Evaluation of Split-Wall Air Conditioning Performance Using Eco-Friendly Refrigerant and a Custom-Built Data Logger

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Abstract. The purpose of this research is to evaluate the performance of a split-wall air conditioning unit utilizing a custom-built data logger. An R290, 2.5 kW split-wall air conditioning unit was installed for this investigation. A custom-built data logger was employed to measure all the evaluation parameters. This data logger was built with an ATmega 2560 microcontroller and integrated with several sensors compacted into one device. The experimental results demonstrate that the Mean Absolute Error (MAE) values for temperature measurement calibrations were 0.45°C for sensor X1 and 0.325°C for sensor X2, respectively. Both sensors exhibited exceptional accuracy and reliability, with their calibration errors falling well within the acceptable tolerance limits established by industry standards. The superior performance of sensor X2, with a lower MAE value, indicates enhanced precision in temperature measurement applications, while sensor X1 also maintained satisfactory accuracy levels for the intended experimental requirements. Regarding system performance, the Coefficient of Performance (COP) analysis revealed that the air conditioning unit achieved a COP value of 3.56. The measured COP of 3.56 indicates that the system generates approximately 3.56 units of cooling output for each unit of electrical energy input, demonstrating remarkable energy efficiency and thermodynamic optimization.

Keywords: Custom-Built Data Logger, Evaluation and Performance, Split-Wall Air Conditioning

1 Introduction

The evaluation of air conditioning system performance has become increasingly critical as energy efficiency standards continue to evolve and environmental concerns drive the demand for more sustainable cooling solutions (Ali & Mahdi, 2023; Negara et al., 2023). Split-wall air conditioning systems, which dominate residential and commercial applications due to their versatility and ease of installation, require a comprehensive performance assessment to ensure optimal operation and energy conservation. The Coefficient of Performance (COP), defined as the ratio of useful cooling output to electrical energy input, serves as the primary metric for quantifying air conditioning

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efficiency and remains fundamental to both regulatory compliance and economic optimization (Li & Li, 2024).

Traditional methods of evaluating split-wall air conditioning performance often rely on standardized laboratory conditions or manufacturer specifications that may not accurately reflect real-world operating environments. These conventional approaches frequently fail to capture the dynamic nature of actual operating conditions, including variable ambient temperatures, humidity levels, thermal loads, and system cycling patterns. Furthermore, existing monitoring solutions are often limited by their reliance on generic measurement equipment that lacks the precision, customization, and cost-effectiveness required for comprehensive long-term performance evaluation (Santosh et al., 2019; Suamir et al., 2020).

The development of custom-built data logging systems presents a compelling alternative to overcome these limitations and provide more accurate, detailed, and economically viable performance assessment capabilities. Custom data loggers can be specifically designed to address the unique measurement requirements of split wall air conditioning systems, incorporating specialized sensors, tailored sampling rates, and application-specific data processing algorithms. This approach enables researchers and practitioners to obtain high-resolution performance data under actual operating conditions while maintaining the flexibility to adapt measurement protocols to specific research objectives or system configurations (Conte et al., 2023; Negara & Anakottapary, 2024).

This research addresses the critical need for improved split-wall air conditioning performance evaluation through the development and implementation of a purpose-built data logging system. The custom approach presented herein demonstrates how targeted sensor selection, optimized measurement protocols, and specialized data processing techniques can provide superior insights into actual system performance compared to conventional monitoring methods. The methodology establishes a framework for accurate, continuous COP assessment that can be adapted to various system configurations and operating environments, ultimately contributing to enhanced energy efficiency and reduced environmental impact in the air conditioning sector.

