

# Heating, Ventilation, and Air-Conditioning (HVAC) System in Physics Laboratory at Laguna University

GLODOVIZA, TRISHA MAE<sup>1</sup>, MARISTELA, MICAELLA ANTOINETTE<sup>2</sup>, OXINA, REX ANGELO<sup>3</sup>  
<sup>1, 2, 3</sup>College of Engineering, Laguna University

**Abstract-** This study designed and evaluated a HVAC system for the Physics Laboratory at Laguna University to improve thermal comfort and indoor air quality. Ducted and Blow-through systems were analyzed using cooling load calculations and CFD simulation through ANSYS Fluent. Results showed that both systems maintained acceptable indoor conditions; however, the blow-through system provided more uniform airflow and achieved a stable indoor temperature of in accordance to the recommended comfort range for laboratories. The selected system was implemented and tested under varying occupancy conditions, showing effective temperature regulation and positive user satisfaction. The study concludes that the blow-through HVAC system is the most suitable configuration for the Physics Laboratory.

**Keywords-** HVAC, Laboratory, Laguna, Simulation, Peak load Condition

## I. INTRODUCTION

A comfortable indoor environment is essential in laboratories to maintain productivity, safety, and effective learning conditions. However, the Physics Laboratory at Laguna University experiences high indoor temperatures and inadequate air circulation, resulting in thermal discomfort and reduced indoor air quality. These conditions highlight the need for an efficient Heating, Ventilation, and Air Conditioning (HVAC) system capable of maintaining proper temperature and airflow distribution. This study focused on the design and evaluation of two HVAC configurations, namely the ducted system and blow-through system, to determine the most suitable system for the laboratory. Cooling load calculations and Computational Fluid Dynamics (CFD) simulation using ANSYS Fluent were conducted to analyze airflow behavior, temperature distribution, and cooling performance. The selected system was further implemented and tested under varying occupancy conditions to evaluate its effectiveness in maintaining indoor comfort. The objectives were to identify and implement the type of HVAC configuration that is suitable for Laguna University's Physical Laboratory in terms of

indoor air quality through indoor temperature, humidity, heat rejection, and occupant capacity.

## II. LITERATURE REVIEW

*HVAC Systems in Laboratory Setting:* University laboratories function as instructional and research environments proper ventilation and environmental control are essential for safety and operational efficiency [1]. Laboratory ventilation systems remove contaminated air, maintain room pressurization, and regulate airflow through coordinated exhaust and supply systems [2], [3], [4].

In laboratory settings, HVAC systems help achieve thermal comfort, indoor air quality (IAQ), and efficient airflow distribution by controlling temperature, humidity, and air cleanliness [6], [7], [9], [10]. Studies show that laboratory spaces should maintain temperatures between 20°C–25°C with 35%–50% relative humidity to provide a safe and comfortable environment [5]. Proper HVAC design must consider building characteristics, occupancy, internal heat loads, and Indoor Environmental Quality (IEQ), as these factors directly affect occupant health, comfort, and productivity [6],[7],[8],[10].

*Ducted Systems and Blow through systems:* HVAC systems are commonly classified as decentralized or centralized systems depending on their method of air distribution and control. Decentralized HVAC systems provide localized cooling and independent temperature control, making them suitable for small to medium-sized buildings because of their low installation cost, operational simplicity, and flexibility [11],[12]. Studies also show that ductless split systems are widely used worldwide due to their efficiency and ease of installation [13].

One important HVAC airflow arrangement is the blow-through configuration, where the fan is positioned before the cooling coil to force air through the system [14]. Research indicates that fan placement affects cooling

efficiency, moisture removal, and overall thermal performance. Blow-through systems may reduce cooling load requirements and improve energy efficiency under specific operating conditions [15].

In contrast, centralized HVAC systems use a central plant with chillers, boilers, pumps, and air-handling units to distribute conditioned air throughout a building [11]. These systems support advanced environmental control strategies and rely heavily on properly designed ductwork for efficient air distribution [10].

*Simulations for HVAC systems:* Building Performance Simulation (BPS) is an important tool in evaluating HVAC systems because it enables the analysis of thermal behavior, energy consumption, and system performance within a building environment. Through computer-based software, BPS creates a digital model of a building that allows engineers to predict building conditions, identify possible issues, and optimize HVAC operation efficiently and cost-effectively [16], [17]. Studies show that BPS helps determine optimal HVAC conditions while reducing energy losses and improving indoor comfort [17], [18].

