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Performance Evaluation of a Locally Assembled Split-Unit Air Conditioning System Using Indigenous Components for Residential Cooling Efficiency

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Abstract: The growing reliance on air conditioning (AC) systems in residential and commercial buildings has led to significant increases in energy consumption and associated greenhouse gas emissions, underscoring the need for cost-effective and sustainable cooling technologies. In this study, the feasibility and performance of a 1-horsepower (1 HP) non-inverter split-unit AC system assembled entirely from locally sourced components were evaluated under controlled residential conditions. Essential parts, including copper tubing, aluminum fins, compressor units, and refrigerant gases, were procured from regional suppliers and integrated following standard Heating, Ventilation, and Air Conditioning (HVAC) design protocols. Performance tests were conducted across five rooms in a residential apartment-comprising a lounge (largest), masters bedroom, and three additional bedrooms of decreasing size-to assess cooling effectiveness. Using an infrared thermometer (IR8895), temperature metrics including saturation temperature, cooling rate, and peak cooling temperature were recorded. Initial room temperatures ranged from 23.5°C to 26.2°C, while final cooling temperatures ranged from 16.1°C to 16.9°C. Cooling time increased progressively with room size, extending from 10 to 100 minutes. Corresponding saturation temperatures were observed at 24.9°C to 26.6°C, with saturation times between 3.24 and 5.43 minutes, and peak temperatures consistent with the final cooling levels. Calculated cooling loads were 28.8 W (small rooms), 47.0 W (medium rooms), and 65.93 W (large rooms), with respective power consumption values of 85.5 W, 142.6 W, and 199.6 W. The Energy Efficiency Ratio (EER) and Coefficient of Performance (COP) were determined to be 9.25 and 2.7, respectively, across room types. The results indicated that the locally assembled split-unit AC system delivered competitive cooling performance relative to commercial equivalents, particularly in terms of thermal regulation, response time, and energy efficiency. The use of indigenous materials and components did not compromise operational reliability or compliance with HVAC standards. These findings support the viability of locally fabricated AC systems as a sustainable alternative for effective residential cooling in resource-constrained settings.

Keywords: Split-unit air conditioner; Local sourcing; Energy efficiency; Thermal performance; Sustainable cooling; Indigenous assembly

1 Introduction

Assembling and testing of split unit AC systems using locally sourced materials is a critical aspect of the HVAC industry. This process involves the construction and evaluation of AC units often used in residential and commercial buildings. These are a type of HVAC system that consists of two main components: an indoor unit (IU) and an outdoor unit (OU). The IU is typically installed inside the building, while the OU is placed outside [1, 2]. These two units are connected by refrigerant lines, which allow for the transfer of heat from the indoor space to the outdoor environment. Assembling and testing of split unit AC systems involve the construction and evaluation of these components to ensure proper functioning and efficiency. The process of assembling a split unit AC system using locally sourced materials begins with the selection of high-quality components such as compressors, condensers, evaporators, and refrigerant lines [3]. These materials are then assembled according to the manufacturer's specifications to create the indoor and outdoor units (IOUs). Once the units are assembled, they are connected by refrigerant lines and electrical wiring to complete the system. These systems are often more affordable than central AC systems, rendering them a desired choice for homeowners and businesses on a budget. Additionally, locally assembled split unit AC systems do not require complex installation and maintenance, as the overall cost is quite affordable [4, 5]. These systems are designed to cool specific areas or rooms, rather than the entire building, which can lead to significant energy savings. By only cooling the spaces that are in use, locally assembled split unit AC systems help reduce energy waste and lower utility bills. However, locally assembled split unit AC systems also have some drawbacks. One potential issue is the noise generated by the OU, which can be disruptive in residential areas [6]. Additionally, these systems may not be as effective in cooling large spaces or multiple rooms, as they are designed for more localized cooling.

Locally assembled split unit AC systems offer a cost-effective and energy-efficient cooling solution for many homeowners and businesses. While they may have some drawbacks, such as noise and limited cooling capacity, their affordability and ease of installation make them a popular choice in many regions. One of the primary issues is the lack of availability of high-quality materials that meet the required standards for the construction of AC systems [7, 8]. Locally sourced materials may not always meet the necessary specifications for durability, efficiency, and safety, leading to potential malfunctions and breakdowns in the system. This can result in increased maintenance costs, reduced energy efficiency, and decreased overall performance of the AC unit [9, 10]. Furthermore, the lack of standardized testing procedures for locally assembled AC systems poses a significant challenge. Without proper testing protocols in place, it is difficult to ensure that the system functions optimally and meets the required performance standards [11]. This can lead to inconsistencies in the performance of the AC unit, as well as potential safety hazards for users. Additionally, the lack of technical expertise and training in assembling and testing AC systems using locally sourced materials is a major concern. Without proper training and knowledge, technicians may not be able to effectively troubleshoot and address issues that arise during the assembly and testing process. This can result in delays, errors, and inefficiencies in the construction of the AC system [12].

The assembling and testing of split unit AC systems using locally sourced materials is a technically challenging process that must be addressed carefully. By addressing the issues outlined in this problem statement, indigenous companies can work towards developing solutions that improve the quality, efficiency, and reliability of locally assembled AC systems. The primary technological innovation presented in this study lies in the design and assembly of locally sourced components for split unit AC systems. Unlike conventional systems that rely heavily on imported parts, the locally assembled units leverage indigenous materials and technologies, thus reducing the carbon footprint associated with transportation and manufacturing. This approach not only enhances local economies but also fosters a sense of ownership and responsibility towards sustainable practices within communities. The main objectives of this study are to investigate the potential of utilizing indigenous resources for achieving sustainable cooling solutions, to demonstrate the effectiveness of locally sourced materials in the assembly and testing of split unit AC systems and to evaluate the performance of the assembled split unit AC system through standard testing procedures.