2 Methodology

2.1 Experimental Setup

The experimental investigation was conducted using a 2.5 kW split-wall air conditioning system operating with R290 refrigerant, which was selected for its favorable thermodynamic properties and eco-friendly characteristics for environmental considerations. R290 is considered a more environmentally friendly refrigerant compared to other types of refrigerants due to its lower global warming potential and ozone depletion potential (Heredia-Aricapa et al., 2020). The system was installed within the Laboratory of Refrigeration at Politeknik Negeri Bali, providing a controlled environment for comprehensive testing while maintaining representative ambient climate conditions characteristic of the Bali region. The performance evaluation methodology was specifically designed to reflect actual operating conditions prevalent in tropical climates, ensuring that the collected data would be representative of real-world applications. The laboratory installation facilitated precise environmental control and accommodated a cooling load of up to 2.5 kW. This cooling load was generated primarily by laboratory equipment utilized during the experimental investigation. The schematic model of the study is displayed in Fig. 1. The equations for determining the COP (Coefficient of Performance) of the air conditioning unit can be seen in Equation 1 (Matsuda et al., 2022).

$$COP = \frac{h1-h4}{h2-h1} \quad (1)$$

Where $h1$ is the enthalpy at evaporator inlet (saturated vapor) (kJ/kg), $h2$ is the enthalpy at compressor outlet (superheated vapor) (kJ/kg), and $h4$ is the enthalpy at evaporator inlet (saturated liquid) (kJ/kg).

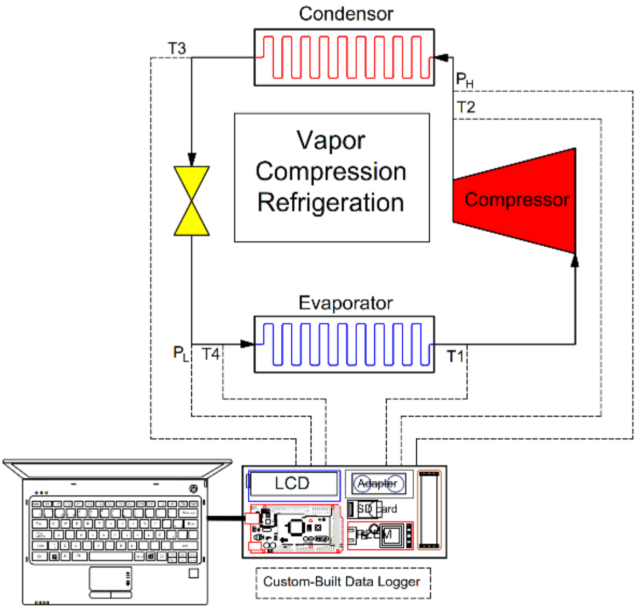

Figure 1. Schematic Model of Experimental Setup

2.2 Custom Data Logger Development

The heart of the measurement system consisted of a purpose-built data logger incorporating an Arduino Mega 2560 microcontroller as the central processing unit. This microcontroller was selected based on its extensive input/output capabilities, robust processing power, and proven reliability in data acquisition applications (Negara et al., 2024). The detailed specifications of the Arduino Mega 2560 are summarized in

Table 1, highlighting the technical features that enable comprehensive data collection and processing for air conditioning performance evaluation. The data logging system integrated multiple DS18B20 digital temperature sensors, chosen for their high accuracy and digital communication capabilities. The sensors were strategically positioned to monitor both evaporating and condensation temperatures, enabling direct measurement of the refrigeration cycle's thermal performance characteristics. Supporting electronic components included an 800 tie-point breadboard for circuit prototyping and component integration, 4.7 kΩ resistors for sensor pull-up configurations, and additional electronic circuits necessary for signal conditioning and data processing. The modular design approach facilitated system modifications and troubleshooting while maintaining measurement integrity throughout the experimental period.

Table 1. Detailed Specifications of Arduino Mega 2560

Specification	Details
Microcontroller	ATmega 2560
Weight	37 grams
Dimensions	101.52 mm x 53.3 mm
Voltage of operating	5V
Pins of analog input	16

2.3 Sensor Calibration and Validation

To ensure measurement accuracy and traceability, both DS18B20 temperature sensors underwent rigorous calibration procedures using a water bath calibration methodology. The calibration process employed a high-precision reference thermometer to establish accurate temperature standards across the operational range. This calibration approach verified sensor performance and enabled the quantification of measurement uncertainties inherent in the data acquisition system. The calibration accuracy was evaluated using the Mean Absolute Error (MAE) metric, calculated according to Equation 1.

$$MAE = \frac{1}{n}\sum_i^n |T_{sensor,i} - T_{ref,i}| \quad (1)$$

where MAE represents the mean absolute error, $T_{sensor,i}$ denotes the individual sensor reading predictions, and $T_{ref,i}$ represents the corresponding reference temperature measurements. This statistical approach provided a comprehensive assessment of sensor performance and established confidence intervals for subsequent performance calculations.

