Study on Fume Hood Improvements for Energy Savings and Minimum Face Velocity

[1]YoungJin Son and [2]Sungmin Bae
[1]Department of Smart Production and Management Engineering, Hanbat National University, Daejeon, Korea.
[2]Department of Industrial and Management Engineering, Hanbat National University, Daejeon, Korea.
[1]Young-jin@naver.com, [2]loveiris@ hanbat.ac.kr

Correspondence should be addressed to Sungmin Bae : loveiris@ hanbat.ac.kr

Article Info
Journal of Machine and Computing (http://anapub.co.ke/journals/jmc/jmc.html)
Doi: https://doi.org/10.53759/7669/jmc202404064
Received 18 August 2023; Revised from 12 December 2023; Accepted 10 June 2024
Available online 05 July 2024.

Abstract – A fume hood is a device that safely exhausts harmful substances generated during the experimental process to the outside, and for the safety of researchers and the protection of experimental samples, the balance between the amount of air flowing in and the speed at which it is discharged to the outside is extremely important. The Face velocity of the fume hood is recommended to be 0.5m/s (ASHRAE 110-2016) specified by the American National Standards Institute (ANSI). The Korea Occupational Safety and Health Corporation specifies 0.4 m/s (KOSHA-G-7-1999). To increase the functionality of the fume hood, it must be operated 24 hours a day while maintaining the prescribed Face velocity to make a safe laboratory environment. However, constantly powering them consumes a significant amount of electrical energy. Therefore, it's crucial to make efforts to reduce energy consumption. Some labs have adopted a method to minimize electrical usage by powering the hoods only when they're in use. In that case, it should be done with great caution. Because hazardous substances inside the hood could be leaked, putting the entire lab at risk. By implementing such measures, organizations and institutions managing lab facilities can effectively reduce energy consumption while ensuring the use of safe fume hoods. Additionally, there's a growing trend in research facilities to maintain Face velocity of fume hoods below 0.25 m/s as part of efforts to decrease and conserve electrical energy. This study stems from preliminary research aimed at achieving a stable face velocity in fume hoods. In this study, to reduce the face velocity of the fume hood, we changed the structural design of the fume hood based on existing research. As a result, the face velocity of the fume hood is reduced from 0.5 m/s to 0.297 m/s. the study reduced the face velocity to a maximum of 0.297m/s. To verify the performance of the fume hood with minimum face velocity, we tested the ventilation performance with the international standard test method. It proves that the fume hood with face velocity 0.297 m/s make no differences compared to existing fume hood with higher face velocity. In addition, the fume hood with minimum face velocity enables the reduction of energy consumption.

Keywords – Fume Hood, Face Velocity, Energy Saving, Laboratory Safety, Design Improvement.

I. INTRODUCTION

Fume hoods used in research laboratories must ensure safety systematic of localized exhaust and ventilation to create a safe experimental environment for researchers working with hazardous materials. In laboratories that are involved in research experimentation, test subjects are placed in fume hood chambers to test and study samples that generate hazardous substances. The control velocity for drawing air into the hood is not a theoretical or calculated value but is mostly determined by practical experience and is influenced by the scattering speed and temperature of the fume according to the characteristics of the pollutant generated and the surrounding airflow [1].

The Korean Occupational Safety and Health Act requires a control wind speed of 0.4 m/s, but only 57.1% of university occupational health departments comply with the safety standard [8]. The reason for the lack of safety compliance with control wind speed, even among experts in research laboratory safety, is thought to be a combination of unclear safety standards and the economics of using electrical energy, as it requires continuous operation 24 hours a day to fully exhaust fumes

Fume hoods are a key piece of equipment in laboratories that work with organic solvents, dusts, acids, and alkalis, and they play an important role in experimental research. The emission of hazardous substances from local exhaust systems should be set in a way that ensures the health and safety of researchers [2]. Analyzing the air flow and introducing a hydrodynamic exhaust system inside the fume hood, i.e. inside the chamber, is crucial to the design of fume hoods to ensure the safety of researchers working with hazardous materials. The primary purpose of local exhaust is to keep the researcher's experimental environment safe from harmful substances [16].

In addition to the systematic study of local exhaust and ventilation systems to meet laboratory safety standards, it is very important to design fume hoods in a way that utilizes fluid dynamics to improve fume hood performance, maintain air flow velocity, and suppress or minimize vortex generation inside the hood [15].

In laboratories of pharmaceutical companies or companies or institutions that specialize in experiments, the blower must run 24 hours a day to ensure the safety of the researchers and the safe use of the fume hood. This generates a lot of power and consumes a lot of energy continuously.

In recent years, as a way to reduce energy, fume hoods have been required to have a face velocity of 0.25 m/s or less by research facility management organizations, institutions, and research facilities, and various research methods are being studied to maintain optimal face velocity using less power to reduce energy. However, the unverified 0.25 m/s criterion is difficult to find in fume hood test standards or previous studies. Ha HC presented a study that maintaining the face velocity of a fume hood at 0.3 m/s can reduce pollutants by more than 80% [1], but it differs from this study in that it is limited to the study of flow rate control to prevent pollution and has not been verified to meet researcher safety and international standards.

This study aims to test and validate the minimum face air velocity of fume hoods that can reduce energy while ensuring the safety of research samples, researchers, and the entire laboratory through structural improvements to existing fume hoods. In addition, the performance verification of the minimum face velocity of the new fume hood was performed according to the standards of ASHRAE-110-2016 of the American National Standards Institute (ANSI) and EN 14175-3 of the European Committee for Standardization (CEN) to prove that the improved fume hood can help reduce energy as well as laboratory safety.

II. LITERATURE REVIEW

Recent Study for Enhancing the Performance of Fume Hood

Hazardous substances are particulate matter such as mist, fume, and dust that contaminate the work environment. Hood refers to a chamber-shaped structure corresponding to the entrance of the local exhaust system [9], which is installed in various forms at the closest location to the source to capture and remove hazardous substances. As shown in **Fig 1**, a local exhaust system is a type of air conditioning system that generates fumes, and a fume hood is a part of it. The fume hood used in the laboratory is a type of industrial ventilation system, which consists of a hood, duct, air clean device, blower, and stack [2,13].

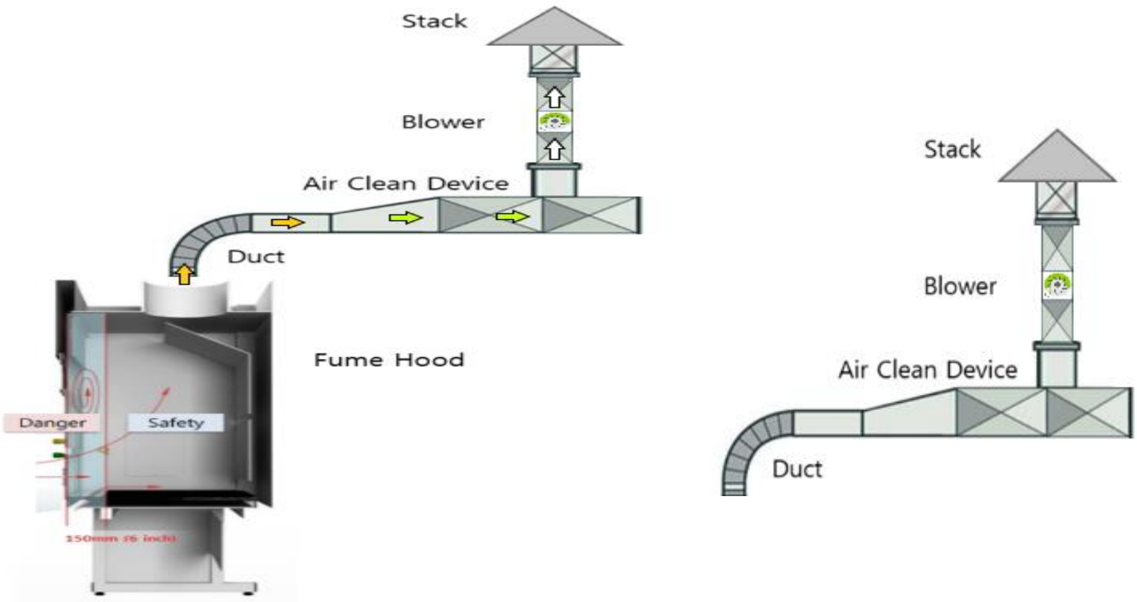


Fig 1. Local Exhaust Ventilation System (KOSHA).