2 Materials and Methods

2.1 Materials for the Split Unit AC system

The procedure adopted for selecting appropriate materials for the assembly of split unit AC systems included the following:

i. Identify the required components
ii. Evaluate material compatibility
iii. Assemble the identified components
iv. Conduct performance testing
v. Finalize material selection

Split unit AC systems are widely used in both residential and commercial settings to provide cooling and comfort. These systems comprise a number of components that synergize to cool the air and maintain a comfortable indoor environment. Some of the key components include expansion valve, capillary tube line, Copper $3/4$ & $1/4$ nobs, water drain tray, evaporator coil, air dust filter, air return, evaporator fan, air swing blade, air swing electric motor, fan blade, remote sensor detector, power park panel, fan capacitor, display indicator, thermostat, indoor to outdoor wire, water drainage rain hoses, high pressure pipes, low pressure pipes, pipe amoflex, indoor brackets, power cord cable, cooling sensor, fan mounting rubber, flaring pipe, fan bracket, coarse filter, motor fan, horizontal flaps, compressor, condenser, cooling fan, air filter, condensation drain, evaporator coil, motor fan, refrigerant, air blower, condensing coil, drainage tray, control board, vertical deflectors, outer case and front panel.

2.2 Research Methodology

Indoor split unit AC systems are necessary for maintaining adequate indoor temperatures in various settings, such as homes, offices, and commercial buildings. The assembly of Split unit AC systems in presents a significant opportunity for local manufacturers to contribute to the country's economic development. However, one of the major issues faced by manufacturers is the sourcing of materials for the assembly process. Some of the materials were sourced from the open Market in Uyo City Metropolis, while some were acquired from suppliers/dealers at the open Market in Onitsha and Aba. Assembling and testing these systems using locally sourced materials can be a cost-effective and sustainable approach. In this study, the step-by-step methodology for assembling and testing an indoor split unit AC system using locally sourced materials are as follows:

i. Procurement of Materials: The first step in assembling an indoor split unit AC system is to procure all the necessary materials. Locally sourced materials such as copper tubing, aluminum fins, refrigerant gas, compressor, evaporator coil, condenser coil, and electrical components were obtained from local hardware stores or suppliers [13]. It is essential to ensure that all materials meet the required specifications and standards for AC systems.

ii. Assembly of Components: Once all the materials are procured, the next step is to assemble the components of the indoor split unit AC system. Start by connecting the compressor to the condenser coil using copper tubing and refrigerant gas. Then, connect the evaporator coil to the condenser coil using aluminum fins and refrigerant gas [4]. Finally, connect the electrical components, such as the thermostat and fan motor, to the system.

iii. Installation of IOUs: After assembling the components, the IOUs of the AC system need to be installed. Place the IU inside the building in a suitable location, such as a wall or ceiling. Then, install the OU outside the building, preferably in a well-ventilated area. Connect the IOUs using refrigerant lines and electrical wiring [14].

iv. Testing and Commissioning: Once the indoor split unit AC system is assembled and installed, it is essential to test and commission the system to ensure proper functioning. Start by checking for any leaks in the refrigerant lines using a leak detector. Then, vacuum the system to remove any air and moisture. Next, charge the system with the appropriate amount of refrigerant gas [15]. Finally, test the system by running it in cooling mode and checking for proper airflow and temperature control.

Assembling and testing an indoor split unit AC system using locally sourced materials can be a cost-effective and sustainable approach. By following the detailed step-by-step methodology outlined in this project, individuals can successfully assemble and test an indoor split unit AC system for various indoor settings. It is essential to ensure that all materials meet the required specifications and standards for AC systems to achieve optimal performance and efficiency.

2.3 Installation Procedure for Split Unit AC Systems

A detailed procedure that was adopted during the installation process of split unit AC systems are as follows:

i. Site Survey and Preparation: Before beginning the installation process, conduct a thorough site survey to ascertain adequate location for the IOUs. Ensure that there is sufficient space for proper airflow and access for maintenance. Clear any obstacles that may obstruct the installation process.

ii. Mounting the IU: Start by mounting the IU on the wall at a height of at least 7 feet above the floor. Use a level to ensure that the unit is mounted evenly. Make sure to leave enough space around the unit for proper airflow and maintenance access.

iii. Installing the Refrigerant Lines: Next, connect the refrigerant lines from the IU to the OU. Use insulated copper tubing to prevent heat loss and ensure efficient cooling. Make sure to properly flare and connect the tubing to prevent leaks.

iv. Electrical Wiring: Connect the electrical wiring from the IU to the OU, following the manufacturer's instructions. Ensure that the wiring is properly grounded and insulated to prevent electrical hazards. Test the electrical connections to ensure they are secure.

v. Mounting the OU: Mount the OU on a stable surface, such as a concrete pad or mounting brackets. Make sure the unit is level and secure to prevent vibration and noise. Ensure that there is proper clearance around the unit for airflow and maintenance.

vi. Refrigerant Charging: Once the IOUs are properly installed and connected, it is time to charge the system with refrigerant. Use a manifold gauge set to measure and adjust the refrigerant levels according to the manufacturer's specifications. Proper refrigerant charging is essential for optimal cooling performance.

vii. Testing and Commissioning: After completing the installation process, test the system to ensure it is functioning properly. Check for any leaks in the refrigerant lines and ensure that all electrical connections are secure. Test the cooling performance of the system in different operating modes to verify proper operation.

