Jurnal Informasi dan Teknologi
https://jidt.org/jidt
2024 Vol. 6 No. 4 Hal: 1-9 e-ISSN: 2714-9730

Evaluation of Thermal Load and Optimization of Energy Requirements for Air Conditioning

Wiyogo✉, Harie Satiyadi Jaya, Vontas Alfenny Nahan[3], Galfri Siswandi, Jhonni Rentas Duling, Pendi, Andi Kurniawan

Department of Mechanical Engineering Education, Faculty of Teacher Training and Education, Universitas Palangka Raya, Indonesia

wiyogo@fkip.upr.ac.id

Abstract

This study evaluates air conditioning systems, focusing on addressing two primary types of heat: sensible and latent heat. Sensible heat, which affects temperature without causing a phase change in the material, is the main contributor to the cooling load and originates from human bodies, electronic equipment, and solar radiation penetrating windows. The study identifies that solar radiation significantly contributes to the heat load, particularly from the North and south sides. Peak heat gain on the north side occurs between 11:00 and 13:00, reaching 285,956 kcal/h, while the south side experiences reduced heat load due to natural shading. Meanwhile, latent heat, which relates to phase changes without a temperature increase, plays a minor role in this context. Heat gain from walls, particularly the east wall in Machine Classroom 1, reaching 5263 kcal/h at midnight, also plays a crucial part. Human activity, with a total of 7920 W or 7.92 kJ/h, and electronic equipment, contributing 32.55 watts or 117.18 kJ/h, add to the overall heat load. The total heat load peaks at midnight, with values around 44.235 kJ/h in Room 1 and 38.972 kJ/h in Room 2. Based on these calculations, the required AC capacity is 42,000 BTU/h for Room 1 and 36,000 BTU/h for Room 2. The capacity conversion shows a need for approximately 12.28 kW for Room 1 and 10.82 kW for Room 2. This study underscores the importance of selecting the appropriate AC capacity based on total heat load calculations involving various factors, especially in tropical regions like Palangka Raya, to ensure efficiency and thermal comfort.

Keywords: *Sensible Heat, Latent Heat, Solar Radiation, Heat Load, Optimization.*

1. Introduction

A stable and comfortable temperature characterizes an ideal learning environment. Learning comfort is a fundamental element that supports the quality of the educational process in higher education institutions. Among the various factors influencing comfort, classroom temperature and air quality play a significant role. In tropical regions like Palangka Raya, where temperatures can reach exceedingly high levels, especially during the summer, attention to these factors becomes increasingly critical. Temperature stability in learning spaces is a crucial component [1], as many educational activities rely on equipment that may emit heat. An increase in thermal load can lead to an inability to manage this load, which may adversely affect health [2]. Moreover, it causes physical discomfort [3] for students and instructors, manifesting as increased fatigue, reduced concentration, and lower productivity, and can disrupt the optimal functioning of the equipment being used. The cumulative effects of discomfort and disturbances ultimately hinder the overall learning process.

Consequently, the implementation of effective and efficient cooling systems is essential, not only to address the generated thermal load but also to ensure that the temperature and air quality within the learning environment remain at levels that support the optimization of cognitive and physical performance, as well as the sustainability of quality academic processes. Air conditioning (AC) is the most effective method for cooling indoor spaces [4]. The use of air conditioners enhances the quality of life, especially on hot summer days [1], [2], [4]. High temperatures negatively impact the human body [5] and cognitive abilities [6]. The increase in body temperature due to exposure to high heat can lead to fatigue, concentration difficulties, and diminished focus, particularly among students [4], [6].

Additionally, when the core body temperature reaches or exceeds 38-39 °C, the risk of heat-related fatigue significantly increases; at even higher temperatures, there is a risk of heatstroke that can lead to failure of the body's temperature regulation system [4]. Fatigue and dehydration caused by high temperatures can also decrease

Receipt: 26-05-2024 | Revision: 29-10-2024 | Publish: 18-12-2024 | doi: 10.60083/jidt.v6i4.597

learning effectiveness. Furthermore, poor air circulation can deteriorate air quality, rendering the room stuffy and hindering students' ability to breathe comfortably. From experiments conducted by [6], it can be concluded that a temperature of 26 degrees Celsius is ideal for classrooms. At this temperature, students tend to feel more physically and mentally comfortable and do not experience significant declines in performance, particularly for tasks requiring memory retention [3] [6].

