting, air cleaner, blower, motor, and exhaust stack. It measures key performance indicators such as face velocity, duct transport velocity, static pressure, and fan performance to determine if they meet recommended guidelines (e.g., from ACGIH, ANSI, ASHRAE). Identification of maintenance needs through physical observation and testing [10], [11].

2. MATERIALS AND METHODS

This section outlines the materials and methods used in the inspection, testing, and evaluation of the Local Exhaust Ventilation (LEV) system at the Hygiene Laboratory, UiTM Bukit Besi. The methodology involves both qualitative and quantitative assessments to determine the effectiveness of the LEV system in protecting laboratory personnel from exposure to hazardous chemicals.

2.1 Instruments

The instruments utilized in this study are essential for accurately measuring various parameters of the LEV system, including air velocity, pressure, and flow rates. Table 2 provides the specifications and inspection details of each instrument used in the testing process.

Table 2: Instruments specification.

Instrument	Brand / Model	Serial No.	Calibration Certificate	Inspection
Smoke Tester Kit 500	Gastec	-	-	To indicate direction of air flow
Hot Wire Anemometer	TSI AIRFLOW/TA430	TA4302149006	NA	To measure air velocity
12" Pitot Tube	DWYER	-	-	To measure velocity and static pressure
Digital Manometer	EXTECH / HD 350	210522497	CA4005D Expiry Date: 24.11.2022	
Measuring Tape	Marksman	5M 16ft	-	To measure area of hood and ducting



(a)Smoke Test Kit



(b)Hot Wire Anemometer



(c)Digital Manometer with pitot tube



(d)Measuring Tape

Figure 1: The picture of related equipment for LEV system testing

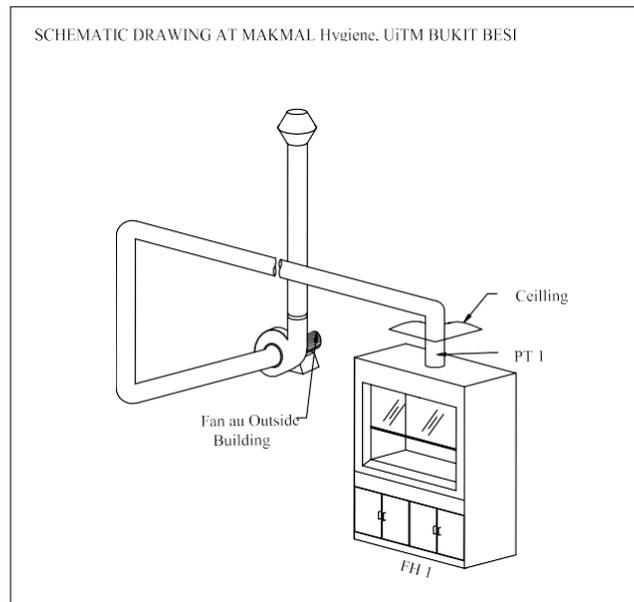


Figure 2: Schematic Drawing at Hygiene Laboratory, UiTM Bukit Besi



Figure 3: Fume hood at Hygiene 2 Laboratory. The point before and after fan were not accessible with 'A' type ladder

2.2 Methodology Overview LEV System

The engineering control apparatus, specifically the (LEV) System, which is deployed in both occupational and non-occupational settings, necessitates periodic evaluations to ensure optimal operational efficiency, adherence to the specified ventilation standards as delineated in the design specifications, and compliance with the stipulations set forth by the Department of Occupational Safety and Health (DOSH), particularly those guidelines advocated in the ACGIH Industrial Ventilation 23rd Edition. The LEV System, nonetheless, mandates the execution of monitoring protocols to document measurements both within and external to the systems. Measurements taken internally pertain to data collected within the ductwork, aimed at assessing static, velocity, and total pressures. Consequently, it becomes feasible to compute traverse velocities and flow rates within the system. Conversely, measurements conducted externally encompass face velocity and capture velocity. Face velocity is defined as the air movement quantified in feet per minute (fpm) at the entrance of a hood, vent, or diffuser, while capture velocity is characterized as the measurement of velocity at a specified distance from the source of contaminant generation to the hood's face. The inspection, testing, and evaluation of the LEV System must be performed in accordance with the methodologies recommended in the ACGIH Industrial Ventilation 23rd Edition.