It is common to think of fume hoods as an area of the facility's HVAC system, with ducts through which air is exhausted by blowers. Therefore, the blower for complete exhaust is used in conjunction with the air conditioning system and is operated at different rotational speeds and produces different noises. The power generated by running the blower for rapid evacuation of harmful fumes consumes a lot of electrical energy. Therefore, the role of reducing noise while reducing electrical energy is emerging as a very important component of research laboratory equipment, and research is being conducted on changing the electromagnetic shape of the motor to reduce the noise and electrical energy of the motor, as well as other noise reduction methods [4].

When designing a fume hood, the air velocity at the face of the hood should generally be maintained between 0.3 and 0.5 m/s for effective pollutant evacuation [11], and the internal structure of the hood should be designed in various structural forms to facilitate evacuation. There are various types of fume hoods depending on the purpose, scope, and method of use, but this study focuses on fume hoods in laboratories that use fumes. In order for the fume hood to function properly as a capture, it is most important that the structure be able to maintain a uniform flow rate and suppress or minimize the generation of vortices inside the hood [15]. Regarding control flow rate, air velocity, and face velocity, Ha explained that it is the air velocity that can control the harmful substances at that point by inhaling the air containing harmful substances from the front or opening of the hood into the hood, and that the control velocity means the average velocity at the entrance of the hood [1,10]. Park JC said that the appropriate exhaust air velocity of the hood is in the range of 0.48~0.55m/s considering the local exhaust efficiency and indoor temperature distribution, and the efficiency of the local exhaust system supply air velocity is the highest at 0.35m/s [5]. The face air velocity of fume hoods used to exhaust hazardous chemicals in chemical laboratories should be 0.4~0.7 m/s depending on the laboratory situation [3], and a control air velocity of 0.4 m/s is regulated when gaseous substances are handled in an enclosed fume hood [12].

The structure of a laboratory fume hood consists of a viewing window and sash for viewing the inside, a work surface for placing experimental objects, an airfoil for fluid flow, and a baffle for smooth air exhaust inside the hood and it is shown in **Fig 2**. Fume hoods are applied differently depending on the purpose of use, and can be categorized into 'basic hoods', 'air curtain hoods', and 'quick-exhaust hoods', and are made in various forms depending on the use of the hood, internal materials, and exhaust methods. **Fig 3** shows air flow diagram by Fume hood type.

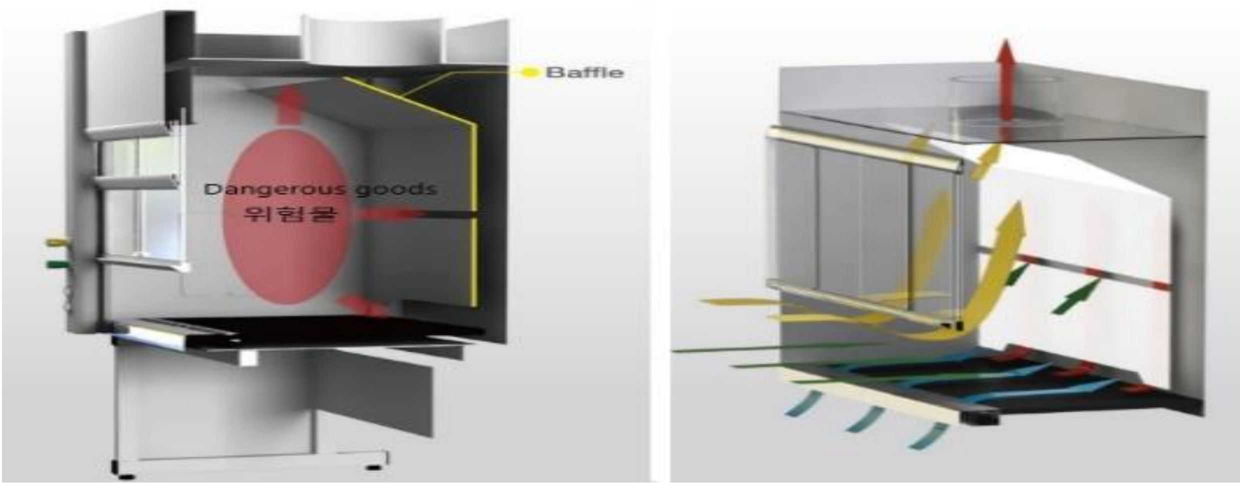


Fig 2. Basic Internal Structure of Fume Hood [25].

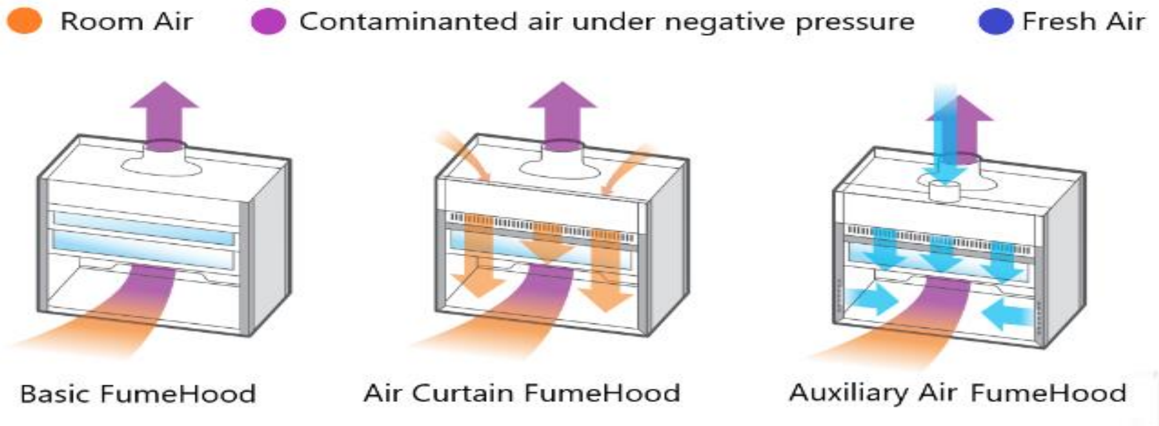


Fig 3. Air Flow Diagram by Fume hood Type [25].

Park.GD emphasized the importance of the structure of the hood by stating that the controlled air velocity of the hood should be vertical and directed inward to overcome any movement [6]. In the breathing zone, a velocity of 0.3 to 0.5 m/s results in uniform air distribution around the perimeter for good air circulation [7], emphasizing the importance of the hood's face air velocity to the safety of the researcher.

For hazardous substances to be controlled, the control flow rate range of 0.4 m/s in the enveloping hood, 0.5 m/s for the side and downward suction type, and 1.0 m/s for the upward suction type is appropriate. [2] When using liquefiable liquids, the fume hood should have a control air velocity of 0.5 m/s to 0.7 m/s [15]. The inlet of the fume hood should be designed with a controlled air velocity of 0.4 to 1.2 m/s to contain laboratory and laboratory contaminants and exhaust all substances generated inside and outside the fume hood, and the air flow direction should be vertical and sucked into the interior of the fume hood [6].

In the exhaust of a fume hood, it was shown that when the supply air was properly distributed while maintaining the flow velocity at the opening, the contaminant concentration in the breathing zone used at the front of the hood was lower [17, 18], indicating that stable air distribution rather than unstable air distribution can prevent the spread of contaminants. Another paper described the structure of a recirculation system by introducing a clean tunnel modular system and mixing 20-30% outside air with a flow velocity of 0.35 m/s from the top to the bottom [19], which is the 'supply-exhaust hood' described in the fume hood type.

In a general chemistry laboratory, the sash is repeatedly opened and closed according to the experimenter's usage. In general, a face air velocity of 0.5 m/s at 100% OPEN is recommended for sashes, but to save energy, the height at which 0.5 m/s is generated by closing the sash is the maximum opening height, preventing the researcher from opening the sash higher than the specified height [12]. An international standard, EN 14175-3, recommends that a sash opening fixture be installed at 500 mm from the working surface. This is a safety measure for researchers to prevent forced primary opening, as rapid sash opening can create vortices and lead to inhalation of hazardous substances (EN 14175-3, clause 3.2) [23].

In this study, we will use the measurement method defined in ASHRAE-110-2016 of the American National Standards Institute (ANSI) and EN 14175-3 of the European Committee for Standardization (CEN) to verify the safety and energy saving factors of fume hoods by reducing the face velocity.

Fume Hood International Standard

The leading fume hood standards are ASHRAE-110-2016 from the American National Standards Institute (ANSI) and EN 14175-3 from the European Committee for Standardization (CEN).

Table 1 shows the international safety standards for fume hoods. These are international standards from organizations involved in laboratory safety, and there is no difference in the standard regulations for the safety of fumes and chemicals in laboratories, but they are applied differently depending on the use and scope defined by the standard.