All these factors underline the necessity for serious attention to thermal comfort in classrooms to create a conducive and productive learning environment. The increased thermal load generated from various machines and equipment operations substantially raises the ambient temperature, creating uncomfortable conditions and temperature fluctuations that can disrupt teaching and learning [2] [3]. The current air conditioning systems have not been able to compensate for these increased thermal loads, resulting in physical discomfort that can disrupt students' concentration and lower teaching productivity. Furthermore, uncontrolled temperatures can potentially affect the performance of technical equipment, accelerate wear and tear, and reduce operational efficiency, ultimately negatively impacting learning outcomes [3].In addressing these challenges, comprehensive and innovative solutions are required to manage thermal loads more effectively. For instance, mechanical ventilation systems can ensure adequate air exchange rates and improve indoor air quality while offering energy savings [7].

Therefore, an in-depth analysis of the specific cooling requirements within the Mechanical Engineering Education Program, considering various variables such as the number of students, the intensity of equipment usage, and room design, becomes crucial. This approach will not only aid in designing a more efficient cooling system but will also mitigate the negative impact of unstable temperatures on academic and operational performance. This research aims to provide a clear overview of the thermal conditions in classrooms, computer laboratories, and thesis examination rooms and identify potential improvements in the cooling system to create a more comfortable and productive learning environment.

2. Research Methods

This study is a quantitative research aimed at analyzing thermal loads and evaluating the effectiveness of the air conditioning system in the Mechanical Engineering Education Program. It employs a research methodology designed to test hypotheses and systematically explain phenomena [8] [9] [10], utilizing a combined approach of literature review and field observation. Field observations were conducted by measuring and recording various physical data of the building, such as building dimensions, the area of walls exposed to direct sunlight, and room capacity. This data was then used to calculate the rooms' peak and average cooling loads, allowing for recommendations on the appropriate type and capacity of air conditioning units. Based on the analysis results, recommendations will be made to adjust the cooling system for more effective and efficient operation. The calculation method involves two approaches: a one-dimensional transient heat transfer model has been developed to estimate the cooling load temperature difference (CLTD) for buildings [11], facilitating the calculation of the necessary cooling loads.

Meanwhile, the Thermal Analysis (TA) method involves a comprehensive thermal analysis of the entire building. The TA method thoroughly evaluates all heat sources entering the building, including heat generated by electronic equipment, lighting, and human activities. This method provides a more accurate picture of cooling needs, considering all factors contributing to indoor temperature increases. Combining these two methods achieves a more precise calculation of the cooling loads required to maintain a comfortable and stable room temperature.

3. Results and Discussion

3.1. Building Data for the Mechanical Engineering Education Program

The Mechanical Engineering Education Program classroom building faces north and consists of two main structures: a laboratory and a program building. This program building has only one floor divided into several rooms, including two lecture halls, one space partitioned into two sections for examination and computer use, and an additional room designated for faculty and program administration. The layout of the building is designed to maximize the functionality of each space. The laboratory, separate from the program building (except for the computer laboratory), allows students to conduct practical sessions without disrupting classroom activities. The faculty and administration room is strategically positioned, facilitating access to daily academic and administrative activities for students and staff. Thus, the building design supports creating an effective and efficient learning environment for the entire scholarly community. Each room measures 10 meters in length, 8 meters in width, and has a height of 4 meters, allowing each classroom to accommodate a maximum capacity of 60 individuals. From the measurements conducted, data was obtained regarding the utilized classrooms, specifically the Mechanical Lecture Room 1 and Mechanical Lecture Room 2. The following data was collected from the survey: Classroom 1: Length 10 meters, Width 8 meters, Height 4 meters, Classroom 2: Length 10 meters, Width 8 meters, Height 4 meters, Computer Laboratory: Length 8 meters, Width 6 meters, Height 4 meters, and Thesis Examination Room: Length 6.5 meters, Width 4 meters, Height 4 meters. Window Specifications:

1. In Classrooms 1 and 2 (Northside/front), six large windows measure 0.7 meters in width and 1.2 meters in height.
2. Classrooms 1 and 2 (South side/back) have nine windows measuring 0.7 meters in width and 1.2 meters in height.
3. Classrooms 1 and 2 (Northside/front) have six small windows measuring 0.7 meters in width and 0.5 meters in height.
4. Classrooms 1 and 2 (South side/back) have nine small windows measuring 0.7 meters in width and 0.5 meters in height.
5. The Computer Laboratory (Northside/front) has four windows measuring 0.7 meters in width and 1.2 meters in height.
6. The Computer Laboratory (Southside/back) has four windows measuring 0.7 meters in width and 1.2 meters in height.
7. The North side of the Thesis Examination Room consists solely of a wooden partition wall.
8. The Thesis Examination Room (Southside/back) has two windows measuring 0.7 meters in width and 1.2 meters in height.
9. The wall thickness is 0.2 meters.