Proper installation of split unit AC systems is essential for optimal performance and longevity. By following this comprehensive procedure, HVAC professionals can ensure a successful installation that meets industry standards and manufacturer specifications. Adhering to best practices in installation will result in a reliable and efficient cooling system for residential and commercial spaces.

2.4 Infrared Thermometer IR 8895

This device, which has a high level of accuracy, works seamlessly in the measurement of non-contact temperature (see Figure 1). Technical details for the infrared temperature measuring device are presented in Table 1. The device is primarily employed in capturing the surface temperature of mobile objects, particularly those that are challenging to access [16]. To achieve optimal measuring output, the IR device is equipped with a laser pointer that accurately focuses on the measuring point. There is room for adjusting the emissivity in order to prevent error-prone results. A variety of distinct materials as well as their corresponding emission levels are provided in the user guide for effective operation. The infrared thermometer IR 8895 is ergonomically designed with simplified principles of operation and features an intuitive button interface, with temperature results presented either in Celsius or Fahrenheit. The measuring instrument features a hold mode to promptly retain the measured results. Moreover, the portable case that comes with the infrared temperature measurement gadget includes a protective pouch [17].

Device name	Infrared Thermometer IR 8895
Temperature measuring range	-40...+816 °C
Accuracy	Approx. ±2%, for further information check data sheet
Resolution	0.1 °C/°F at <280 °C; 1.0 °C/°F at >280 °C
Emission factor	Adjustable 0.3...1.0
Display	LCD-Display, illuminated; switchable to °C or °F
Optics	12:1
Response time temperature	500 ms
Auto Off	After aprox. 10s
Battery	2x 1.5 V, Mignon AA
Dimensions	(LxWxH) 195 x 134 x 50 mm
Weight	0.3248 kg

Figure 1. Technical details of the handheld infrared temperature measuring device

Table 1. Dimensions of rooms where the assembled AC unit was tested on

Rooms	Length	Breath	Height
Lounge	4.440	4.200	3.00
Masters Room	3.840	4.250	3.00
Room 2	3.600	3.100	3.00
Room 3	3.290	3.200	3.00
Room 4	3.190	2.690	3.00

Figure 2 is an illustration of the plan view of the building that the locally assembled split unit AC system was tested on. From the illustration, the building consisted of the lounge, which had the highest dimension and size, followed by the Masters Room, Room 2, Room 3 and Room 4, which had the smallest size in the category.

3 Theoretical Framework Based on Thermodynamic Equations of Split Unit AC

Split unit AC systems rely on mathematical formulas and thermodynamic equations to operate effectively and provide optimal cooling comfort. One of such mathematical formulas used in split unit AC systems is the heat transfer equation, which is based on the first law of thermodynamics. This equation is used to calculate the amount of heat absorbed by the evaporator coil and the amount of heat rejected by the condenser coil. Another one is the refrigeration cycle equation, which describes the process by which refrigerant absorbs heat via indoor air and releases it to the outdoor air. This equation is based on the second law of thermodynamics and includes terms such as enthalpy, entropy, and temperature to calculate the efficiency of the refrigeration cycle. Some common mathematical equations related to split AC units are as follows:

3.1 Latent Heat Loads

One of the most effective techniques for dehumidification is cooling the air below its dew point, therefore, 100% saturation. The latent heat to be extracted is given by Eq. (1):

$$Qlatent = m \times hfg \times (Wo - Wi) \tag{1}$$

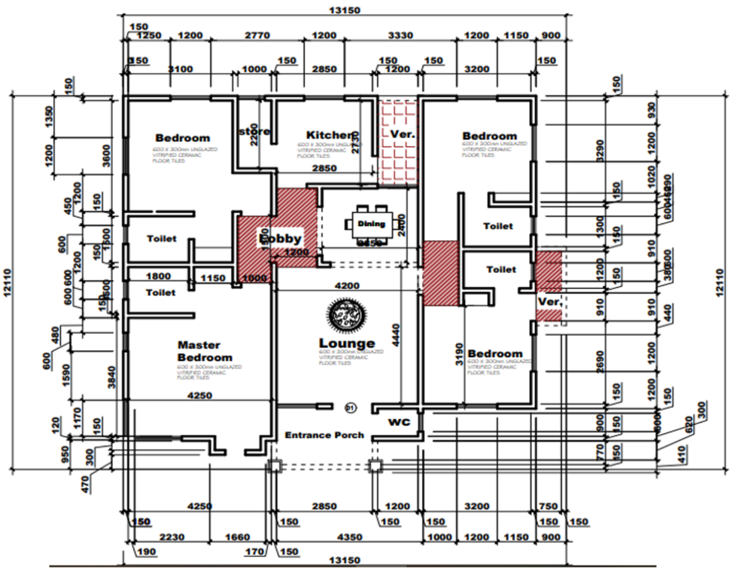

Figure 2. Building plan that the locally assembled split unit AC system was tested on

where, Q = Cooling energy, m = Mass flow rate of air, hfg = Latent heat of vaporization of water, Wo, Wi = Moisture content of air.

Moisture content present in the air must be extracted in order to achieve the humidity requirements. This is given by Eq. (2):

$$Qlatent = 4,840 \times CFM(Wo - Wi) \tag{2}$$

where, CFM = Air circulation flow, Wo = Outside moisture content of air and Wi = Inside moisture content of air.