Table 1. Fume Hood International Standard

Standard	American National Standards Institute (ANSI)	European Committee for Standardization (CEN)
Regulations	ASHRAE 110-2016	EN 14175-3
Purpose	Regulation and standards for environments where exposure to chemical substances may occur.	Maintaining a safe environment when using chemical substances.
Application	Workplaces where chemical substances are used	Ensuring a safe working environment within laboratories.
Guidelines	Guidelines for risk assessment of fumes and gases	Safety guidelines for workers exposed to chemical substances.
Content	Evaluation procedures for fume and gas leakage in testing gases.	Guidelines for chemical exposure-related laboratory safety.

ASRAE-110-2016 focuses on criteria for ventilation and airtightness performance for fume-related chemicals [13] and emphasizes criteria for evaluating gas leaks and hazards in laboratories. In the United States, in particular, the Occupational Safety and Health Act (OSHAct) has been strengthened and a separate regulation (OSHA CFR 1910.1450 Occupational Exposure to Hazardous Chemicals in Laboratories) has been established for laboratory work with hazardous substances [6]. The American National Standards Institute (ANSI) has established safety regulations for fume hoods and recommends that the average face velocity of the air flowing in front of the fume hood should be at least a certain value (0.5 m/s). Exhaust air velocity is an important performance factor of fume hoods, and the National Fire Protection Association (NFPA) in the United States recommends 0.508~0.762m/s as the recommended exhaust air velocity [5,12], and the standard of 0.5m/s as a constant value of exhaust air velocity is set to talk about an environment where researchers can safely conduct experiments. Therefore, it can be seen that fume hood safety standards in the United States are not based on energy reduction, but on ensuring that researchers conducting experiments are safe from harmful substances.

Energy savings are just as important as safety regulations for fume hoods. According to Mills E ,Sartor D (2005), the cost of energy used in fume hoods is a significant expense. Along with basic compliance with regulations for safe laboratory research, this study also advocates for reducing the energy costs of fume hoods by reducing the face air velocity. As the study in **Fig 4** shows, fume hoods are costly in terms of electrical energy, both nationally and regionally. Reducing fume hood air velocity means reducing electricity use, so many research organizations around the world are pursuing efforts to reduce fume hood air velocity. As fume hoods are safety equipment for experiments, it is also important to reduce energy and ensure that they are manufactured in compliance with safety regulations.

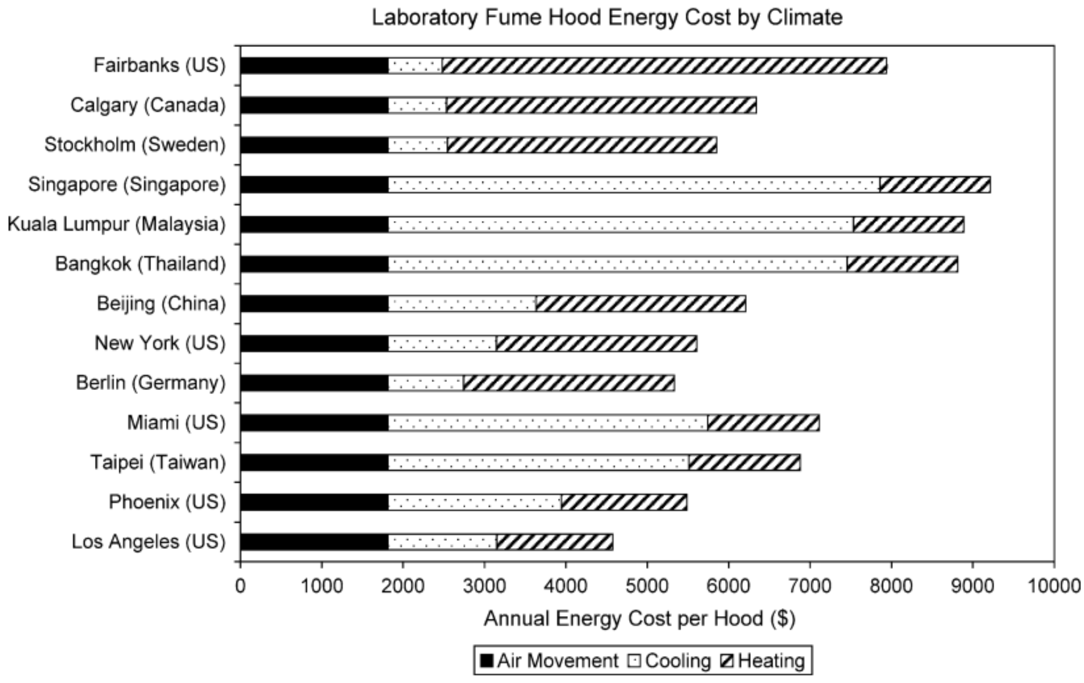


Fig. 1. Assumes a 2-meter nominal hood opening, 30.5 m/min face velocity, fuel reheat, 24-h operation per ANSI standards, weather data from [7], cooling plant efficiency 1.0 kW/ton, ventilation system efficiency of 1.8 W/CFM per [8], and reheat results in a load of 3,525 MJ/m^3-min-year (94,608 BTU/cfm-year). Electricity counted at 3.6 MJ/kWh.

Fig 4. Laboratory Fume Hood Energy Cost by Climate [20].

A study on laboratory safety found that the average controlled air velocity of fume hoods in more than 400 university research laboratories was 0.37 m/s, which is lower than the standard required by the Occupational Safety and Health Act [19]. Because research laboratories contain many types of chemicals and a variety of experiments, experimenters may be exposed to harmful substances in small but continuous amounts [19], and it is recommended that chambers should be stored and used in a way that does not impede airflow, not only during experiments in the chamber but also when analytical instruments are used in the chamber. As shown in **Fig 5**, the use of equipment inside the chamber requires the addition of a bottom structure to ensure that the airflow is unobstructed so that a proper exhaust system can be operated, which is a basic requirement for the use of fume hoods [15].

For researcher safety, SEFA recommends 6 inches (150 mm) from the sash to the work surface. This prevents backflow of hazardous materials that could expose the researcher to the hazardous materials being tested and it is shown in **Fig 6** [24].

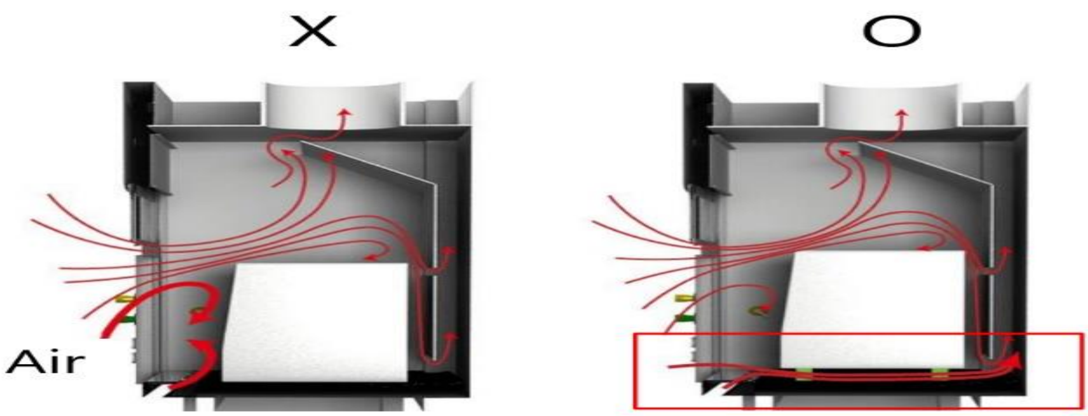


Fig 5. Precautions for Using Equipment Inside the Chamber [25].

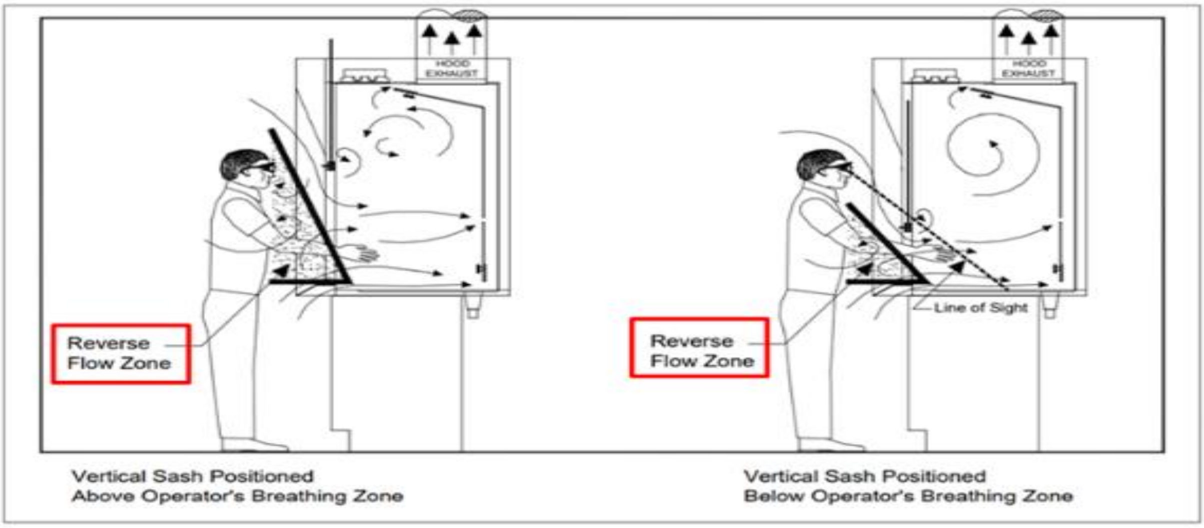


Fig 6. 6inch(150mm) Safe Zone [24].