3.2. Heat Load Gain

Cooling systems are known for two types of heat: sensible heat (heat that causes temperature changes without phase changes). Any heat source that can raise the room's temperature is marked by an increase in the temperature of the dry bulb (Tdb), which will increase the sensible heat load. Latent heat is heat that causes a change in phase without causing a temperature change, for example, evaporating heat. Any heat source that can add to the latent load. The heat load that becomes the cooling load generally comes from various sources, including active human body heat, solar heat, or other electronic devices. Typical heat sources are heat that comes from the outside of transparent insulated walls (through conduction), heat that enters through glass or transparent materials (through radiation), heat that is carried by air from outside the cooling room, heat that comes from products/objects that are cooled, heat that comes from workers/operators or heat that comes from equipment stored in the room such as electric motors, lights, other electrical equipment such as LCD projectors or laptops/computers.

3.3. Calculation of Heat Gain Through Window

The cooling load was calculated in both lecture rooms, namely classrooms 1 and 2, the computer room, and the exam room. The calculated cooling load is the windows facing north and south.

1. The area of windows and doors facing north
   Door = 2 m x 1.5 m = 3 m^2
   Large windows = 1.2 m x 0.7 m x 18 windows = 15.52 m^2
   Small Window (ventilation window) = 0.5 m x 0.7 m x 24 pieces = 8.4 m^2
   Total utara = 3 + 15,52 + 8,4 m^2 = 26,92m^2
   All four rooms have many advantages, especially natural lighting and air circulation. The total window area of the lecture hall, computer room, and exam room, which faces north, has the same value, which is 26.92 m^2 each.
2. South-facing window area
   Large window = 1.2 m^2 x 0.7 m^2 x 27 pieces = 22.68 m2
   Small Window (ventilation window) = 0.5 m x 0.7 m x 27 pieces = 9.45 m^2
   Total utara = 22,68 + 9,45 m2 = 32,13 m^2
   The total window area of the room facing south has the same value, 32.13 m^2 each.

Heat gain from the east and west sides of lecture hall two is not considered because the east side borders the wall of the Mechanical Engineering 1 lecture room. In contrast, the west side borders the Mechanical Engineering Education Study Program exam room. Thus, the case in the computer room, on the west side is adjacent to the lecturer's room, and on the east side, it is adjacent to the thesis exam room. The calculated cooling load is only focused on the lecture hall of Machine 1 on the east side, while the west side is not calculated because it is directly adjacent to the lecture hall of Machine 1. This calculation is ignored because both sides of the wall are not exposed to sunlight, so there is no heat load in the area. Heat gain is observed and calculated every hour, starting from 09.00, assuming that the temperature conditions in the classroom are still conducive during lecture hours from 07.00 to 08.40. The calculation of heat gain is carried out until 15.00 using the formula:

$$q_{sg}\text{ (Jam 9)} = [A.\ I_{T.}\ \tau.\ \textit{(Shading)}]^{North} + [A.\ I_{T.}\ \tau.\ \textit{(Shading)}]^{South} \quad (1)$$

Where:

A	=	Total window area
IT		Solar radiation in a given area (The value is obtained from the Solar Radiation Table; the position of the building is assumed to be at point 0o LU.
T	=	Transmission factor (The value is obtained from the table. Transmission factor from the window: the position of the window is not directly exposed to sunlight due to the canopy on the south side and the terrace in the north position, so it is assumed that the transmission factor with shade 0.50)
Shading	=	Shadow factor (The value is obtained from the window shading coefficients table; the thickness of ordinary sheet glass is 3 mm. Assuming the window has shade, then the shade coefficient with the protective crown is 0.55)

The results of the calculation of heat gain through glass are as follows:

1. Heat Gain Per Hour in the northern part
   q_{sg} (9 AM) = $[A.\ I_{T.}\ \tau.\ \textit{(Shading)}]^{North}$ = 15,52 x 61 x 0.50 x 0.55 = 260,181 ccal/h
   q_{sg} (10 AM) = $[A.\ I_{T.}\ \tau.\ \textit{(Shading)}]^{North}$ = 15,52 x 65 x 0.50 x 0.55 = 277,42 ccal/h
   q_{sg} (11 AM) = $[A.\ I_{T.}\ \tau.\ \textit{(Shading)}]^{North}$ = 15,52 x 67 x 0.50 x 0.55 = 285,956 ccal/h
   q_{sg} (12 AM) = $[A.\ I_{T.}\ \tau.\ \textit{(Shading)}]^{North}$ = 15,52 x 67 x 0.50 x 0.55 = 285,956 ccal/h
   q_{sg} (1 PM) = $[A.\ I_{T.}\ \tau.\ \textit{(Shading)}]^{North}$ = 15,52 x 67 x 0.50 x 0.55 = 285,956 ccal/h
   q_{sg} (2 PM) = $[A.\ I_{T.}\ \tau.\ \textit{(Shading)}]^{North}$ = 15,52 x 65 x 0.50 x 0.55 = 277,42 ccal/h
   q_{sg} (3 PM) = $[A.\ I_{T.}\ \tau.\ \textit{(Shading)}]^{North}$ = 15,52 x 61 x 0.50 x 0.55 = 260,181 ccal/h
2. The per-hour heat gain on the south side is negligible due to a significant shading factor. On the south side, there is a canopy, and the building of the Building Engineering Education Laboratory is on the south side, so it is assumed that the walls or glass on the south side are not exposed to direct sunlight. The results of the calculation are then classified in the Per-Hour Heat Gain table for the northern, southern, eastern, and western parts of the four lecture rooms, which are as follows:

Table 1. Heat Gain Through Room Window

Time	Heat Gain per Side (kcal/hour)				Total	
	North	South	West	East	Ccal/hour	kJ/hour
9	260,181	0	0	0	260,181	1088,597
10	277,42	0	0	0	277,42	1160,725
11	285,956	0	0	0	285,956	1196,44
12	285,956	0	0	0	285,956	1196,44
13	285,956	0	0	0	285,956	1196,44
14	277,42	0	0	0	277,42	1160,725
15	260,181	0	0	0	260,181	1088,597
		Total				8088,597

Nb. 1 Ccal = 4,184 KJ

3.4. Calculation of Heat Gain Through Walls

The heat gain through the mechanical engineering classroom 2, computer room, and thesis examination room is disregarded because both sides of these rooms, on the west and east, are adjacent to walls (with significant shading factors). Conversely, the mechanical engineering classroom one directly receives sunlight on the eastern side. A canopy mitigates the heat gain on the southern wall, and the Educational Building Laboratory obstructs sunlight. Hence, this factor is neglected due to shading. The wall type (F) consists of 100 mm concrete blocks with a 25 to 50 mm partition or a 100 mm facing brick with a 100 mm partition and plaster (100 mm concrete wall with internal and external plaster). The building is assumed to be at 0° North Latitude. To determine the wall area on the eastern side, the following calculation is performed:

Eastern Wall Area = Wall area without windows/ventilation = 8 m x 10 m = 80 m².

The heat gain through the eastern wall (mechanical engineering classroom 1) is calculated hourly using the formula:

$$q\_w = [UA\ (CLTD)] \quad (2)$$

Where:
U = Coefficient of heat transfer design for roofs, walls, or glass.
A = Surface area of roofs, outer walls, or outer glass, calculated from the building drawings.
CLTD = Temperature difference for cooling loads, roofs, walls, or glass.

Where U is the Coefficient of heat transfer design for roofs or external walls, with a value of 1/R = 1 / 0.38 = 2.6315 W/m^2 K (lightweight aggregate concrete, 200 mm), CLTD represents the heat transfer coefficient derived from the CLTD table for wall type F exposed to sunlight. The calculation results are as follows:

q_w (9 AM) = [UA(CLTD)] = [2.6315 x 80 x 16] = 3368.32 ccal/h
q_w (10 AM) = [UA(CLTD)] = [2.6315 x 80 x 21] = 4420.92 ccal/h
q_w (11 AM) = [UA(CLTD)] = [2.6315 x 80 x 24] = 5052.48 ccal/h
q_w (12 PM) = [UA(CLTD)] = [2.6315 x 80 x 25] = 5263 ccal/h
q_w (1 PM) = [UA(CLTD)] = [2.6315 x 80 x 24] = 5052.48 ccal/h
q_w (2 PM) = [UA(CLTD)] = [2.6315 x 80 x 22] = 4631.44 ccal/h
q_w (3 PM) = [UA(CLTD)] = [2.6315 x 80 x 20] = 4210.4 ccal/h

3.5. Calculation of Heat Gain from Human Activity, Equipment, and Airflow

In calculating the heat load from human activities, the time frame is from 9 AM to 3 PM, with cooling loads assessed bi-hourly. Before the calculations, observations were conducted to assume that the heat load from the lights in the room was negligible since the lights are not activated during classes due to sufficient natural lighting.