Computational Fluid Dynamics (CFD) is commonly integrated into HVAC simulations to analyze airflow, heat transfer, and air distribution inside enclosed spaces [18]. CFD simulations allow engineers to predict airflow behavior and evaluate thermal conditions without extensive physical testing [19]. Research also indicates that CFD thermal analysis improves HVAC model optimization while minimizing time and expenses [20].

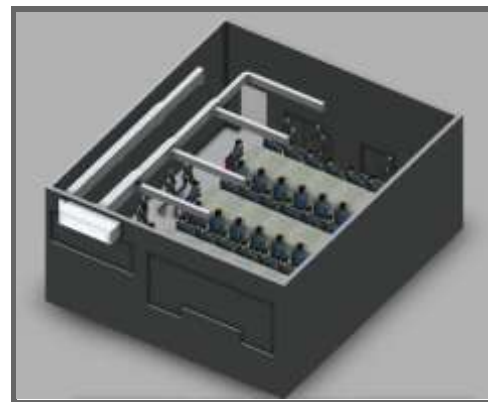
Among the available simulation tools, ANSYS Fluent is widely used for analyzing fluid flow and heat transfer phenomena in HVAC applications because of its accuracy and reliability in engineering simulations [21].

### III. METHODOLOGY

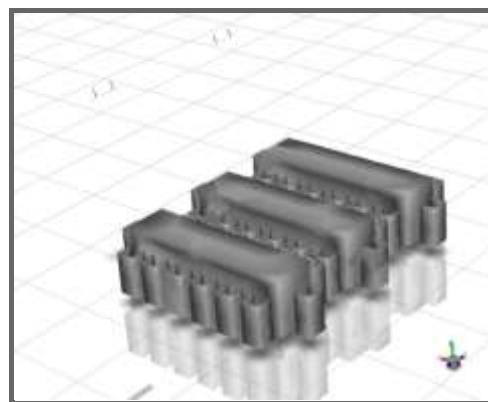
This study focused on the design, simulation, and implementation of an efficient HVAC system for the Physics Laboratory at Laguna University. The aim was to improve indoor air quality, thermal comfort, and cooling performance within the laboratory environment.

Prior to the design of the HVAC system, the required cooling load capacity of the laboratory was determined

through manual engineering computations. The total heat transfer within the laboratory enclosure was calculated using the Cooling Load Temperature Difference (CLTD) method. The total cooling load considered sensible and latent heat contributions from occupants, lighting systems, electrical appliances, ventilation, infiltration, windows, doors, roof, and external walls. Based on the conducted calculations, the total computed cooling load requirement of the Physics Laboratory was determined to be 5 hp, which served as the basis for the selection and design of the proposed HVAC systems.



(a)



(b)

Fig.1. Designed HVAC Configurations: (a) ducted system, (b) blow-through system

Two HVAC configurations were developed and analyzed: the ducted HVAC system and the blow-through system. The ducted configuration incorporated ductwork layouts, air terminals, and airflow distribution components, while the free-blow system utilized direct air discharge without extensive ducting. Both systems were designed to maintain the target indoor temperature range of 20°C to 25°C under

varying occupancy conditions. CAD-based layouts and BPS techniques were utilized to evaluate airflow behavior, temperature distribution, and system efficiency. CFD simulations were also employed to analyze air circulation and thermal performance within the laboratory space.



(a)



(b)

Fig. 2. Implemented blow-through system: (a) Fan Coil Unit, (b) Condensing Unit

Following simulation and comparative analysis, the more efficient HVAC configuration was selected for actual implementation in the Physics Laboratory—the Blow-through System. The selection process was based on the system's thermal performance, airflow distribution, cooling efficiency, humidity control, and ability to maintain the desired indoor temperature range under varying occupancy conditions. Considerations such as ease of installation, compatibility with the existing laboratory structure, and minimization of structural modifications were also taken into account during the final selection of the HVAC design.



Fig. 3. Observation and performance testing of the implemented system

The installed system was then subjected to performance testing under actual operating conditions. Parameters monitored during the testing phase included indoor temperature, relative humidity, heat rejection, and the effect of varying numbers of occupants on thermal performance. Ten (10) operational trials were conducted to determine the consistency and effectiveness of the implemented HVAC system.

To further evaluate the effectiveness of the implemented HVAC system, survey questionnaires were administered to laboratory users to assess satisfaction regarding thermal comfort, air quality, and overall indoor conditions. Statistical tools, including measures of central tendency and Cronbach's Alpha analysis, were applied to validate the reliability of the gathered data and evaluate the consistency of responses. The collected data were analyzed and interpreted to determine whether the implemented HVAC system successfully improved the indoor environmental quality of the Physics Laboratory.