Measurement of Face Velocity

To measure the face air velocity, the hood is divided into a grid with openings and sashes and measured using an anemometer at each section. This is in accordance with the EN-14175-3 test method.

In order to create a safe environment in research laboratories, the need for relevant laws and regulations and the standardization of facilities and equipment necessary to ensure laboratory safety are fundamental preventive measures [6]. EN 14175-3 provides safety criteria for research laboratories as a whole and provides a more comprehensive standard for research safety facilities by providing safety guidance for the exhaust of research facilities, not just the exhaust of fume hoods. While both ASHRAE 110-2016 and EN 14175-3 provide safety standards for fumes in laboratories, this study chose to use the European EN 14175-3 method of verification because it is more stringent than ASHRAE 110-2016 in terms of face air velocity verification of fume hoods and safety standards for researchers.

III. IMPROVEMENT FOR FUME HOOD FOR ENERGY SAVING AND MINIMUM FACE VELOCITY

Product Design Improvement for Minimum Face Velocity

The design method of the hood should be carried out in an optimal design method for the indoor recirculation airflow situation of the ventilation method and the production method in which the production line is operated through simulation capable of flow analysis based on various basic data [7,9]. **Fig 7** is the result of the analysis of the change of airflow due to the opening and closing of the sash and the exhaust path of the fume generated inside the chamber, which shows the safe exhaust path of the fume inside the chamber through the baffle through the thermal fluid analysis program. The use of CFD for new hoods is critical to design development, and it has been shown that the design of fugitive emissions can be reduced by 65% depending on the flow direction of the fluid dynamics [21]. It was concluded that the commercial availability of CFD is only a design aid for visual phenomena, and that practical flow analysis is best accomplished using validated test methods. Fume hoods in laboratory environments can also turn into experimental environments that generate a large amount of energy and noise due to the use of blowers due to the continuous emission of harmful gases [3]. Therefore, the internal structure of the fume hood should be designed to maintain a constant airflow [14] so that the intake and exhaust of fumes can be well achieved.

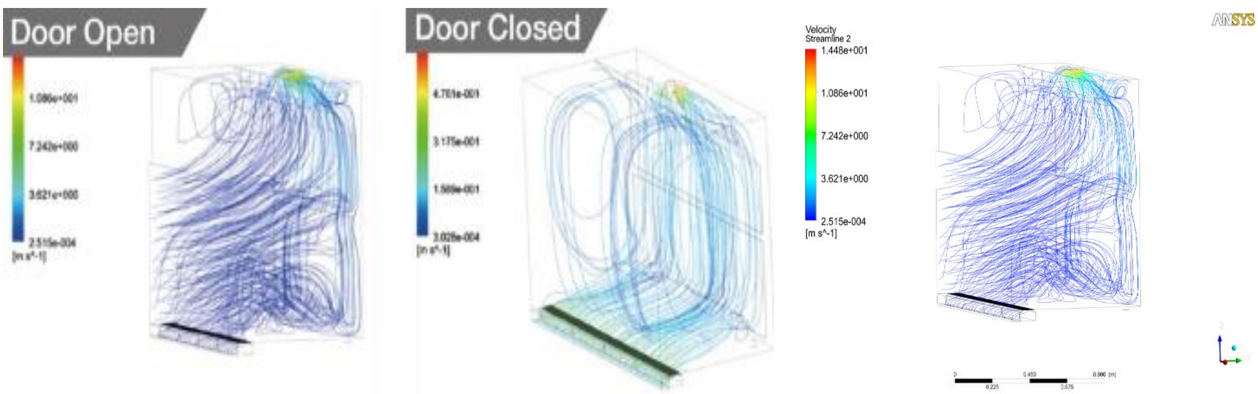


Fig 7. Fume Hood Air Flow Simulation (CFD).

The function of the baffle is critical to improving fume hood performance. If the hood does not adequately capture contaminants, decontamination becomes inefficient [11] and hazardous substances remain inside, endangering researchers and samples. As shown in **Fig 8**, the flow distribution and contamination concentration are improved when baffles are installed on the inside of the fume hood and are better in fume hoods with double baffles than single baffles [10]. Therefore, the importance of the airflow position and angle of the rear baffle inside the hood and the upper baffle toward the duct is confirmed to be the optimal structural form that can change the performance and verify the safety of the fume hood against the face velocity.

Fig 8. Fume Hood Baffle [25]

The structure of the fume hood must be designed so that the intake and exhaust airflow is unobstructed. Baffle modifications and improvements are the most important way to meet the new standards, as they have been tested and evaluated in numerous tests and face air velocities. The importance of the air flow position and angle of the rear baffle inside the hood and the upper baffle toward the duct is the optimal structural form that can change the performance and change the face velocity of the fume hood. Therefore, the design criteria is the change and angle of the baffle.

The reason why the baffle was modified to improve the material is that the smoke test of the inhaled fume showed that the change was very insignificant to establish data for the face air velocity. Changes in the side structure and superstructure of the chamber only had a short-term effect on the fume path and vortex phenomenon, and the vortex phenomenon quickly dissipated over time, showing that it did not affect the fume emission of the hood. Therefore, the positioning and angle of the rear baffle and the positioning of unobstructed parts are very important for the fume path and the exhaust of residual harmful substances at the corners.

Jung JH research proposed a method to improve the shape and angle of the baffle inside the hood for uniform exhaust flow at the opening of the hood as a way to resolve the imbalance of the control flow rate [15] and showed the process of complete exhaust of the fume present inside. Therefore, in this study, through the process of previous research and theoretical background, we improved the design of the inner rear baffle and upper baffle as shown in **Fig. 9**, and through simulation and several design changes and experiments, we finalized the form that has been verified for product improvement.

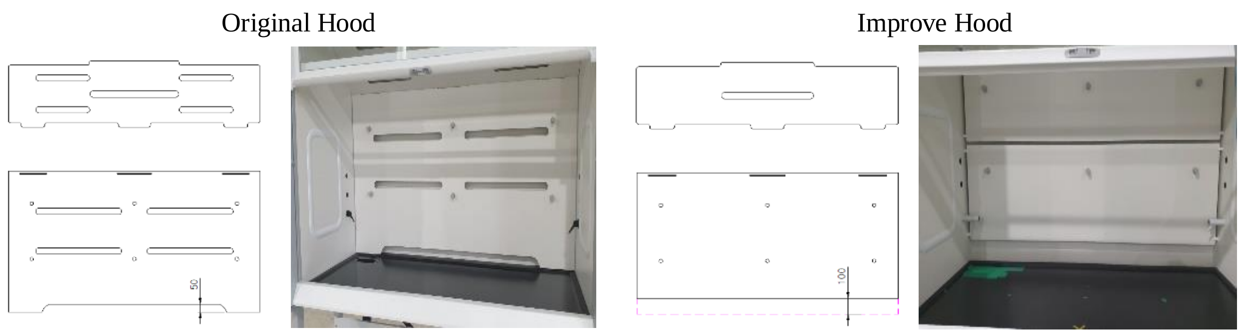


Fig 9. Baffle Changes.

We validated the performance of the improved product against three fume hood performance test criteria that are directly related to researcher safety. We applied the international standards EN-14175 and ASHRAE-110-2016 for the performance verification tests.

First, the face velocity test, in which the measuring surface of the hood opening was divided into 15 categories, and a structure was set up to measure the wind speed for a certain period of time for each category and it is shown in **Fig 10**. The experimental process is shown in **Fig 11**.