a. Calculation of Heat Load Due to Activities of Students and Lecturers from 9 AM to 3 PM: Referring to the Table of Heat Gain Rates from Occupants in Conditioned Spaces, it is assumed that the number of students and lecturers (N) in the class is 60, with moderate activity levels contributing sensible heat gain of 73 W and latent heat gain of 59 W. Thus:

   $q_{sensibel}$ = N. Scensible Heat Addition = 60. 73 = 4380 W
   q_{laten} = N. Latent Heat Addition = 60. 59 = 3540 W

   From the calculation of sensible and latent heat, the total heat from human activities is obtained:

   total = $q_{sensibel} + q_{laten}$ (W) = 4380 + 3540 (W) = 7920 W = 7,92 kJ/Jam

b. The calculations assume that the airflow entering and exiting through doors, ventilation, and infiltration are negligible. This is because airflow from infiltration or exfiltration typically occurs only when there is a significant temperature difference between the interior and exterior of the room. When indoor and outdoor temperatures are not drastically different, the effects of this airflow become minimal and are considered not to impact the calculations significantly. Therefore, the influence of airflow through doors, ventilation, or building gaps is deemed irrelevant and excluded from the thermal load analysis when the indoor temperature remains relatively stable and approaches the outdoor temperature.

c. Calculation of Heat Load from Electrical Equipment: This calculation is crucial to ensure that every heat source, whether from artificial lighting or electronic devices, is accurately accounted for in the thermal analysis of the room. Although the heat load from lighting is disregarded due to non-usage, the load from electronic devices is still calculated to provide a clear picture of the room's cooling requirements. The total load from these devices must be considered in the design of the cooling system to maintain a comfortable temperature during class hours.

d. Heat from Lights: From 9 AM to 3 PM, it is assumed there is no heat contribution from lights in the classroom. This assumption is based on the results from six observations indicating that the lights are not used during class hours due to sufficient natural lighting in the room. This adequate lighting condition renders lights unnecessary, thus excluding the heat load typically generated by lights from the calculations.

e. Calculation of Heat Load from Electronic Devices: The heat load generated by electronic devices such as LCD projectors, laptops, and fans is calculated based on the standards outlined in the Table of Metabolic Types of Heat Plants for Various Activities (SNI 03-6572-2001). This standard categorizes LCD projectors, laptops, and fans as light electrical activities with a heat generation value of 37 Btu/Hour. Considering that the conversion of 1 Btu/Hour is equivalent to 0.293071 watts/hour, each electronic device produces 10.85 watts of heat. Thus, the total heat load of these three devices is 10.85 watts (LCD projector) + 10.85 watts (laptop) + 10.85 watts (fan), which totals 32.55 watts or equivalent to 117.18 kJ/h.

3.6. Total Number of Outdoor and Indoor Heat Loads

The results of the calculation of outdoor and indoor heat loading can be compared in Table 2. Total outdoor and indoor heat gain.

Table 2. Total Outdoor and Indoor Heat Gain: 1

Rooms	hours of activity	Heat Gain (kJ/Hr)				Total (kJ/h)
		Window	Wall	Human of activity	Electrical equipment	
Room 1	9	763.74	3368.32	38016	117.18	42265.24
	10	813.82	4420.92	38016	117.18	43367.92
	11	838.86	5052.48	38016	117.18	44024.52
	12	838.86	5263	38016	117.18	44235.04
	13	838.86	5052.48	38016	117.18	44024.52
	14	813.82	4631.44	38016	117.18	43578.44
	15	763.74	4210.4	38016	117.18	43107.32
Total		810.243	4571.291	38016	117.18	43514.7143

Table 3. Total Outdoor and Indoor Heat Gain 2

Rooms	hours of activity	Heat Gain (kJ/Hr)				Total (Kj/h)
		Window	Wall	Human of activity	Window	
Room 2	9	763.74	0	38016	117.18	38896.92
	10	813.82	0	38016	117.18	38947
	11	838.86	0	38016	117.18	38972.04
	12	838.86	0	38016	117.18	38972.04
	13	838.86	0	38016	117.18	38972.04
	14	813.82	0	38016	117.18	38947
	15	763.74	0	38016	117.18	38896.92
Total		810.243	0.000	38016	117.18	38943.423

Table 4. Total Heat Gain Outside and Inside Computer Rooms and Exams

Rooms	hours of activity	Heat Gain (kJ/Hr)				Total (kJ/h)
		Window	Wall	Human of activity	Electrical equipment	
Computer Room	9	763.74	0	38016	117.18	38896.92
	10	813.82	0	38016	117.18	38947
	11	838.86	0	38016	117.18	38972.04
	12	838.86	0	38016	117.18	38972.04
	13	838.86	0	38016	117.18	38972.04
	14	813.82	0	38016	117.18	38947
	15	763.74	0	38016	117.18	38896.92
Total		810.243	0.000	38016	117.18	38943.423