3 Result and Discussion

3.1 Sensor Calibration

Both temperature sensor X1 and sensor X2 were calibrated using Mean Absolute Error (MAE) analysis to obtain accurate sensor measurements. The temperature water bath calibration was divided into four different temperature points, including 25°C, 50°C, 75°C, and 100°C, to establish a comprehensive calibration curve as shown in Table 2. The corresponding reference temperature measurements were obtained using a high-precision digital thermometer that was equipped with a traceable calibration certificate. This reference thermometer had an accuracy of ±0.1°C and a resolution of 0.01°C, ensuring reliable standard measurements for the calibration process. This range was selected to cover the typical operating conditions expected during experimental procedures and to ensure linear response verification across the measurement spectrum.

Table 2. Comprehensive Calibration Curve of DS18B20 Sensors with High-Precision Digital Thermometer

Measuring points	Corresponding reference temperature	Average measurement of Sensor X1	Average measurement of Sensor X2
1	24.9	25.2	24.9
2	49.2	50	50.2
3	75.2	74.3	74.3
4	100.7	99.6	99.6

Both sensors X1 and X2 underwent multiple testing procedures, specifically three replicate measurements, before obtaining the average results to ensure statistical reliability. The sensors were subjected to various temperature conditions using a water bath system. This triplicate testing protocol was implemented to minimize measurement uncertainty and identify potential outliers in the sensor response data. From Table 2, the temperature measurement calibrations for both sensor X1 and sensor X2 can be observed. The MAE analysis for sensor X1 yielded a result of 0.45°C. This result was deemed acceptable because it falls within the specified MAE tolerance value of ±0.50°C. Furthermore, the MAE result from sensor X2 was 0.325°C, which is significantly lower than that of sensor X1. This superior performance of sensor X2 demonstrates enhanced precision and reliability in temperature measurement applications. The calibration results indicate that both sensor X1 and sensor X2 are well-calibrated instruments due to their demonstrated capability and accuracy, which remain within the established calibration standard values. The successful calibration of both sensors ensures that subsequent temperature measurements will maintain high accuracy and reliability throughout the experimental process. These calibrated sensors provide confidence in data collection and support the validity of temperature-dependent analyses in the research study.

3.2 COP Analysis

Figure 2 illustrates the evaporating temperature profile of the split wall air conditioning system throughout the experimental period. As can be observed, the temperature initially starts at approximately 26°C, which corresponds to the ambient room temperature before the system activation. Subsequently, the temperature drops sharply to 14°C at around 1200 seconds, indicating the rapid engagement of the refrigeration cycle and the onset of effective heat removal from the evaporator coil. The system experiences a further slight temperature decrease to 10°C at 3600 seconds, demonstrating the continued optimization of the refrigeration cycle as thermal equilibrium is approached. This phenomenon results from the evaporator in the air conditioning system operating under optimal conditions (Negara et al., 2024), which leads to an efficient refrigerant temperature reduction. The progressive temperature drop indicates proper refrigerant flow, adequate heat transfer surface area, and effective thermal exchange between the refrigerant and the surrounding air.