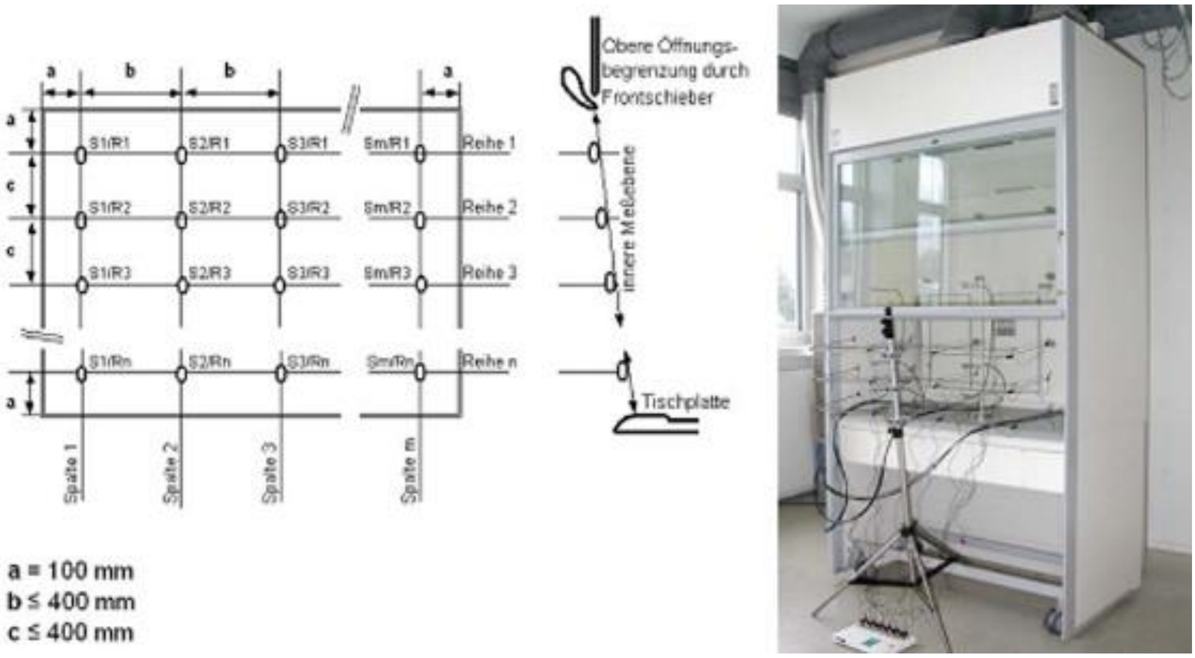


Fig 10. EN-14175-3 Test [23]

Fig 11. Face velocity Test [24]

The Face Velocity test in **Fig 12** is a fume hood test in which a structure is set up to measure the air velocity at the measurement face of the hood opening as specified in EN 14175-3, and individual velocities are measured and recorded (EN 14175-3, 5.2).

Kim JM and Kim YS stated that if the hazardous substances are handled in the lower part of the fume hood where the control flow rate is relatively low, it is difficult to capture them properly, and the likelihood of exposure to hazardous substances will be greater when the researcher conducts direct experiments in front of the fume hood, and the safety of the researcher cannot be guaranteed due to the mixing of fluid molecules with each other, so the fume hood should be designed in such a way that the control flow rate can be maintained [3, 12].

Second, **Fig 13** shows the process of testing for human health hazards. To measure the air velocity, we followed the standard of ASHRAE 110-2016, which stipulates that no harmful gases should be detected by measuring 3 inches (75 mm) from the sash and 22 inches (550 mm) from the working surface (ASHRAE-110-2016, 4.8) [24].

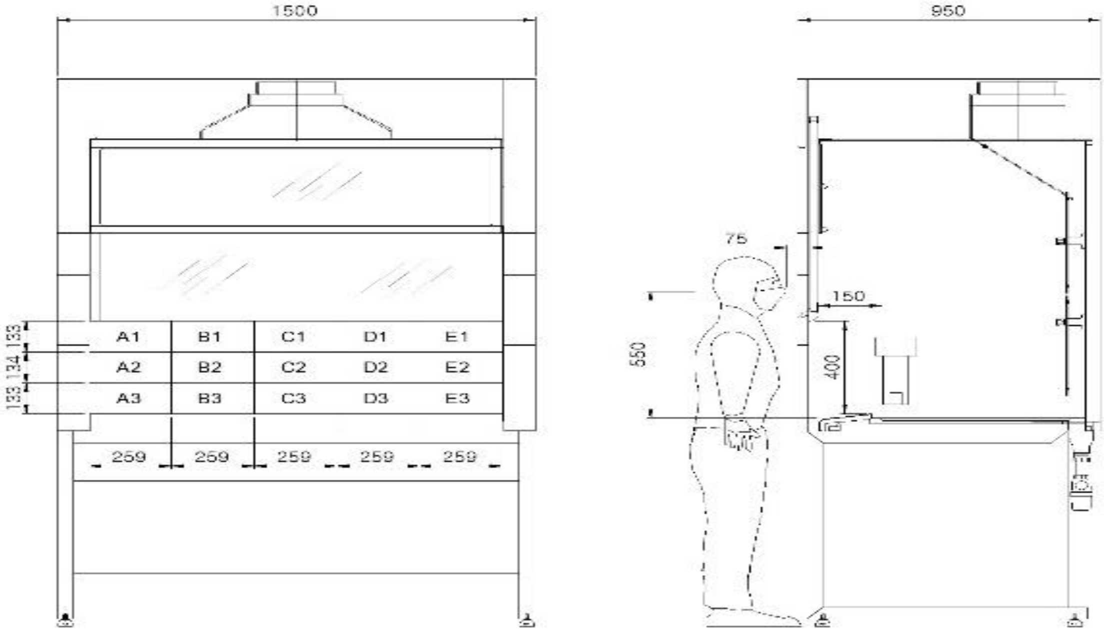


Fig 12. Diagram of Hood Opening Showing Face Velocity Traverse Locations.

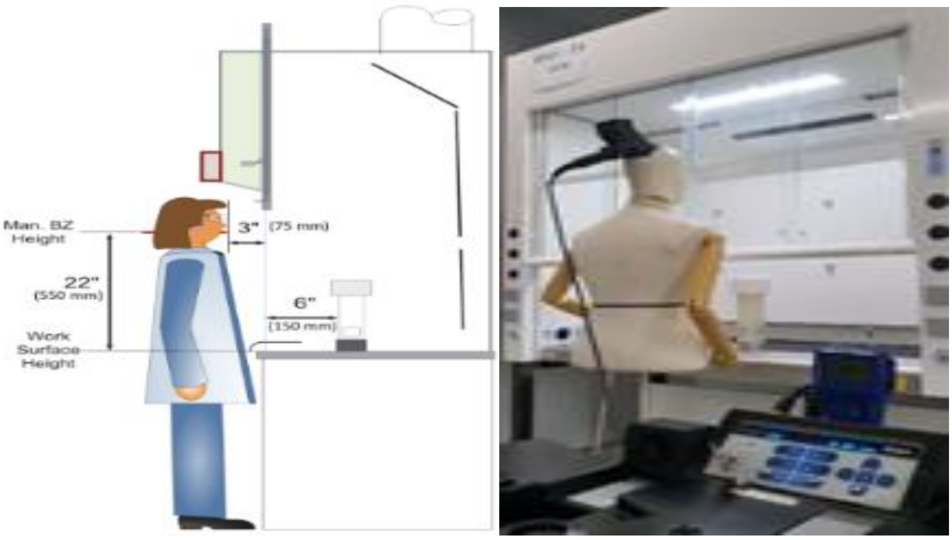


Fig 13. Mannequin and Ejector Positions.

Thirdly, the face air velocity test of fume hoods requires a visual pattern test to measure the invisible air flow, which is a visualization test to show the fume movement in a way that allows the researcher to trust the test. **Fig.14**, **Fig 15** is the Smoke Test, which visualizes the emissions from the hood chamber and shows the exhaust pattern of harmful gases (EN 14175-3, 5.3).