3.2 Heat Loss by Conduction

The method for calculating heat loss in the cooling process is by conduction, determined by Eq. (3):

$$Q = k \times A \times \Delta T / t \tag{3}$$

where, k = Thermal conductivity of materials, A = Area, ΔT = Average temperature difference across the material, t = Thickness of a wall of some material. Substances with higher specific heats require more heat energy to lower temperature than do substances with a low specific heat. Therefore, the heat energy required to lower the air temperature is given by Eq. (4):

$$Q = m \times Cp.(To - Ti) \tag{4}$$

where, Q = Heat energy needed, m = Mass of a substance, Cp = Specific heat of air, $To - Ti$ = Dry Bulb temperature of air change.

The exergy input into the split unit AC unit in the form of electric energy transfer to the electric motor of the compressor is determined via Eq. (5).

$$e_{in} = N_{in} \cdot 10^{-3} / G \tag{5}$$

Or, as a percentage of the exergy that is transferred to the split unit AC unit is given by Eq. (6):

$$D = e_{beg} - e_{end} \cdot 100 / e_{in} \tag{6}$$

where, e_{beg} and e_{end} are values of the specific exergy of the refrigerant at the beginning and end of the split unit AC cooling cycle. Exegetic balance of the one-stage compressor of the split unit AC for 1 kg/s flow of a circulating working refrigerant is given by Eq. (7):

$$e_{in} = e_{out} + \Sigma \text{d} \tag{7}$$

Or as a percentage of E_{in}

$$E_{in} = E_{out} + \Sigma\text{D} \tag{8}$$

where, E_{in} is the specific exergy transfer to the split unit AC, E_{out} is the quantity of the specific exergy going out of the split unit AC, Σd is the total losses of specific exergy in all component of the AC unit, E_{in} , E_{out} , ΣD are exergy of the split unit AC , which is spent in maintaining the cooling process [10, 18]. Exergy loss in the AC comprises losses of exergy in the compressor, due to the irreversible heat transfer in the condenser, the capillary tube (throttle) and the losses of exergy in the evaporator, which are represented by Eq. (9) or (10):

$$\Sigma d = d_{comp} + d_{cond}^{irrev.h.tr} + d_{thr} + d_{ev} \tag{9}$$

$$\Sigma D = D_{comp} + D_{cond}^{irrev.h.tr} + D_{thr} + D_{ev} \tag{10}$$

where, D_{comp}, $D_{cond}^{irrev.h.tr}$, D_{thr}, D_{ev} are exergy losses in the compressor, condenser, capillary tube as well as the evaporator.

3.3 Energy Analysis

To determine the cooling capacity, actual load, power consumption and COP of a locally assembled 1HP split unit AC, an outside temperature of 28°C was measured using the handheld infrared temperature measuring device shown in Figure 1. Considering that cooling load is a function of room sizes, insulation as well as heat sources, part load ratio (PLR) of 0.3, 0.5 and 0.7 were considered for small, medium and large rooms. In this case, Rooms 3 and 4 were considered as small rooms, Room 2 and Masters Room were considered as medium rooms, while the Lounge was considered as a large room. These considerations were based on the dimensions of the rooms presented in Table 1.

Since the 1HP split unit AC used in this study has a cooling capacity of about 9000BTU/hr, converting BTU/hr to watts yields:

$$9000\frac{BTU}{hr} = 2637watt \tag{11}$$

The cooling capacity of the AC unit is 2637 $watt$. To determine the actual cooling load (ACL), Eq. (12) was employed:

$$\text{Actual cooling loading} \;=\; \text{Part Load Ratio} \;\times\; \text{Cooling Capacity} \;\div T_{\text{outside}} \tag{12}$$

Applying Eq. (12), for small, medium and large rooms yielded the following ACLs:

$$\text{ACL for small rooms } = (0.3 \times 2637) \div 28 = 28.3 \text{ W}$$

$$\text{ACL for medium rooms } = (0.5 \times 2637) \div 28 = 47 \text{ W}$$

$$\text{ACL for large room } = (0.7 \times 2637) \div 28 = 65.93 \text{ W}$$

where, T_{outside} is the outside temperature, which was measured at 28°C, which is the average annual temperature in Nigeria. To determine power consumed by the split AC unit, Eq. (13) was considered:

$$\text{Power consumption } = \frac{\text{Cooling load}}{EER} \tag{13}$$

where, EER is the Energy Efficiency Ratio.

Considering that the 1HP non-inverter split unit AC had an EER of 9.25, power consumptions (PC) for small, medium and large rooms were determined as:

$$PC \text{ for small rooms } = \frac{791}{9.25} = 85.5 \text{ W}$$

$$PC \text{ for medium rooms } = \frac{1319}{9.25} = 142.6 \text{ W}$$

$$PC \text{ for large room } = \frac{1846}{9.25} = 199.6 \text{ W}$$

To determine the COP of the split AC unit, Eq. (14) was applied:

$$COP = \frac{EER}{3.412} \tag{14}$$

$$COP = \frac{9.25}{3.412} = 2.7$$

where 3.412 is a conversion factor from Watts to British Thermal Unit (BTU).