The Local Exhaust Ventilation (LEV) system necessitates the implementation of systematic monitoring procedures to accurately document measurements both within and external to the systems. Internal measurements pertain to the collection of data from within the ducts, which serves to ascertain static, velocity, and total pressures. Consequently, the calculations of traverse velocities and airflow within the system can be derived. External measurements encompass assessments of face velocity and capture velocity. Face velocity is defined as the rate of air movement measured in feet per minute (fpm) at the aperture of a hood, vent, or diffuser. Conversely, capture velocity is a specific measurement of velocity taken at a designated distance from the source of contaminant emission to the face of the hood. The evaluation, testing, and appraisal of the LEV system must be executed in accordance with the prescribed methodologies delineated in the Industrial Ventilation: A Manual of Recommended Practice, 23rd Edition, published by ACGIH [8].

2.3 Measurement of LEV system

Inspection and examination of the LEV System which including:

Hood

Visual evaluation was conducted through a comprehensive observation of the overall Local Exhaust Ventilation (LEV) System. A smoke tube, employed to illustrate airflow patterns, was utilized to assess the efficacy of the suction provided by the system. For an enclosure hood characterized by an open front face, which is requisite for work operations such as fume hoods and booth hoods, a smoke test was performed at the sash opening to evaluate the containment efficiency of the hood across its frontal plane.



Figure 4: A smoke tube used for smoke face /capture test

Smoke test

Smoke can be used to indicate the direction and pattern of air movement around the source and to show whether air is drawn from the source into the LEV system. The smoke tube will be discharged around the edge of the hood face and hood capture. All air movement should be into the hood. With this test, any visible emission of smoke from the hood indicates inadequate containment (qualitative analysis). Smoke test is carried out at 1D, 2D and 3D of the fume hood.

Face velocity measurement of fume hood and slot hood.

The sash was divided into several sections in Figure 5. The measurement of the face velocities is taken at the fully sash opening, maximum working level (2/3 opening) and (1/3 sash opening). Measurement is carried out by taking and recording readings at the centre of each section.



Figure 5: The sash divides into several sections by using a measuring tape and cellophane tape

All the measured face capture velocities are averaged and compared with an average of standard criteria using the following formula.

$$Q = VaA$$

$$Va = V1 + V2 + \dots + Vn / N$$

Where, Q = Rate of flow for enclosure hood (m^3/s)
 Va = Average face capture velocity (m/s)
 A = Cross-section area of opening (m^2)

Duct



Figure 6: Determine the velocity pressure (VP) using manometer and pitot tube.

Determine the duct diameter and calculate the duct area.
 Determine the locations for static pressure and traverse velocity of duct for testing.
 Conduct static pressure and traverse velocity measurement by using manometer and pitot tube.
 Traverse velocity of the duct were calculated as below:

$$V = 4005\sqrt{VP}$$

where, V in fpm and VP in inches water gauge (in Wg)