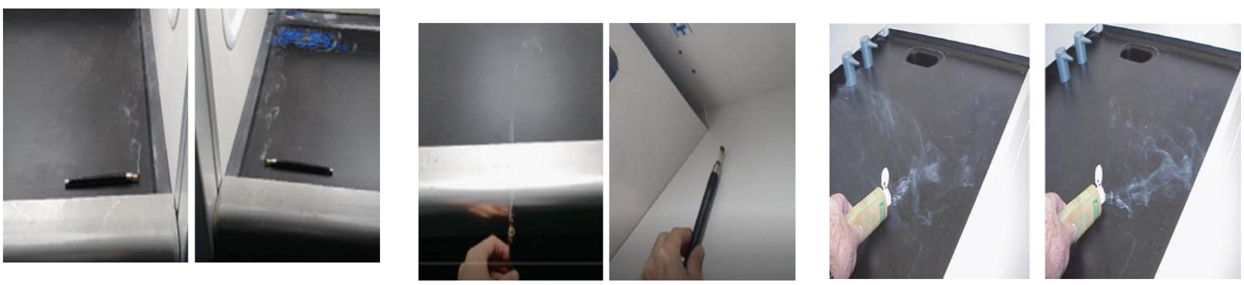
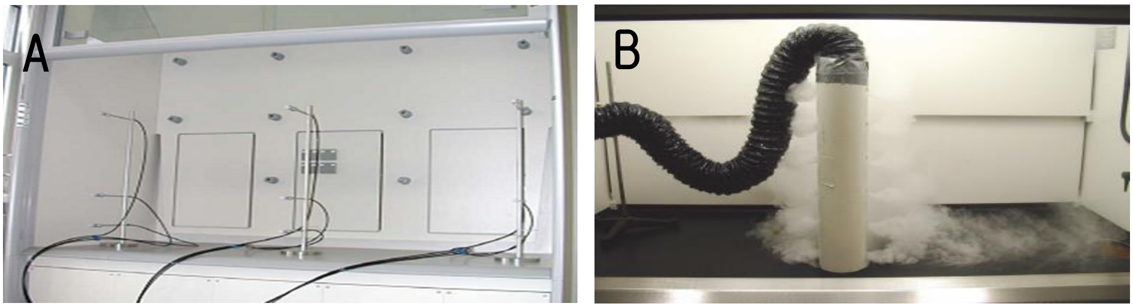


Fig 14. Smoke Test.

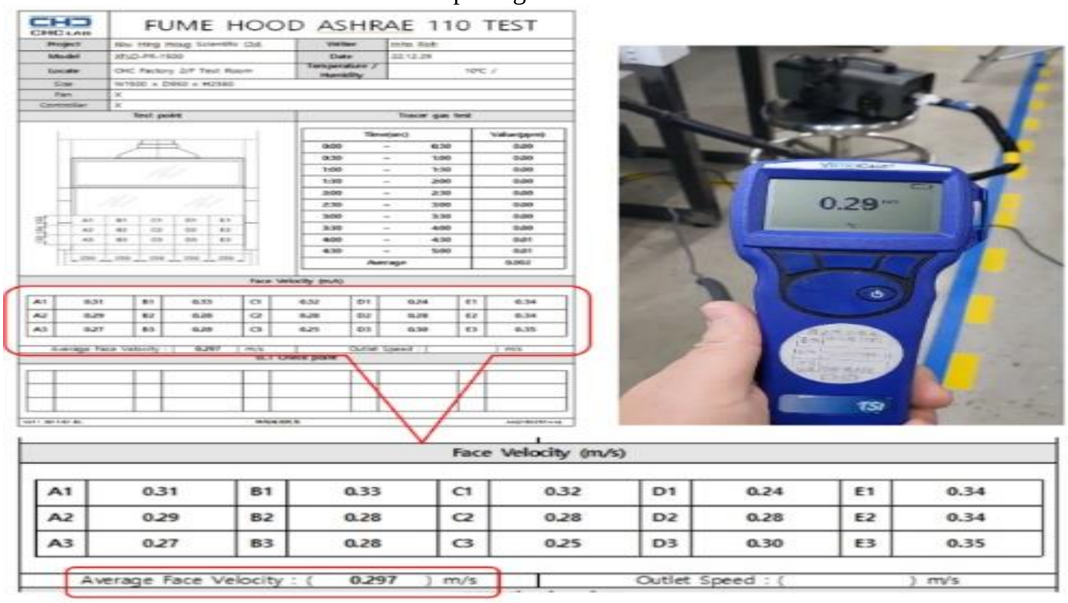


EN 14175-3 test [23]. ASHRAE-110-2016 test [24].

Fig 15. Cylinder Diffusion of Smoke from Smoke Generator.

Fume hood performance tests with the improved baffle design resulted in an average of 0.297 m/s, which is lower than the European standard of 0.5 m/s, the American standard of 0.4 m/s, and the Korean standard of 0.4 m/s. The control flow rate and flow rate of fume hood exhaust are determined by the speed of the blower [16]. The results show that the use of high-efficiency electric motors in the blower enables efficient power energy distribution [4], which allows low electrical energy to be used to maintain a safe fume hood face air velocity, thus satisfying both stability and energy savings. **Table 2** is the fume hood face air velocity measurement data, and **Table 3** is the tracer gas leakage test result, which is required to be satisfied with no leakage of tracer gas and no more than 0.05 ppm of gas leakage when the blower is operated with electric energy used at 5% OPEN of the exhaust dampers at a wind speed of 0.3 m/s (ASHRAE-110-2016, 7.2).

Table 2. Hood Opening Measurement Face Result



FUME HOOD ASHRAE 110 TEST

Face Velocity (m/s)

A1	0.31	B1	0.33	C1	0.32	D1	0.24	E1	0.34
A2	0.29	B2	0.28	C2	0.28	D2	0.28	E2	0.34
A3	0.27	B3	0.28	C3	0.25	D3	0.30	E3	0.35

Average Face Velocity : (0.297) m/s | Outlet Speed : ( ) m/s

Table 3. Tracer Gas Test

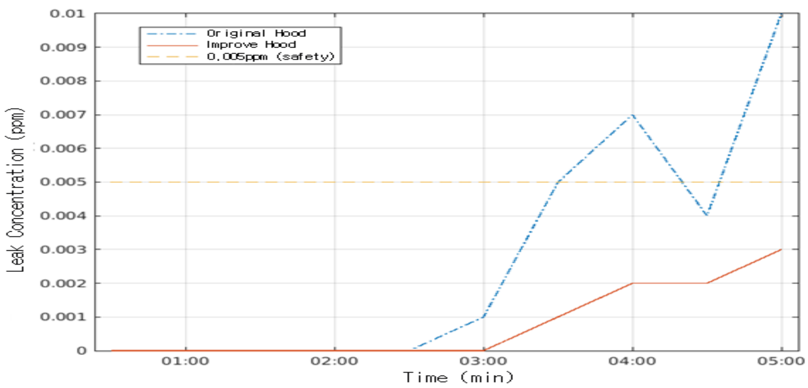


Table 3 shows the results of the tracer gas leakage test, which according to ASHRAE 110-2016 requires no leakage of tracer gas (SF6) after measurement for 5 minutes after gas distribution (Section 8.1.11). CFD simulations showed that the gas leakage test was significantly reduced with the improved hood baffle. In an overseas study by Huang R F [22], the face velocity is minimized in the experiments. The results of SF6 gas leakage test using 0.25m/s as the standard for the face velocity showed that the leakage concentration was only 0.001ppm up to 0.003ppm. (Huang R F ,Chen J K ,Hung W L(2012)).

In this study, the tracer gas (SF6) test was also conducted, and according to the standard of ASHRAE 110-2016 (8.1.11), the average value after measuring for 5 minutes should not exceed 0.005 ppm. However, as shown in Table 3, the phenomenon of rapid changes in the leakage test process is a new discovery in the trial test, which provides an opportunity to discover the importance of the test site and the importance of regular test checks of existing hoods, and the development of the new improved fume hood has achieved satisfactory results that meet international standards, with an average leakage concentration of 0.003 ppm over a period of time.

The test step in **Fig 16** checks for harmful gases that have stagnated inside the chamber due to vortices, and no leakage to the outside was found. The other type of check is to ensure that the hazardous gases generated within the chamber do not backflow to the outside (View a), and to ensure that the hazardous gases are naturally inhaled and exhausted into the hood from the researcher's position (View b).

View a (IN) View b (OUT)

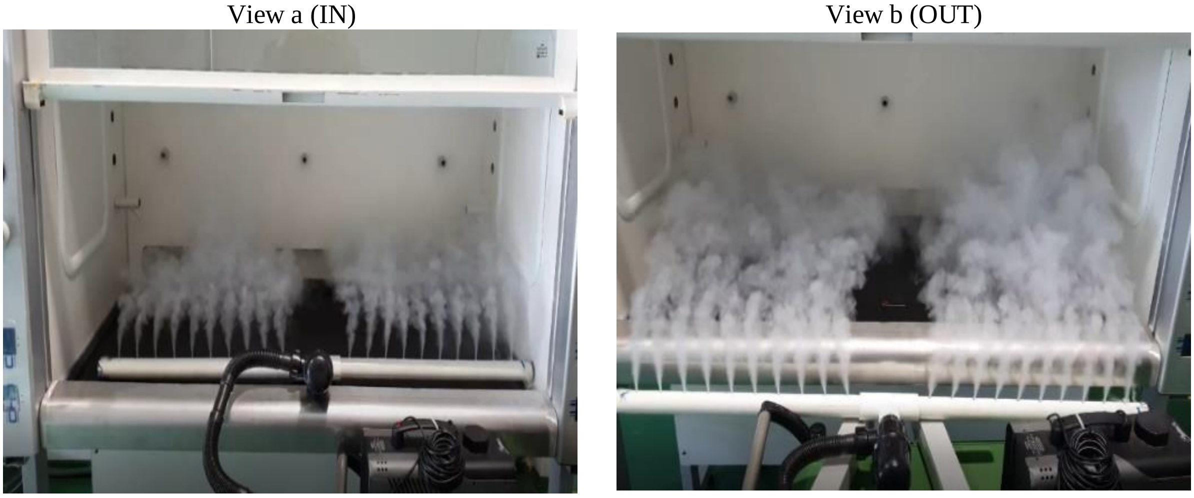


Fig 16. Face velocity Test Results.