3.7. Calculation of Cooling Requirements

To calculate the power required by an air conditioner (AC) compressor or cooling unit with a capacity of 1 PK (Paard Kracht), we refer to a standard value of 735.5 watts per hour, equivalent to 0.7355 kW. This determination aligns with the provisions outlined in the Minister of Energy and Mineral Resources Regulation (ESDM) No. 304 of 2012, establishing basic parameters for efficiency and energy use in room cooling devices [12].To determine the necessary AC capacity in a room, we must consider the total heat load calculated previously. This heat load is generated from various factors, including sensible and latent heat produced by internal sources such as humans and electronic equipment and heat entering from outside through walls, windows, and roofs. Once the total heat load is calculated, the next step is to convert this value into the required cooling capacity. This cooling capacity is typically expressed in British Thermal Units per hour (BTU/hour) or kilowatts (kW). It is important to note that 1 PK equals approximately 9,000 BTU/hour. By utilizing this conversion, we can determine how many AC units are needed to achieve the desired temperature in the room, considering other factors such as energy efficiency, air distribution, and thermal comfort.

Based on the analysis presented, the following are the steps to calculate the AC requirements:

1. Total Heat Load:
   Room 1 has a total heat load of approximately 44.235 kJ/hour.
   Room 2 and the computer and exam rooms have a total heat load of roughly 38.972 kJ/hour.
2. Conversion from kJ/hour to BTU/hour: 1 kJ = 0.947817 BTU. Therefore, to convert the total heat load to BTU/hour:
   Room 1: 44.235 kJ/hour × 0.947817 BTU/kJ = 41.907 BTU/hour
   Room 2: 38.972 kJ/hour × 0.947817 BTU/kJ = 36.926 BTU/hour

3. Determination of AC Requirements:
   AC units typically have cooling capacities in multiples of 9,000 BTU/hour. Hence, we must determine the required AC units or the appropriate AC capacity. Room 1 has a cooling load of approximately 41.907 BTU/hour, indicating that Room 1 requires an AC unit with a minimum capacity of 42,000 BTU/hour. This can be achieved by installing two units of AC with a capacity of 24,000 BTU/hour each or one unit with a capacity close to this requirement. Room 2's computer and exam room have a cooling load of approximately 36.926 BTU/hour. Therefore, an AC unit with a minimum capacity of 36,000 BTU/hour is necessary for these three rooms.
4. AC Capacity in Kilowatts (kW):
   1 kW is equivalent to 3,412 BTU/hour. For Room 1: 41,907 BTU/hour ÷ 3,412 = 12.28 kW. And For Room 2: 36,926 BTU/hour ÷ 3,412 = 10.82 kW

Consequently, Room 1 requires an AC unit with a capacity of approximately 12.28 kW, while Room 2 requires an AC unit with a capacity of roughly 10.82 kW.

3.8. Discussion of Calculation Results

The room cooling system faces two primary types of heat that must be managed: sensible heat and latent heat. Sensible heat, which influences temperature increases without changing the phase of the material [13], is a key component affecting the cooling load in the room. Sources of sensible heat vary, including heat produced by the human body [5], [14], electronic equipment, and solar radiation penetrating through windows [13], [15]. This radiation becomes a significant factor, particularly on the North and south sides of the room, where heat gain through windows contributes meaningfully to the total heat load. According to calculations, peak heat gain on the north side occurs between 11:00 AM and 1:00 PM, reaching 285,956 kcal/hour, indicating vigorous solar radiation intensity during this period.

Conversely, heat gain from the south side is relatively low due to canopies and surrounding buildings acting as natural shades blocking direct sunlight. The effective use of shading devices, such as windows equipped with shading, has been shown to significantly reduce incoming solar radiation [7] [16], thereby decreasing the heat load that the cooling system must address [7]. On the other hand, latent heat, which causes phase changes without temperature variations, has a minor contribution to room cooling, primarily because dominant processes such as evaporation or condensation do not occur within the room. However, other heat sources, such as heat gain through walls, also play an essential role. For example, on the east wall of Classroom 1, heat gain peaks at noon at 5,263 kcal/hour due to direct sunlight exposure, which raises the surface temperature of the wall and, consequently, the indoor temperature. Meanwhile, heat gain through the walls on the west and south sides can be considered negligible due to the effectiveness of the available shading. Another room protects the west wall; the south wall is covered by a canopy and other structures, reducing heat gain.