IV. RESULTS

A. Use of Simulation Software

Table I. Indoor Conditions met by Ducted Design through Simulation

Indoor Air Conditions	
Air Velocity (inside the duct works)	7.5422 m/s
	8.09 m/s
	9.03 m/s
Air Velocity (output)	10 m/s
Indoor Air Temperature	19°C

The ducted system design reached a temperature lower than that of the cooling comfort range. Moreover, the ducted system design produced a concerning high velocity output. The Total Pressure Drop derived reached 200.4408 Pa for the overall ducting.

Table 2. Indoor Conditions met by Blow-Through System design through Simulation

Indoor Air Conditions	
Air Velocity Output	0.4095 m/s
	0.2047 m/s
Indoor Air Temperature	24°C

On the other hand, the blow-through system design met the desired temperature of 24°C between the range of cooling comfort. Hence, the air velocity outputs are well within the desirable velocity range for occupancy space.

B. System Implementation

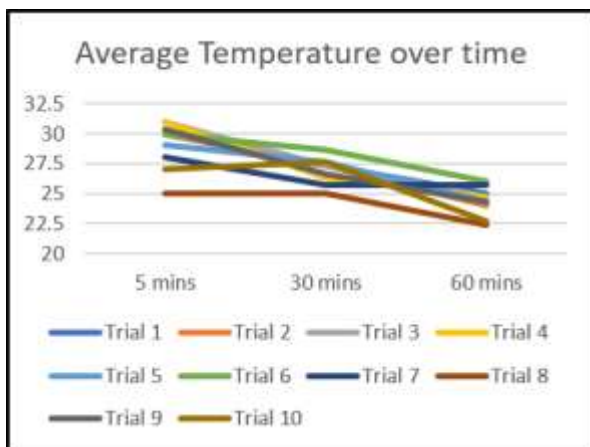


Fig. 4. Temperature Gathered Over Time from the 10 Trials

Figure 4 illustrates the behavior of temperature inside the room after the system was implemented and operated over time. A pattern emerged from the graph where a downward slope is evident which indicates a drop in temperature. It is also noticeable that the endpoints of each trial are divided into two— trial endpoints are concentrated either above 24°C or below 23°C

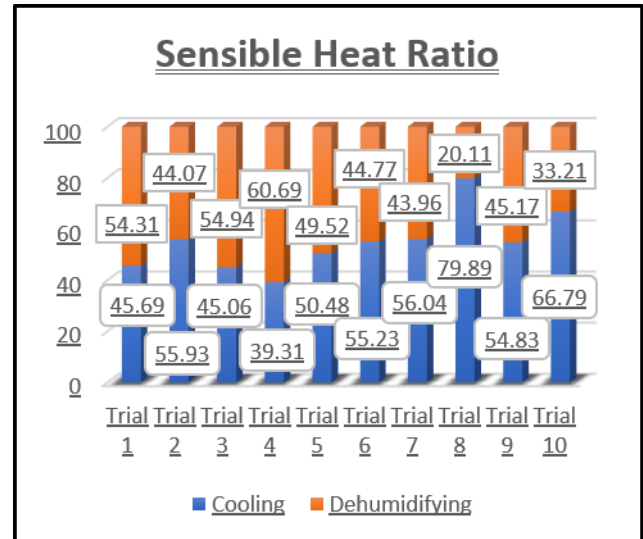


Fig. 5. The Sensible Heat Ratio from Each Trials

The Sensible Heat Ratio (SHR) was computed to determine how the system operates at different situations. Figure 3 shows the performance of the system in percentages in terms of cooling, highlighted in blue, and dehumidifying, highlighted in orange.

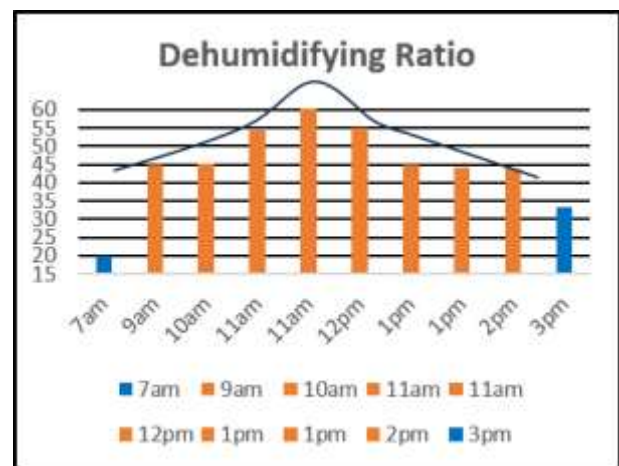


Fig. 6. Graph of Dehumidifying Ratios

The dataset of dehumidifying ratio during the peak load period has a Mean of 49.085, a Median of 57.815, a Mode

of 44.77, a Standard Deviation of 6.5491, and a Coefficient of Variation of 13.34%. A value of Coefficient of Variation between 10% to 20% is usually considered very good, meaning the data is highly consistent with little variation [22].