4 Results and Discussions

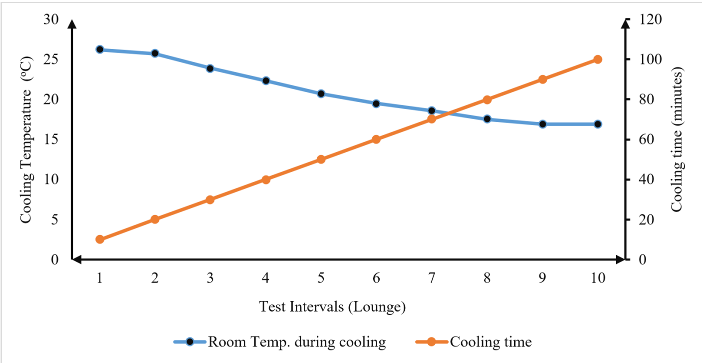

Figure 3. Lounge cooling temperature and cooling time at different testing intervals

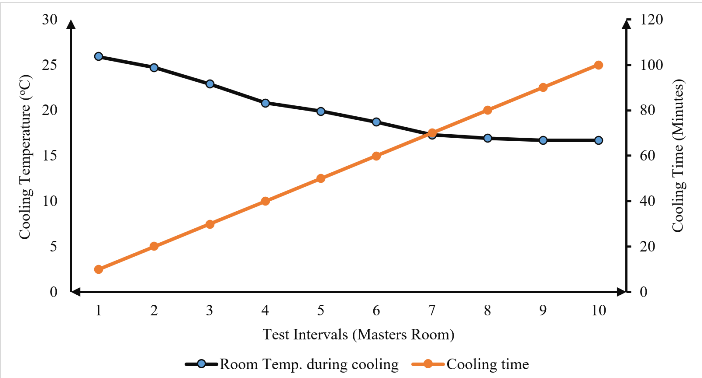

Figure 4. Masters room cooling temperature and cooling time at different testing intervals

Testing a locally assembled split AC unit in an apartment requires a detailed process that involves several steps that must be followed carefully to evaluate the performance and efficiency of the unit. The necessary equipment and tools were prepared for the testing exercise. Additionally, it was ensured that the apartment is airtight, although not with 100% certainty, while also ensuring a stable temperature and humidity level to provide consistent testing conditions. The room temperature prior to commencement of the testing was measured using an infrared thermometer, IR 8895 model. The split AC unit was installed following the procedure outlined earlier in the methodology. It was ensured that the unit was securely mounted and connected to the power source, while checking for leaks or damages in the installation process to prevent any inaccuracies in the test results. The installation was carried out in specified rooms based the sizes and dimensions specified in Figure 2 and Table 1. The split AC unit was turned on and allowed to run for a specified period to stabilize the temperature in the apartment. Using an infrared thermometer, the temperature was measured at different locations in the room to ensure uniform cooling. A constant split unit AC temperature of 16°C was maintained throughout the testing process. It was ensured that the time it took for the split unit to reach the desired temperature was measured and recorded [19]. Data collected from the testing process were properly compiled and analysed. The data was analysed via the Microsoft Excel package, 2022 version. The analysed data, which focused mainly on the split unit cooling temperature and cooling time, are presented in Figure 3 to Figure 7 respectively. The cooling temperature refers to the temperature at which the system is set to cool the air, while the cooling time refers to the amount of time it takes for the system to reach the desired temperature. From the plots in Figure 3 to Figure 7, it took the assembled split AC unit a longer time interval to cool a bigger/larger room than a smaller room with the same AC conditions. For proper understanding of this occurrence, it is significant to acquire the basic principles of thermodynamics that govern the operation of an AC unit. The cooling process in an AC unit involves the transfer of heat from the indoor environment to the outdoor environment [20]. This transfer of heat is achieved via the refrigeration cycle, which is described in the following sequence: Absorption of available heat within the room by the evaporator coil and dispensing to the refrigerant, which flows directly to the compressor, for further compression into liquid [21, 22]. The liquid is conveyed to the condenser coil, where the available heat is dissipated to the environment via the effect of ambient cooling, and the motor fan, while the gaseous state is maintained again. The warm liquid refrigerant travels to the expansion valve, where it is de-pressurized and further cooled to a low temperature. The cooled low-pressure liquid travels to the evaporator coil, via the air blower to cause cooling of the room. The process is repeated as long as the AC unit is on, and the cooled air continues to circulate in the room, providing comfort to the users.

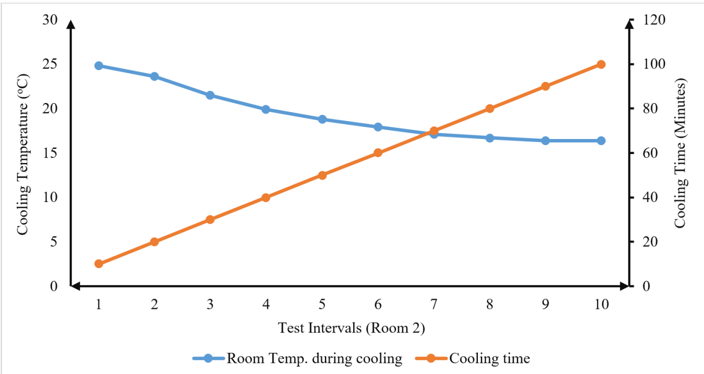

Figure 5. Room 2 cooling temperature and cooling time at different testing intervals