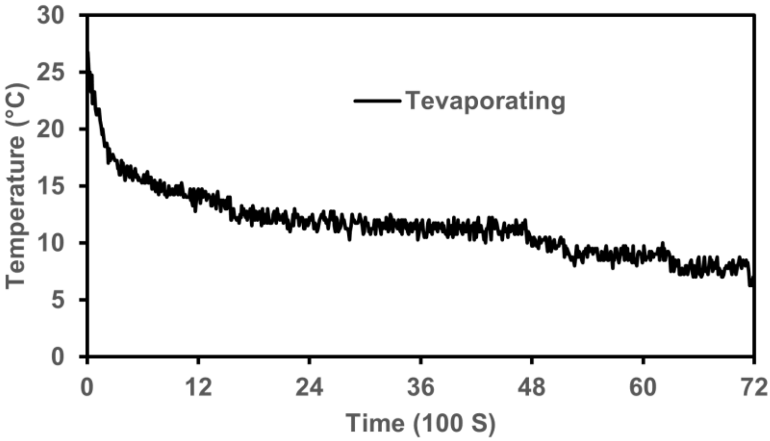

Figure 2. Evaporating Temperature Profile of Split-Wall Air Conditioning

Furthermore, this cold refrigerant effectively absorbs the sensible and latent heat loads from the conditioned space, thereby completing the thermodynamic cycle as designed. The heat absorption process facilitates the removal of thermal energy from the indoor environment, contributing to the desired cooling effect. At approximately 6000 seconds, the evaporating temperature stabilizes at 7°C and remains relatively constant throughout the remainder of the evaluation period. This steady-state condition indicates that the system has reached thermal equilibrium and is operating at its designed capacity (Negara et al., 2025).

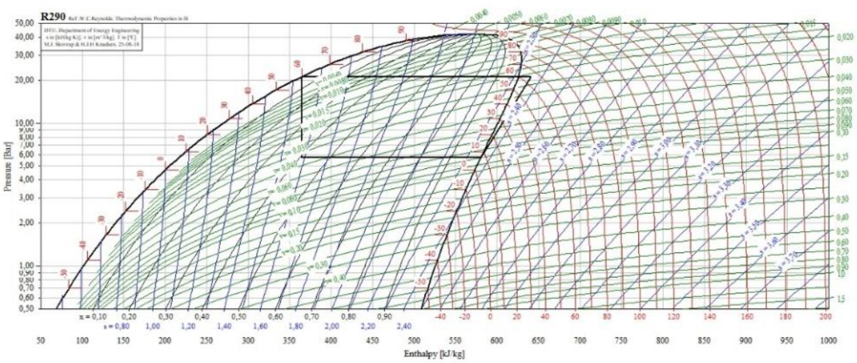

Figure 3. P-H Diagram of a Split-Wall Air Conditioning System using R290, Generated by CoolPack

The Coefficient of Performance (COP) was calculated using CoolPack software, a specialized thermodynamic analysis tool widely recognized in the HVAC industry for its accuracy in refrigeration system calculations. This software facilitates precise COP determination by incorporating comprehensive thermodynamic properties and cycle analysis algorithms. Based on the calculations performed using CoolPack, considering the measured evaporating and condensing temperatures, which were 6.5°C and 60°C, the COP of the air conditioning unit was determined to be 3.56. This result is considered to be an acceptable and efficient COP value, indicating superior performance of the air conditioning system. The obtained COP of 3.56 demonstrates that the system delivers four units of cooling capacity for every unit of electrical energy consumed, reflecting excellent energy efficiency and optimal refrigeration cycle performance. This high COP value suggests proper system design, adequate refrigerant charge, clean heat exchanger surfaces, and optimal operating conditions, all of which contribute to the overall energy efficiency and environmental sustainability of the cooling system. Figure 3 shows the P-H diagram generated from CoolPack based on air conditioning evaluation.

4 Conclusion

The comprehensive performance evaluation revealed that the air conditioning unit achieved a Coefficient of Performance (COP) of 3.56. This COP value indicates that the system generates approximately 3.56 units of cooling output for each unit of electrical energy input, demonstrating remarkable energy efficiency and optimal thermodynamic performance. The evaporating temperature profile showed effective system operation, with stabilization at 7°C under steady-state conditions. The custom-built data logger approach provides superior insights into actual system performance compared to conventional monitoring methods, offering a cost-effective alternative for comprehensive long-term performance evaluation. These findings contribute significantly to enhanced energy efficiency and reduced environmental impact in the air conditioning sector, supporting the development of more sustainable cooling solutions in tropical climate applications.

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