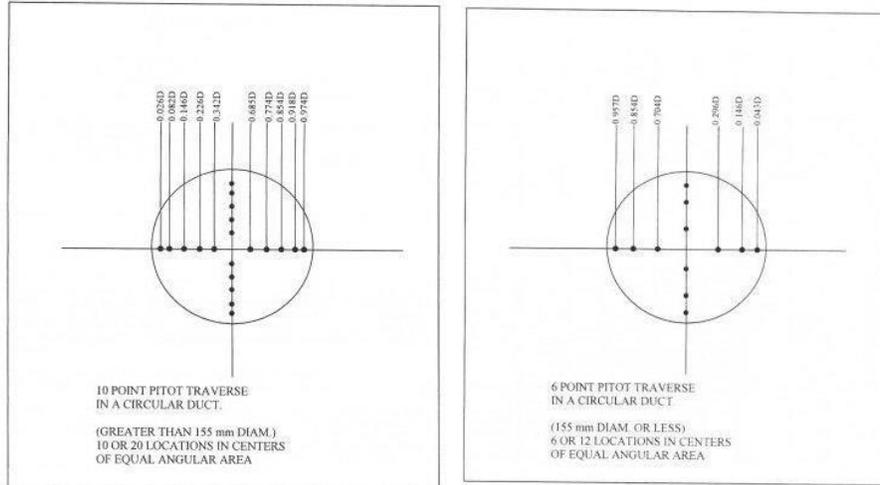


Figure 7: Point Pitot Traverse in a Circular Duct

3. RESULTS AND DISCUSSION

This section presents the results of the inspection, testing, and examination of the LEV system at the Hygiene Laboratory. The findings are discussed in relation to the system's performance, compliance with safety standards, and overall condition.

3.1 Physical Observation and Smoke Test

The physical observation and smoke test were conducted to evaluate the condition and functionality of the LEV system components, including the fume hood, ducting, and centrifugal fan. The results are summarized in Table 3, providing an overview of the physical state of the equipment and the effectiveness of the smoke containment.

During the smoke test, the fume hood (FH-HYGIENE) demonstrated excellent performance with smooth smoke flow and no visible escape of smoke from the hood at the recommended sash height of 19.7 inches. This indicates that the fume hood is effectively containing hazardous fumes and maintaining proper airflow within the laboratory environment.

The results from the physical observation and smoke test indicate that the LEV system is generally in good condition, with all components functioning as intended. However, the absence of air cleaning devices and dampers in the ducting system suggests potential areas for improvement to further enhance the efficiency and safety of the ventilation system. The face velocity and traverse velocity measurements were within acceptable ranges, as shown in Table 4. These findings align with the standards set by the ACGIH and the USECHH 2000 Regulations, confirming the system's capability to provide adequate protection against hazardous chemical exposure.

Table 3: Physical Observation and Smoke Test

No	Equipment	Remarks
1	Hood	Fume Hood (FH-HYGIENE) physical condition shown no damage and in good condition
2	Light	Light is fully function
3	Ducting	All system were using PVC ducting No damper were install at the all hood to control the airflow. Overall ducting is in good condition
4	Air Cleaning Device	There were no air cleaner install for all the LEV System.
5	Centrifugal Fan	All centrifugal fan were in good condition and no abnormal sound.
6	Stack	Stack were in good condition and 3 meter or 10 feet from the adjacent rooflines.
7	Smoke Test	Fumehood FH-HYGIENE: The smoke pattern was smooth in flow and no escaped from hood at 19.7-Inch opening sash (working height).

Table 4: Fume hood current status after periodic testing

Tagg.	Smoke Test	Face Velocity	Traverse Velocity in Duct	
			Before fan	After fan
FH HYGIENE	<i>Excellent</i>	Pass	Pass	N.A

Notes: N.A – Not available due to the accessibility issue

3.2 Face Velocity Analysis. Recommended (80 -100 fpm) by ACGIH for Fume Hood FH HYGIENE

Based on the results in Table 5, the face velocity for fume hood at 29.5-inch distance is below the recommended limit (80 fpm – 100 fpm) as per requirement by ACGIH. For Full Sash Level the face velocity is 40.2 fpm, which is below the recommended range.

Table 5: Face velocity and flow rate result as compared by ACGIH Guideline

FH	Sash Position (Sash height)	Face Velocity V_{face} (fpm)		Type	Hood	Face size (ft)	Face area (ft ²)	Face Flow Rate, Q_{face} (cfm)		Remarks	
		Rec. value	Tested					Rec. value	Tested	Acc.	Rej.
FH Hygiene	Full Sash Level (29.5 Inch)	80-100	40.2	Slot	4.23 x 2.46	10.41	833-1041	418			X
	2/3 opening (Maximum Working height) (19.7 Inch)	80-100	61.8	Slot	4.23 x 1.64	6.94	555-694	429	✓		
	1/3 Opening (9.8 Inch)	80-100	85.9	Slot	4.23 x 0.82	3.47	278-347	298	✓		