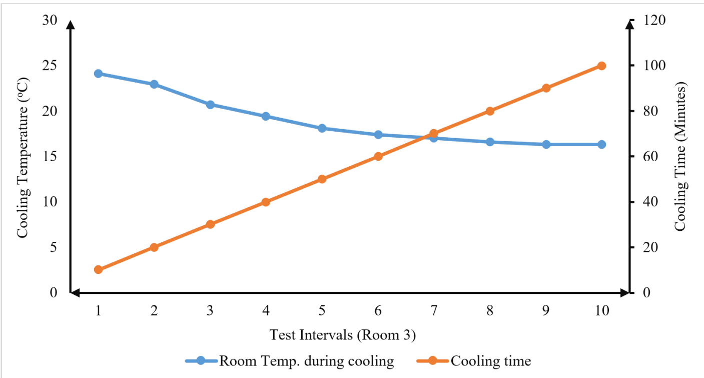

Figure 6. Room 3 cooling temperature and cooling time at different testing intervals

Thermodynamically, the reason why the assembled split AC unit took a longer time interval to cool bigger/larger rooms than smaller rooms could be attributed to factors such as the size of the room and insulation of the room. In the smaller rooms (see Figure 6 and Figure 7), the AC unit was able to cool the space more quickly because the volume of air that needed to be cooled is relatively small. This means that the AC unit can effectively remove the heat from the room and maintain a comfortable temperature in a shorter period of time. However, in the larger rooms (see Figure 3 to Figure 5), the volume of air that needed to be cooled was significantly higher, which posed a challenge for the AC unit to effectively remove heat from the space. The size of the room also affected the air circulation within the space. In a smaller room (see Figure 6 and Figure 7), the air circulation is more efficient, allowing the cooled air to spread evenly throughout the space. This resulted in a quicker cooling process as the temperature is more evenly distributed. On the other hand, in a larger room (see Figure 3 to Figure 5), the air circulation may have been less efficient, leading to pockets of warm air that took longer to cool down. This uneven distribution of temperature prolonged the cooling process in the larger rooms. The insulation of the room played a crucial role in the cooling process [23, 24]. In a smaller room with good insulation, the heat transfer between the indoor and outdoor environments is minimized, allowing the AC unit to cool the space more efficiently. However, in a larger room with poor insulation, the heat transfer is more significant, requiring the AC unit to work harder to maintain a comfortable temperature. This increased workload results in a longer time interval to cool a larger room compared to a smaller room. The thermodynamic principles governing the operation of a split AC unit provide a compelling explanation for why it takes a longer time interval to cool a bigger/larger room than a smaller room. Factors such as the volume of air, air circulation, and insulation of the room all contribute to the efficiency of the cooling process. By understanding these principles. The performance of AC units in different room sizes can be optimized to achieve optimal cooling efficiency.

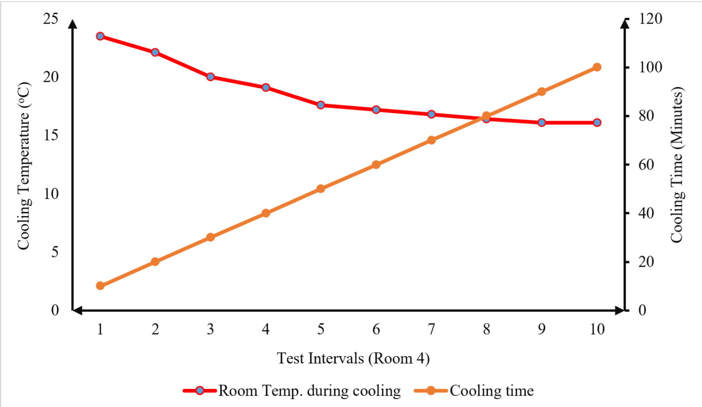

Figure 7. Room 4 cooling temperature and cooling time at different testing intervals

4.1 Saturation Temperature and Time

Figure 8 is a graphical representation of room saturation temperature and saturation time. The plot illustrates that rooms of small sizes and dimensions (such as rooms 3 and 4) exhibit lower saturation temperatures, which implies rapid cooling at shorter time durations. On the other hand, larger rooms, particularly the lounge and master's room, exhibit increased saturation temperature at a slightly higher time duration, which implies that there may be a delay in the cooling processes of the room.