Human activity within the room also represents a significant heat source, with 60 students and faculty generating both sensible and latent heat. The total heat gain from human activity reaches 7,920 W, equivalent to 7.92 kJ/hour, indicating that the number of occupants and their activity intensity must be considered in designing an effective cooling system. Although the heat contribution from electronic equipment such as LCD projectors, laptops, and fans is relatively tiny compared to other heat sources, it remains essential to include in the total heat gain, with a cumulative value of 32.55 W or 117.18 kJ/hour. After considering all these factors, the total heat load within the room is calculated, peaking at noon with values of approximately 44.235 kJ/hour in Room 1 and 38.972 kJ/hour in Room 2. The higher heat load in Room 1 compared to Room 2 indicates that direct sunlight exposure on the east wall and north windows is a primary factor influencing fluctuations in heat load. This necessitates designing a cooling system capable of addressing varying heat loads, particularly during daytime when solar radiation reaches its highest intensity.

Each room's required air conditioning capacity is determined based on the total heat load calculations for Room 1, Room 2, the computer room, and the examination room. Utilizing the conversion of 1 kJ = 0.947817 BTU, Room 1 requires approximately 41,907 BTU/hour, and Room 2 needs about 36,926 BTU/hour. Given that AC capacities are typically available in multiples of 9,000 BTU/hour for Room 1, with a requirement of approximately 41,907 BTU/hour, it is recommended to use an AC unit with a minimum capacity of 42,000 BTU/hour. This can be achieved by installing two units of 24,000 BTU/hour each or one unit with a capacity close to that figure. For Room 2, with a heat load of 36,926 BTU/hour, an AC unit with a minimum capacity of 36,000 BTU/hour is required. This cooling capacity is converted into kilowatt (kW) units to provide a broader perspective. Knowing that 1 kW is equivalent to 3,412 BTU/hour, the required cooling capacity for Room 1 is approximately 12.28 kW, while Room 2 is about 10.82 kW.

This analysis emphasizes that selecting the appropriate AC capacity should not solely depend on the room size but also on total heat load calculations involving various factors. Considering the heat loads generated by occupants, equipment, and heat influx from external sources, we can ensure that the chosen cooling system will be efficient and effective in creating a comfortable environment. In tropical regions such as Palangka Raya, where heat intensity can be exceptionally high, particularly during the day, determining the correct AC capacity becomes increasingly vital for maintaining thermal comfort while optimizing energy use.

4. Conclusion

Sensible heat, which affects temperature increases without changing the phase of the material, is a primary component of the room cooling load. Sources of sensible heat include heat generated by the human body, electronic equipment, and solar radiation penetrating through windows. Solar radiation contributes significantly to the heat load, particularly from the North and south sides. On the north side, peak heat gain occurs between 11:00 AM and 1:00 PM, reaching 285,956 kcal/hour, whereas the south side experiences a reduction in heat load due to natural shading. Effective shading can reduce incoming solar radiation, decreasing the heat load the cooling system must address.

Meanwhile, latent heat, which causes phase changes without temperature variations, has a more minor contribution in the context of room cooling. Other heat sources, such as heat gain through walls, also play an essential role. On the east wall of Classroom 1, heat gain peaks at noon, amounting to 5,263 kcal/hour due to direct sunlight exposure. Human activity within the room, particularly with 60 students and faculty, generates sensible and latent heat at 7,920 W or 7.92 kJ/hour. Although relatively small, the contribution of heat from electronic equipment, such as LCD projectors and laptops, must still be considered, totalling 32.55 W or 117.18 kJ/hour.

Total heat load calculations indicate that the peak heat load occurs at noon, with approximately 44.235 kJ/hour values in Room 1 and 38.972 kJ/hour in Room 2. The higher heat load in Room 1 compared to Room 2 signifies that direct sunlight exposure on the east wall and north windows is a primary factor influencing heat load fluctuations. Based on the calculations, the required air conditioning capacity for Room 1 is approximately 41,907 BTU/hour, and Room 2's is 36,926 BTU/hour. It is recommended to use an air conditioner with a minimum capacity of 42,000 BTU/hour for Room 1, which can be achieved with one unit of 24,000 BTU/hour or two units of 12,000 BTU/hour each. Room 2's required AC capacity is at least 36,000 BTU/hour. Converting capacity to kilowatt units shows that Room 1 requires approximately 12.28 kW, while Room 2 requires around 10.82 kW. This analysis underscores the importance of selecting the appropriate AC capacity based on room size and total heat load calculations involving various factors. In tropical regions like Palangka Raya, determining the correct AC capacity is crucial for maintaining thermal comfort while optimizing energy use.