Note : $Q_{\text{face}} = V_{\text{face}} \times A_{\text{face}}$; $A_{\text{face}} = \text{Face area}$

: Rec. = Recommended, Acc. = Accept, Rej. = Reject

For 2/3 Opening the face velocity is 61 fpm, which is within the recommended range and for 1/3 Opening, the face velocity is 85.9 fpm, which is also within the recommended range. According to [11] optimal performance is achieved with 2/3 opening at 9.8 inches, ensuring safety and efficiency. The tested flow rate for the fume hood at different sash positions varies from 418 cfm to 298 cfm. The flow rate is another important factor that determines the performance

of a fume hood. A higher flow rate generally indicates better removal of hazardous materials. For further safety precaution, it is recommended to use 2/3 opening (9.8-inch) as per working height for the fumehood for an effective performance and meets the requirement set by ACGIH (80 fpm – 100 fpm). The maximum to operate the sash in safe condition to maintain the efficiency is at 19.7 inch.

3.3 Results For Measurement Of Static Pressure (Sp), Velocity Pressure (Vp), Total Pressure (Tp), Transport Velocity And Flow Rate (Ducting Section)

The performance of duct transport velocity is based on guidelines by ACGIH, 1000 – 2000fpm. Based on Table 6, the average duct transport velocity for the fume hood hygiene laboratory at point P1 is greater than 1000 fpm, thus the selected exhaust fan is acceptable due to good performance at the point before the fan and after the fan.

Table 6: The results of traverse/transport velocity, SP, VP, TP and flow rate in ducting for fumehood FH hygiene laboratory

Point (Pt)	Duct size (in)	Duct area (ft ²)	SP (in w.g.)	VP (in w.g.)	TP (in w.g.)	Velocity (fpm)		Flow Rate (cfm)		Remarks	
						Rec. value	Tested	Rec. value	Tested	Acc.	Rej.
1	8	0.349	-0.200	0.129	-0.071	1000-2000	1437	349-698	502	/	

Note: BF= Before Fan, AF= After Fan, Acc. = Accept, Rej. = Reject

3.4 Fan Performance Analysis (Brake Horsepower (Bhp) Calculation)

Brake House Power (BHP) for Fume Hood FH Hygiene can't be calculated because Velocity Pressure (VP) and Static Pressure (SP) at before and after fan can't be measured due to accessibility issue.

Table 7: Brake Horse Power (Bhp) Calculation

Description	Speed (rpm)	FSP (in w.g.)	FTP (in w.g.)	BHP (hp)	Flow rate (Q) (cfm)
Baseline	1400	N.A	N.A	N.A	N.A

3.5 Performance Comparison

Based on the Figure 8, the substantial drop from 109 fpm to 40.2 fpm suggests a significant decline in performance between 2023 and 2024. A significant reduction in performance (as indicated by the drop from 109 to 40.2) could imply issues such as clogged filters, reduced airflow, or other mechanical problems affecting the fume hood's ability to maintain proper face velocity

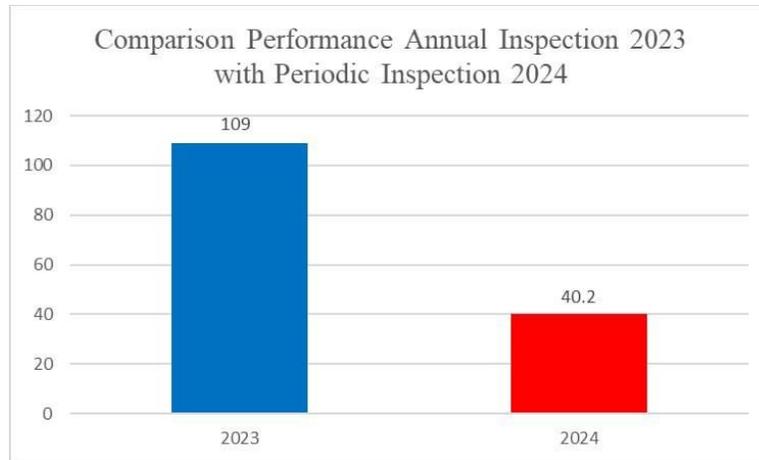


Figure 8: Comparison Performance Annual Inspection 2023 with Periodic Inspection 2024 for Face Velocity