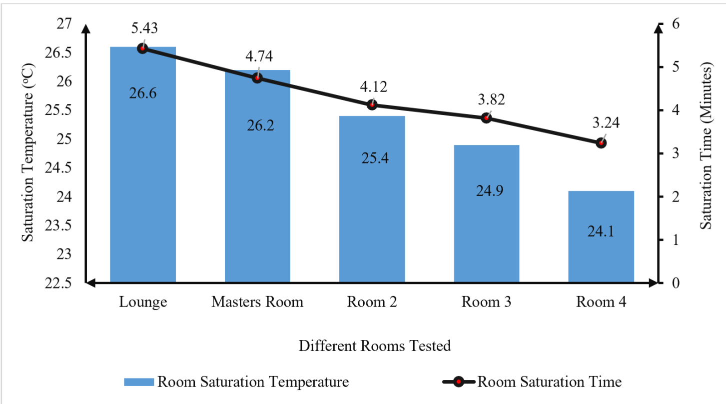

Figure 8. Plot of room saturation temperature and saturation time

In terms of energy efficiency, room saturation temperature is important for preventing overcooling and reducing energy consumption, while room peak temperature is crucial for ensuring that the AC system operates efficiently and effectively. In the context of split unit AC systems, saturation temperature is a critical parameter that determines the refrigerant's state within the system. By controlling the saturation temperature, the system can effectively regulate the cooling capacity and maintain a consistent temperature output. Room cooling saturation temperature is a critical parameter in the operation of split unit AC systems. It refers to the temperature at which the refrigerant in the evaporator coil reaches a state of saturation, where it exists as a mixture of liquid and vapour [25, 26]. This temperature is directly related to the cooling capacity of the AC system and plays a key role in determining the efficiency and performance of the system. As shown in Figure 8, the saturation temperature can be observed as a key point where the cooling process begins to take effect. As the room temperature rises above the set point on the thermostat, the AC system activates and begins to cool the room by circulating refrigerant through the evaporator coil. As the refrigerant absorbs heat from the room air, it undergoes a phase change from liquid to vapour, reaching its saturation temperature in the process. The saturation temperature is a critical parameter because it represents the point at which the refrigerant is able to absorb the maximum amount of heat from the room air [27, 28]. This is important for ensuring that the room is cooled efficiently and effectively, as any deviation from the saturation temperature can result in reduced cooling capacity and decreased performance of the AC system. By monitoring the room cooling temperature and cooling time in a split unit AC system, it is possible to optimize the operation of the system and ensure that the room is cooled to the desired temperature in a timely manner. Moreover, by maintaining the saturation temperature within the optimal range, it is possible to achieve maximum cooling efficiency and performance, resulting in a comfortable indoor environment for occupants.

4.2 Peak Temperature and Time

Similar to the case of saturated temperature and time in Figure 8, rooms with small sizes and dimensions quickly attended the lowest peak temperature at the shortest time interval, which implies efficient cooling as shown in Figure 9. However, rooms with larger sizes were observed to approach the peak temperature with prolonged time interval.

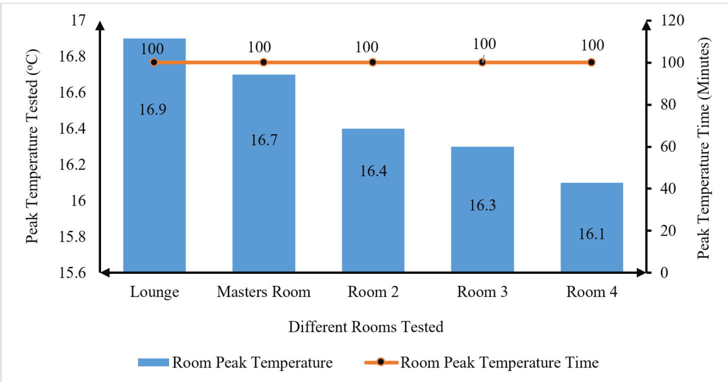

Figure 9. Plot of room peak temperature and peak temperature duration

On the other hand, peak temperature refers to the highest temperature reached within the system during operation. In other words, it is the highest temperature reached in a room during a cooling cycle of the split unit AC system. A room peak temperature that is too high can lead to discomfort and reduced productivity, while a room peak temperature that is too low can result in energy wastage and increased operating costs [29, 30]. Monitoring and controlling the peak temperature is essential for preventing overheating and ensuring the system's overall efficiency and longevity. The relationship between saturation temperature and peak temperature in split unit AC systems is crucial for achieving optimal performance. By maintaining the saturation temperature within a specified range, the system can effectively manage the peak temperature and prevent overheating. Additionally, proper insulation and refrigerant charge levels are essential factors that influence both saturation and peak temperatures in the system.

4.3 Energy Performance

The EER is a critical metric that quantifies the cooling output of an AC system relative to its energy consumption. The EER, defined as the ratio of cooling output (in BTUs) to the electrical input (in watts), provides a direct measure of energy efficiency. An EER of 9.25 indicates that for every watt of electrical energy consumed, the system delivers approximately 9.25 BTUs of cooling. Conversely, the COP, which represents the ratio of useful heating or cooling provided to the energy consumed, is crucial for understanding the operational efficiency of the system. A COP of 2.7 suggests that for every unit of energy consumed, the system provides 2.7 units of cooling. From Eq. (12), the actual cooling loads of 28.8, 47, and 65.93 W for small, medium, and large rooms (see Figure 10), present a clear framework for assessing the performance of cooling systems.

The relationship between room size and cooling load is not linear; larger rooms typically require disproportionately higher cooling loads due to increased surface area and heat gain from external sources. However, the ACL for the various rooms is discussed as follows:

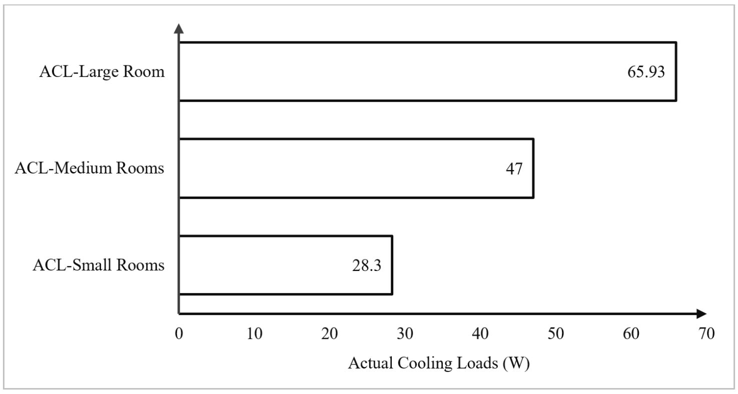

Figure 10. Plot of actual cooling loads for various room sizes

i. Small Rooms (28.8 W): In smaller spaces, the non-inverter AC system operates closer to its optimal efficiency. The lower cooling load allows the system to maintain a high EER, as the compressor can run at a more consistent speed without frequent cycling. This results in reduced energy consumption and enhanced cooling efficiency.