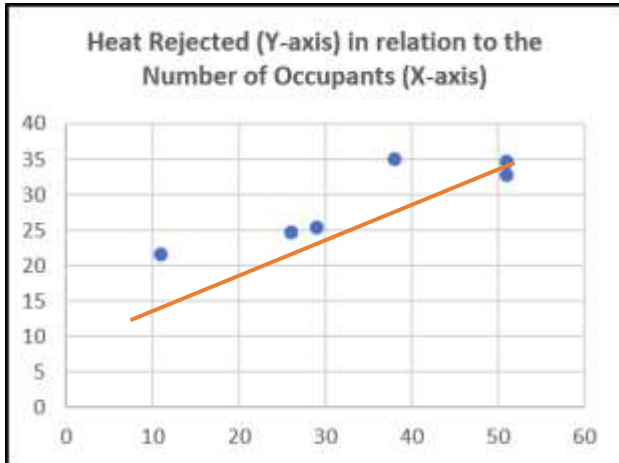


Fig. 7. Graph of the Relationship Between Heat Rejected and the Number of Occupants

A simple regression line suggests that there is a direct relation between the two variables. A Multiple R value of 0.9008, suggesting that a strong linear relationship, and a Squared R value of 0.8114, suggesting that 81.14% of the of the heat rejected can be accounted for the number of occupants, were obtained. A Probability value (P-value) of 0.014280676 was obtained which is lower than 0.05 solidifying that there is indeed a direct relationship between the heat rejected and the number of occupants.

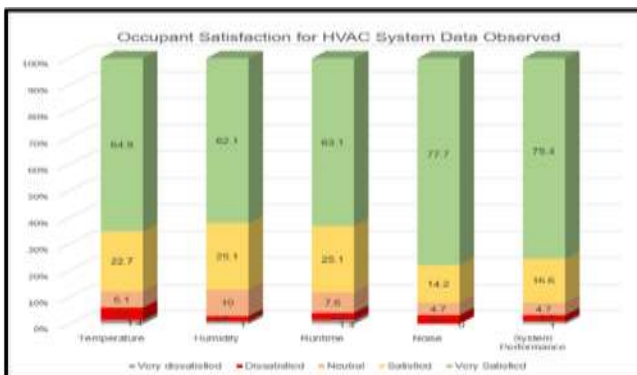


Fig. 8. Occupant Satisfaction for the Implemented HVAC System for the Different Parameters

Figure 8 illustrates the overall responses from the 211 respondents. For the temperature, a CSAT score of 88%

was obtained. A CSAT score of 87% for Humidity, 88% for the Runtime of the system, 91% for the Noise Level, and 92% for the system performance. Overall, a CSAT score of 89.2% was obtained.

The Cronbach's alpha was computed to have a value of 0.9908 which confirmed that the survey was indeed reliable as an alpha value of  $\alpha \geq 90$  suggests an excellent internal consistency.

## V. CONCLUSION

The Design and Implementation of HVAC system in Physics Laboratory at Laguna University was successfully conceptualized and assessed through validated computations, theoretical applications and repeated observations. Blow-Through design configuration has maintained the standard laboratory conditions. It was therefore implemented and it continuously sustains a consistent indoor air quality within the lab.

Key outcomes of the study include:

*Unit work is maximized within the first 30 minutes.* The system provides a great compressor work at the beginning of the observation period, which gradually decreases once the indoor temperature approaches 25°C to 23°C.

*Stable air condition.* Once the indoor air reaches 24°C with a relative humidity of 45%, observed records indicated that there are no further significant changes within the air quality inside the lab.

*Reduced moisture within the area.* Dehumidification is prioritized due to poor indoor air condition. However, heat load variations relative to time affects the moist reduction rate.

*Equal air distribution.* Temperature finding of the distributed thermometers was found to have 0-0.5°C differences which proves that the whole perimeter receives an equal amount of air circulation.

*Heat rejection rates depend on the number of occupants within the room.* Higher heat rejection values were observed in trials with higher number of occupants. With a  $\pm 2.9031$  freedom of error, the amount of heat to be rejected can be predicted by the number of occupants during classes

of 120 min duration at peak load conditions using the equation:

$$Y = 0.3241x + 18.1895$$

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