According to [12], the substantial drop in face velocity may indicate maintenance issues or environmental changes affecting fume hood performance. According to [8], increasing flow rate in fume hoods can enhance hazardous fume removal. However, it's crucial to maintain flow within recommended levels for optimal performance and energy efficiency, balancing safety and effectiveness. Therefore, optimal face velocity is crucial for ensuring that contaminants are effectively captured and exhausted out of the lab.

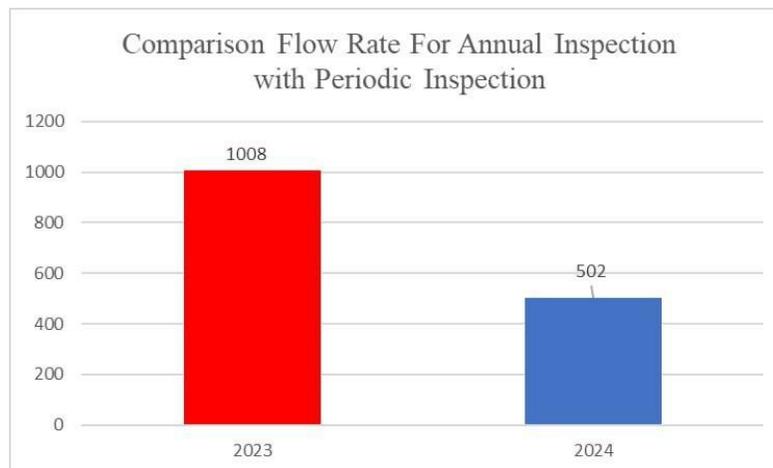


Figure 9: Comparison Flow Rate for Annual Inspection 2023 with Periodic Inspection 2024

Based on Figure 9, the flow rate in 2023 was 1008 but in 2024, the flow rate dropped significantly to 502. This indicates a substantial reduction in the fume hood's airflow capacity, which can severely impact its effectiveness in removing hazardous fumes. The significant drop in flow rate from 1008 to 502 implies that the fume hood's effectiveness in capturing and exhausting contaminants has likely decreased. This reduction can be due to lack of regular maintenance can lead to gradual degradation of performance.

4. CONCLUSION

The fume hood in the Hygiene Laboratory at UiTM Bukit Besi is not performing optimally according to ACGIH standards, particularly at full sash opening. There has been a significant decline in performance between 2023 and 2024, with face velocity dropping from 109 fpm to 40.2 fpm at full sash opening. The flow rate has also decreased substantially from 1008 cfm in 2023 to 502 cfm in 2024, indicating reduced effectiveness in capturing and exhausting contaminants. The fume hood meets recommended standards only at 1/3 sash opening (9.8 inches), with a face velocity of 85.9 fpm. The duct transport velocity is acceptable, being above the recommended 1000 fpm. Full assessment of fan performance (Brake Horse Power calculation) was not possible due to inaccessibility of some measurement points.

5. RECOMMENDATION

Establish a regular maintenance schedule for the fume hood, including cleaning to prevent issues. Inspect immediately to find the cause of the performance drop from 2023 to 2024, checking fans, motors, and ductwork. Limit the sash opening to 19.7 inches to meet safety regulations. If maintenance doesn't help, consider upgrading components and assessing ventilation capacity. Improve measurement accessibility and conduct quarterly performance tests. Train staff on proper fume hood use, including sash height, safe equipment placement, and compliance with USECHH 2000. Schedule regular cleaning, avoid chemical storage in the hood, and ensure proper PPE use. [13].

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