ii. Medium Rooms (47 W): As the cooling load increases, the system's efficiency may begin to decline. The non-inverter design, characterized by its fixed-speed compressor, may struggle to adapt to varying thermal loads. Consequently, the system may experience periods of inefficiency, particularly during transitional phases when the compressor cycles on and off, leading to increased energy consumption relative to the cooling output.

iii. Large Rooms (65.93 W): In larger spaces, the limitations of a non-inverter system become more pronounced. The fixed-speed compressor is less capable of modulating its output to match the higher cooling demand, resulting in significant energy waste. The system may operate at a lower EER due to frequent cycling, which not only increases energy consumption but also affects the overall comfort level within the space. The relationship between cooling loads and the efficiency of the 1HP non-inverter AC system is multifaceted. While the system demonstrates commendable performance at lower loads, its efficacy diminishes as the cooling demand escalates. This phenomenon underscores the importance of selecting appropriate AC systems based on room size and cooling requirements.

Moreover, the inherent design limitations of non-inverter systems, which lack the ability to modulate compressor speed, exacerbate inefficiencies in larger spaces. This raises critical questions regarding the sustainability of such systems in the context of rising energy costs and environmental concerns. The argument for transitioning to inverter technology, which offers variable-speed compressors capable of adjusting to fluctuating cooling demands, becomes increasingly compelling. The findings suggest that there is a critical need for the development of advanced cooling technologies that can adapt to varying load requirements without sacrificing efficiency. Innovations such as variable refrigerant flow systems, smart thermostats, and improved insulation materials could enhance the performance of cooling systems across different room sizes. From Eq. (13), the power consumption rates of 85.5, 142.6, and 199.6 W (see Figure 11) represent distinct operational states of the non-inverter AC unit, which can be attributed to varying load conditions and ambient temperature fluctuations.

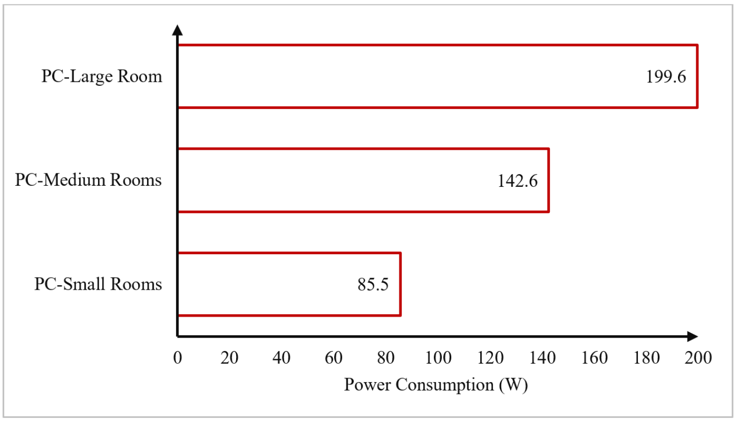

Figure 11. Plot of power consumption for various room sizes

The power consumption and COP from 1HP non-inverter AC in this study differ from 2HP non-inverter AC, ranging from 311 to 1214 W, and 2.34 to 2.74 in the study of Pham et al. [31]. In a similar study by Alghamdi and Krarti [32], COP ranging from 1.8 to 3.5 was reported for conventional systems, which imply that the COP of 2.7 obtained in this study is ideal, indicating that locally sourced materials for AC assembly align with the 3 R's sustainable waste management of reuse, reduce and recycle. The lowest power consumption of 85.5 W suggests an optimal operational state, likely under moderate cooling demands. In contrast, the higher consumption levels of 142.6 and 119.6 W indicate optimum energy usage under normal thermal loads. The EER, defined as the ratio of cooling output (in BTUs) to electrical input (in watts), provides a quantitative measure of efficiency. An EER of 9.25 implies that for every watt consumed, the unit delivers approximately 9.25 BTUs of cooling. This efficiency rating, while indicative of the unit's performance, must be contextualized within the framework of its power consumption levels. The observed power consumption levels, coupled with the EER and COP, suggest that an ideal energy saving has been achieved [33].

5 Conclusion

The findings from this study on assembling and testing of split unit AC systems using locally sourced materials have provided valuable insights into the feasibility and effectiveness of utilizing indigenous resources for the production of such systems. The results of the study have demonstrated that it is indeed possible to construct high-quality AC units using materials that are readily available within the local market. One of the key benefits of using locally sourced materials for the production of split AC systems is the potential cost savings that can be achieved. By sourcing materials locally, manufacturers can reduce their reliance on expensive imported components, thereby lowering production costs and making the final product more affordable for consumers. This can be particularly beneficial in Nigeria, where access to imported goods may be limited or more expensive. Furthermore, the study has also highlighted the importance of rigorous testing and quality control measures in ensuring the performance and reliability of locally assembled AC units. By subjecting the systems to a series of comprehensive tests, it is possible to identify and address potential issues before the units are brought to market. This not only helps to maintain high standards of quality but also enhances the overall credibility and reputation of locally produced AC systems. The findings from this study underscore the potential for leveraging locally sourced materials in the production of indoor split unit AC systems. By harnessing the resources that are readily available within the local environment, manufacturers can create products that are not only cost-effective but also of high quality and reliability. Further research and development in this area could help to unlock even greater potential for utilizing indigenous resources in the production of AC systems, ultimately benefiting both manufacturers and consumers alike.

As recommendation for further studies, the precision of the experimental setup would be enhanced by conducting a controlled experiments to examine the frequency and accuracy of data recording, including power consumption measured, and other critical information.

Data Availability

The data used to support the research findings are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflict of interest.

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