Energy Efficiency for Fume Hood

Through experimental studies, we would like to determine the extent to which the improved fume hood provides energy savings. In a general chemistry laboratory, the appropriate face air velocity is 0.25~0.3 m/s when the sash is 100% open and 0.5 m/s when it is 50% open [13], and the front sash is frequently opened and closed depending on the experimenter's research method and shape. According to Kim, the face air velocity should be constant when the sash is 100% open and 50% open, and the face air velocity of 0.4 m/s should be kept constant regardless of whether the sash is open or not [11]. However, in general laboratories, the face air velocity is not consistent depending on the opening of the sash between 100% and 50% open, so when the sash is opened and closed, the fume inside the sash flows back out, causing dangerous cases of inhalation by researchers. Fume hoods also do not allow the exhaust blower to run at 100% for safe use. This is because if the blower is operated at 100%, the harmful gases formed inside the fume hood may be discharged to the outside along with the research samples. Also, if the exhaust volume of the blower is low, there is a risk of cross-contamination between the harmful gases inside the chamber and the research samples. Therefore, the air velocity on the inlet side of the fume hood is maintained at 0.4 m/s with 20~50% blower operation.

Table 4 is a graph comparing the face velocity of the fume hood with the exhaust air volume. The fume hood is a device that smoothly exhausts air through a blower, and it is an experimental device connected to an air conditioning system. The air velocity is supposed to change depending on the opening of the exhaust air volume. However, due to the nature of laboratories using fume hoods, 100% of the exhaust air volume is not used in case of fire, fume, or emergency. In case of an emergency, 100% of the exhaust air volume can be used for quick exhaust for the safety of the laboratory and the safety of the researchers. Therefore, the use of the fume hood blower for normal laboratory operation maintains an appropriate amount of exhaust airflow, which is recommended by international standards as 0.4~0.5m/s. Maintaining face air velocity for the safety of researchers and exhaust air volume to reduce power usage also has a significant impact on energy savings by reducing the power used by fume hoods.

Table 4. Face Velocity and Exhaust Air Volume

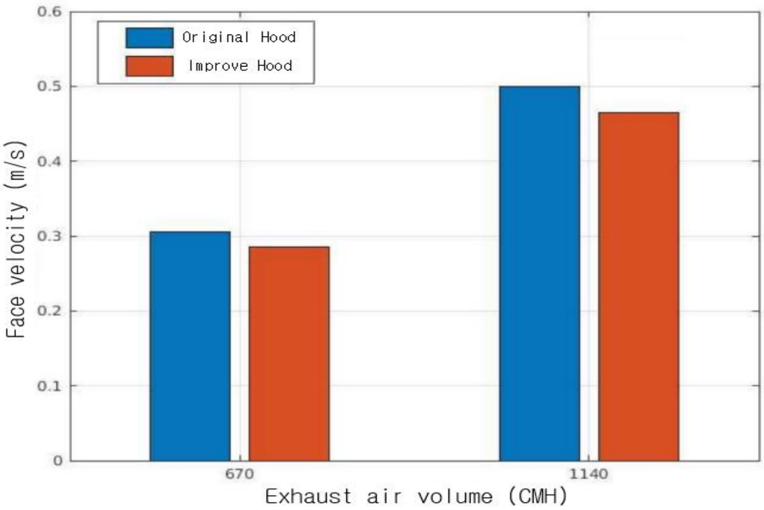
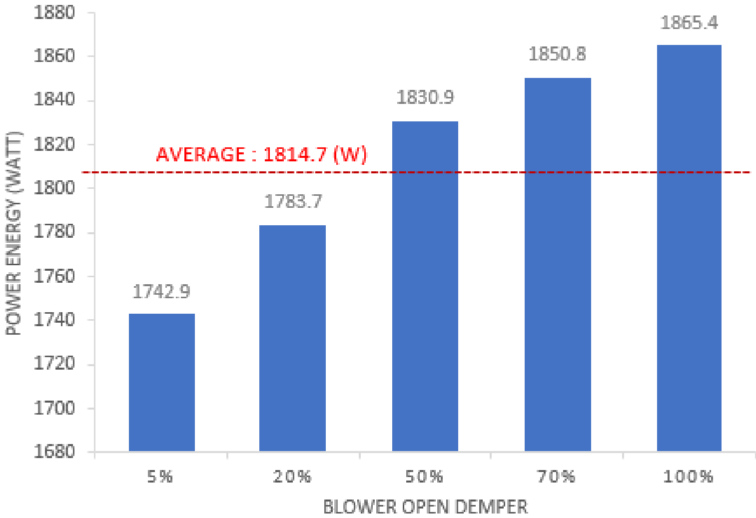


Table 5 shows a comparison of fume hood power usage before and after the fume hood structure improvement. Before the improvement, the average power used was 2345.6 W based on a face air velocity of 0.4 m/s. With the improved hood, the face air velocity was maintained at 0.297 m/s, and the power consumption was measured, and the power consumption was 1814.7 W, which is 22.6% less than before the improvement. This measurement of power is a measurement method that applies the general fume hood usage method, the opening and closing method of the blower, and the opening and closing method of the dampers, and the average value is obtained by measuring the power according to the opening and closing method of the blower of the supply and exhaust. It shows the usage and average value of power energy according to the opening of the exhaust demper of the fume hood, and it was possible to reduce the amount of power used for the blower while maintaining the average speed of the face velocity at 0.297m/s, and the result showing a reduction in power energy of 22.6% was obtained.

Table 5. Blower Open Demper



IV. CONCLUSION

Fume hoods used in laboratories are important experimental equipment that ensures the safety of researchers and the safety of experimental samples. Maintaining a constant air velocity is key to effectively managing fume emissions during experiments. Proper use of a fume hood requires a controlled air velocity of 0.4 m/s to capture contaminants in the chamber while effectively exhausting harmful substances. During experiments in the fume hood's chamber, the blower must run 24 hours a day to minimize fume backflow and ensure safe exhaust, and the face velocity must be maintained at a constant speed to minimize fume exhaust and veortexing. The resulting power consumption could be a significant economic burden so reducing power consumption by using a fume hood is a very important consideration. In this study, the face velocity of the fume hood was adjusted to 0.297 m/s and we reduced 22.6% of energy compared with a prior situation, which satisfied both the safety of the researchers and the economics of management. Fume hoods are a fundamental piece of equipment for researchers to conduct safe experiments, so reducing fixed energy costs is a key part of managing a lab. However, artificially controlling the face velocity of the fume hood can compromise the safety of researchers and the protection of research samples. Rather than simply reducing the energy, a compromise between economic and ergonomic safety experiments is needed. As shown in previous studies, it is possible to implement a variable control system. However, it was concluded that the initial goal of this study, which was to achieve speeds below 0.25 m/s, is not feasible with the current structure and system. The use of blowers for exhaust requires a certain amount of continuous power to maintain a face velocity. Considering the amount of power used by the air conditioning system, it is natural for laboratory managers to seek further energy reduction.

In this study, we try to find the lowest face velocity of the fume hood for reducing energy consumption and protecting the researcher's safe. The average face velocity of experimental exhausts set by international organizations is between 0.4 m/s and 0.45 m/s. These are the minimum regulations for safe use of the fume hoods. With the internal structural improvement of the fume hood, we can reduce the face velocity to 0.297 m/s, which satisfies the international regulations for the safety of the researcher and the experimental sample. This was the best that could be achieved with structural improvements to the baffle and airfoil, but we recommend the face velocity of the fume hood is 0.3 m/s – it is the minimum face velocity for guarantee the safety of researchers. Requiring a lower face velocity in the name of energy savings would not only compromise the safety of the researchers conducting the experiments, but also the protection of the samples being studied. In previous studies, the face velocity of 0.3 m/s could be enough for reducing pollutant capture experiments with different hood type. [2] The standardized test methods for the fume hoods so far are face velocity, gas outflow test, and smoke pattern test, as conducted in research experiments. It is expected that more experimental data could be accumulated if professional hood testing equipment are introduced.