References

[1] Y. Wu, M. Yuan, Z. Wang, and X. Li, "The effect of air conditioners on occupants' thermal adaptive behaviours and wellbeing: Advances and challenges," *E3S Web Conf.*, vol. 80, pp. 1–5, 2019, doi: 10.1051/e3sconf/20198003003.

[2] G. Forzieri, A. Cescatti, F. B. e Silva, and L. Feyen, "Increasing risk over time of weather-related hazards to the European population: a data-driven prognostic study," *Lancet Planet. Heal.*, vol. 1, no. 5, pp. e200–e208, 2017, doi: 10.1016/S2542-5196(17)30082-7.

[3] B. Lala and A. Hagishima, "Impact of Escalating Heat Waves on Students' Well-Being and Overall Health: A Survey of Primary School Teachers," *Climate*, vol. 11, no. 6, 2023, doi: 10.3390/cli11060126.

[4] K. Lundgren-Kownacki, E. D. Hornyanszky, T. A. Chu, J. A. Olsson, and P. Becker, "Challenges of using air conditioning in an increasingly hot climate," *Int. J. Biometeorol.*, vol. 62, no. 3, pp. 401–412, 2018, doi: 10.1007/s00484-017-1493-z.

[5] M. N. Cramer, D. Gagnon, O. Laitano, and C. G. Crandall, "Human Temperature Regulation Under Heat Stress in Health, Disease, and Injury," *Physiol. Rev.*, vol. 102, no. 4, pp. 1907–1989, 2022, doi: 10.1152/PHYSREV.00047.2021.

[6] J. Liu, J. Kang, Z. Li, and H. Luo, "Overall effects of temperature steps in hot summer on students' subjective perception, physiological response and learning performance," *Energy Build.*, vol. 247, no. October 2020, 2021, doi: 10.1016/j.enbuild.2021.111124.

[7] H. Y. Bai, P. Liu, M. Justo Alonso, and H. M. Mathisen, "A review of heat recovery technologies and their frost control for residential building ventilation in cold climate regions," *Renew. Sustain. Energy Rev.*, vol. 162, no. April, 2022, doi: 10.1016/j.rser.2022.112417.

[8] Creswell. J.W., *Research designs. Qualitative, quantitative, and mixed methods approaches*, vol. 4, no. 11. 2009. doi: 10.1128/microbe.4.485.1.

[9] P. Leavy, *Research Design*, 1st ed. United State Of America: The Guilford Press A Division of Guilford Publications, Inc. 370 Seventh Avenue, Suite 1200, New York, NY 10001, 2017.

[10] K. McCusker and S. Gunaydin, "Research using qualitative, quantitative or mixed methods and choice based on the research," *Perfus. (United Kingdom)*, vol. 30, no. 7, pp. 537–542, 2015, doi:

10.1177/0267659114559116.

[11] K. Bansal, S. Chowdhury, and M. R. Gopal, "Development of CLTD values for buildings located in Kolkata, India," *Appl. Therm. Eng.*, vol. 28, no. 10, pp. 1127–1137, 2008, doi: 10.1016/j.applthermaleng.2007.08.005.

[12] Kementerian ESDM, *Peraturan Menteri ESDM Nomor 304 Tahun 2012*. 2012, p. 14.

[13] Y. Gao *et al.*, "Thermal performance analysis of sensible and latent heat thermal energy storage tanks: A contrastive experiment," *J. Build. Eng.*, vol. 32, no. July, p. 101713, 2020, doi: 10.1016/j.jobe.2020.101713.

[14] W. Aftab, A. Usman, J. Shi, K. Yuan, M. Qin, and R. Zou, "Phase change material-integrated latent heat storage systems for sustainable energy solutions," *Energy Environ. Sci.*, vol. 14, no. 8, pp. 4268–4291, 2021, doi: 10.1039/D1EE00527H.

[15] M. Liu, S. Riahi, R. Jacob, M. Belusko, and F. Bruno, "Design of sensible and latent heat thermal energy storage systems for concentrated solar power plants: Thermal performance analysis," *Renew. Energy*, vol. 151, pp. 1286–1297, 2020, doi: 10.1016/j.renene.2019.11.115.

[16] I. Omar, A. M. Mohsen, K. A. Hammoodi, and H. A. Al-Asadi, "Using total equivalent temperature difference approach to estimate air conditioning cooling load in buildings," *J. Eng. Therm. Sci.*, vol. 2, no. 1, pp. 59–68, 2022, doi: 10.21595/jets.2022.22684.