To efficiently utilize a safe hood, it is crucial to maintain a consistent face velocity regardless of the sash opening degree. This implies that the performance should remain constant even when energy usage varies between 100% and 50%. Therefore, a hood capable of maintaining safe and effective exhaust using only 50% of the energy would be an exceptionally effective choice for laboratory managers and administrators. The findings of this study are expected to make significant contributions to the advancement of laboratory safety practices and the creation of safe working environments for researchers. With the development of new fume hoods with streamlined inner chambers that can control air volume, face velocity, the problem of vortices, and natural air exhaust may be eliminated and the desired control of 0.3 m/s or less may be possible. However, in the current situation, it is believed that maintaining the face velocity for the safety of the lab and researchers is more necessary than artificially controlling the face velocity for energy savings. The experimental results of this study suggest that 0.297 m/s is a new standard for safe laboratory and researcher safety and electrical energy reduction.

However, the results of the stand-alone fume hood may not be universally applicable to all laboratory settings. Therefore, future research aims to investigate the reduction rates and safety assurance of airflow test values for standalone hoods and interconnected fume hoods used together. In addition, there is a need for further research and performance validation concerning the implementation of energy-saving measures to achieve the required 0.25m/s face velocity as mandated by regulatory bodies and laboratory management entities. Furthermore, investigations conducted in controlled laboratory environments, accounting for external factors, are imperative to validate the efficacy and applicability of these measures across diverse research facilities.

Data Availability
No data was used to support this study.

Conflicts of Interests
The author(s) declare(s) that they have no conflicts of interest.

Funding
No funding agency is associated with this research.

Competing Interests
There are no competing interests.

References

[1]. Ha HC (2010), " A Study on the Suitability of the Control Flow Rate of the Hood of Local Exhaust System", 2010-72-889, KOSHA, http://oshri.kosha.or.kr. 5p. 21p. 145p https://oshri.kosha.or.kr/oshri/publication/researchReportSearch.do?mode=view&articleNo=63081

[2]. Rie DH (1997), " Implementation and innovation of an industrial ventilation facilities.". SAREK J, 26 (2): 67-75. https://scienceon.kisti.re.kr/commons/util/originalView.do?cn=JAKO199722454382632&oCn=JAKO199722454382632&dbt=JAKO&journal=NJOU00290364

[3]. Kim JN (2022), A Study on laboratory space plan for enhanced safety, korea university, A master's thesis. 13p. 72p.

[4]. H.-J. Jang, C.-H. Lee, C.-M. Kim, and K.-C. Kim, "Design of BLDC Motor for Air Conditioning and Reduction of Torque Ripple with Slot Asymmetric Application," The Journal of Innovation Industry Technology, vol. 1, no. 2, pp. 25–31, Sep. 2023, doi: 10.60032/jiit.2023.1.2.25.

[5]. Park JC (2003), A Study on the Improvement Strategies for Exhaust Performance in Commercial Kitchen Hoods, SAREK, Vol.15, No.5, pp439-445,

https://scienceon.kisti.re.kr/commons/util/originalView.do?cn=JAKO200311921641399&dbt=JAKO&koi=KISTI1.1003%2FJNL.JAKO200311921641399

[6]. Park GD (2017), A Study on the Safety Facility Standardization for Chemical Laboratory using Anthropometry, Graduate School, Myongji University. 43p. 111p.

[7]. An JS (2023), Evaluation of Airborne Infection Risk according to Operation of Mechanical Ventilation and Recirculation Airflow System, University of Seoul, A master's thesis. 29p.

[8]. Park IK (2011), The Current Status of Occupational Health Management of University Laboratories. Graduate School of Public Health, Daegu Haany University. 14p.

[9]. Y.-H. Kim and J. Lee, “Technology and Service Trends for Ensuring Safety in Smart Manufacturing,” The Journal of Innovation Industry Technology, vol. 1, no. 3, pp. 123–128, Dec. 2023, doi: 10.60032/jiit.2023.1.3.123.

[10]. S.-C. Lee, Y.-Y. Ok, and S.-G. Yoo, “Local Exhaust Ventilation Characteristics of Limestone Dust by Model Experiments and Numerical Simulation,” Journal of the Korean Society of Mineral and Energy Resources Engineers, vol. 50, no. 5, pp. 660–666, Oct. 2013, doi: 10.32390/ksmer.2013.50.5.660.

[11]. Lim KB, Choi SK (2001), Numerical study of a flow field in a fume hood, Hanbat National University Transactions of Institute for Foundational Technology for Production, Vol.1, No, 1 pp.55~62 http://imgsvr.riss4u.net/contents/kdam4/A/8715/0101/8715010108.pdf

[12]. Kim JH (2016), A Study on the Classification of Hazardous Explosion Area and Management Measures in Laboratories Handling the Flammable Liquids, Seoul National University of Science and Technology, A master's thesis. 31p.

[13]. Kim YS, Oh YK (2008), A Study on Improvement of Industrial Hood in Ventilation System for Elimination of Harmful Material and Dust, KSMTE, Vol. 20, No. 4, pp .238~244. 2008, https://scienceon.kisti.re.kr/commons/util/originalView.do?cn=JAKO200817154052493&dbt=JAKO&koi =KI STI1.1003%2 FJNL.JAKO200817154052493

[14]. Han DH, Park MK (2005), Development of Basic Local Exhaust Ventilation System for Experimental Education, JEHS Vol. 31, No. 5, pp 372~378, 2005, https://scienceon.kisti.re.kr/commons/util/originalView.do?cn=JAKO200503018449615&dbt=JAKO&koi=KISTI1.1003%2FJNL. JAKO200503018449615

[15]. J.-H. Jung, S.-W. Lee, S.-M. Lee, B.-H. Shon, J.-H. Lee, and Y.-J. Jung, “Improvement of Capturing Velocity in the Fume Hood using Computational Fluid Dynamics(I) - Uniform flow,” Journal of the Korea Academia-Industrial cooperation Society, vol. 14, no. 2, pp. 962–969, Feb. 2013, doi: 10.5762/kais.2013.14.2.962.

[16]. H. Kim and K. Jeong, “Development of an Automatic Face Velocity Controller for a Fume Hood System,” Journal of The Korean Society of Manufacturing Technology Engineers, vol. 22, no. 2, pp. 304–309, Apr. 2013, doi: 10.7735/ksmte.2013.22.2.304.

[17]. I.-K. Park, S.-W. Lee, J.-H. Jung, and Y. G. Phee, “A Study on the Status of Management for Personal Protective Equipments & Fume Hoods in University Research Laboratories,” Journal of Korean Society of Occupational and Environmental Hygiene, vol. 24, no. 2, pp. 229–237, Jun. 2014, doi: 10.15269/jksoeh.2014.24.2.229.

[18]. Park JC(2009), A Numerical Analysis for the Performance Improvement of Fume hood Exhaust Air using an Air-Curtain, Hanyang University, A master’s thesis. 5p

[19]. Noh TK(2021), A Study on the Characteristics of Etching Process Fume by Functional Change of Semiconductor Local Exhaust System, Korea National University of Transportation, A master's thesis. 15p UCI : I804:43010-200000500860.

[20]. E. Mills and D. Sartor, “Energy use and savings potential for laboratory fume hoods,” Energy, vol. 30, no. 10, pp. 1859–1864, Jul. 2005, doi: 10.1016/j.energy.2004.11.008.

[21]. P. J. Witt, C. B. Solnordal, L. J. Mittoni, S. Finn, and J. Pluta, “Optimising the design of fume extraction hoods using a combination of engineering and CFD modelling,” Applied Mathematical Modelling, vol. 30, no. 11, pp. 1167–1179, Nov. 2006, doi: 10.1016/j.apm.2006.02.003.

[22]. “Flow and Containment Characteristics of a Sash-less, Variable-Height Inclined Air-Curtain Fume Hood,” The Annals of Occupational Hygiene, Mar. 2013, doi: 10.1093/annhyg/met011.

[23]. European Committee for Standardization (CEN). EN 14175: Laboratory furniture - Fume cupboards - Safety and performance requirements. Brussels: CEN; [2003]. https://www.cencenelec.eu/areas-of-work/cen-cenelec-topics/

[24]. American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). ASHRAE 110-2016: Method of testing performance of laboratory fume hoods. Atlanta: ASHRAE; 2016.https://www.ashrae.org/search?q=ASHRAE-110-2016

[25]. CHC Lab’s, Educational material, http://www.chclab.com