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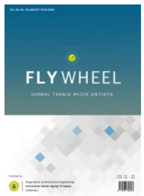

Analysis of Cooling Load in Room GK1-103, Institut Teknologi Sumatera

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ABSTRACT

This study evaluates the actual cooling load of a classroom in a university to assess whether the installed air conditioning capacity meets requirement to achieve thermal comfort. Environmental data, including temperature and humidity, were collected on-site in order to obtain accurate results that reflect actual use-case conditions. Cooling loads from occupants, equipment, lighting, and transmission were calculated using standard approach to ensure alignment with industry practices. The total cooling load was estimated at 13659.9 W with lighting and 13429.5 W without lighting, both exceeding the current installed cooling system with capacity of 10040 W. Transmission heat gain was the largest contributor, highlighting the importance of building envelope performance. The findings indicate that the current AC system is undersized, suggesting cooling capacity expansion or load reduction strategies. Furthermore, this paper offers a reference for cooling system evaluation on other similar rooms in the university.

Keywords: *Cooling Load Analysis, Cooling load, Cooling capacity, Air Conditioning, HVAC*

1. BACKGROUND

As Indonesia experiences warm and humid tropical climates, air conditioning is a crucial factor in a building's energy consumption. That said, cooling load calculation is one of the key aspects of energy-saving measures [1]. Cooling load, which refers to the amount of heat energy that must be removed to maintain a comfortable indoor environment, is affected by various factors such as external temperature, building design, occupancy levels, and internal heat sources. Accurate cooling load calculations help engineers and designers create systems that meet comfort demands without excessive energy consumption.

Institut Teknologi Sumatera (ITERA) is committed to fostering green and energy-efficient campus, which makes the study of cooling loads particularly relevant. During the design process of rooms and buildings, engineers have estimated the required air conditioning units for the rooms. However, the actual use-case of the rooms post-commissioning sometimes does not exactly fit the initial design, hence evaluation adjustments are needed [2].

The objective of this work is to present an analysis of the cooling load based on the current actual use-case of a room in ITERA, and, with the obtained information, provide recommendations. The principal questions guiding this work are: (1) What is the real cooling load of the room in a typical day? and (2) Is the capacity of current air conditioning installation sufficient to overcome the load?

This paper describes a systematic analysis, assessing different parameters that influence the cooling load. Factors such as solar radiation, ventilation rates, and the quality of building insulation are evaluated in this paper to provide a detailed understanding of their impact on cooling requirements. Through this systematic and didactic presentation, this paper aims to improve the accuracy of cooling load estimations in ITERA's buildings and serves as a reference for other rooms with similar utilizations.

2. METHODOLOGY

2.1 Environmental data collection.

As the initial stage, it is essential to collect environmental data that affects room temperatures, such as outdoor temperature, humidity, and sunlight levels. By gathering this information, we get a clear picture of the external factors that impact how much cooling each room will need, especially given ITERA's warm climate.

This data was retrieved from the Meteorology, Climatology, and Geophysical Agency (BMKG). Nevertheless, to improve accuracy of the local temperature reading, we supplemented the measurement with our own measurements in vicinity of the building with a handheld thermometer (Fluke 971).

2.2 Room physical measurement

We also measured room physical dimensions. This includes the length, width and height of the room. This measurement will provide information on the area and volume of the room that are taken in to account in the calculations.

2.3 Occupancy and equipment usage monitoring

Monitoring how rooms are used is also important. We tracked the number of people typically in the room and how often it's occupied, as people add heat to the room. Additionally, we record the types of equipment and lighting used, as these also produce heat, affecting the room's cooling needs.

2.4 Temperature and humidity monitoring

Using temperature and humidity sensors in the room that we want to analyze, we monitor real-time indoor conditions. This allows us to see how these conditions change during the day and how they are affected by both outside weather and internal activities, giving us precise data for cooling calculations. For this task, we employed digital temperature and humidity meter, placed in the middle of the classroom and the reading was recorded from time to time.

2.5 Data analysis

Finally, we analyzed all the data that we get to calculate room cooling load. The data was further processed statistically to obtain the figures to be used in cooling load calculations. Based on the calculation, we made analysis which would lead to conclusion and recommendation.

3. DATA COLLECTION

3.1 Building data collection

To conduct a comprehensive cooling load analysis, we chose Gedung Kuliah Umum 1 (GKU-1) classroom 103 at ITERA, detailed building data was collected to understand the structural factors influencing heat accumulation and dissipation within the space. The room's dimensions are as follows: 12 m length, 7.8 m width, and 3 m height.

To assess internal heat gains, we recorded occupancy information, capturing typical numbers of students and staff and their time spent in each room. This is important because human activities affect thermal balance of the ambient air as well as the surrounding surfaces [3]. Furthermore, data on equipment and lighting usage was collected, including details on common devices such as projector, laptops, handphones, and lighting types. These internal heat sources significantly influence the room's cooling load and must be considered for an accurate calculation of energy needs.

3.2 Weather data collection

In addition to building-specific information, environmental conditions were monitored to understand how external factors affect the cooling requirements of classroom 103 GKU-1. This weather data collection focused on metrics such as outdoor temperature, humidity levels, and solar radiation, which are particularly relevant in warm, tropical climate such as the place where ITERA is located. By collecting data from November 4 to November 10, 2024, as tabulated in Table 1, we aimed to capture daily variations in temperature and humidity, providing a realistic picture of the external conditions that impact indoor cooling demands.

Table 1. Weekly temperatures

Date	4	5	6	7	8	9	10
Output temperature (°C)	31	29	29	29	31	31	31
Input temperature (°C)	24	24	23	24	25	24	24
Humidity (%)	57	57	42	84	80	40	63

There are many different models and techniques available for calculating the distribution of solar radiation on and in buildings [4]. It influences heat gain through windows and walls exposed to sunlight, contributing significantly to the overall thermal load. Humidity levels were also monitored, as they impact indoor air quality and cooling needs, particularly in regions with high ambient moisture.

By integrating both building-specific and environmental data, we can generate a precise assessment of the cooling load required to maintain comfortable indoor temperatures in classroom 103 GKU-1.

4. CALCULATION

4.1 Occupants load

In the cooling load calculations, occupants have a significant impact on the required cooling load of buildings [1]. Occupants contribute to both sensible heat (from body temperature) and latent heat (from moisture) that can significantly impact the cooling requirements of a space.

By assessing the occupant load, the number of people expected to occupy the area and their associated heat gains. Designers can determine how much cooling is necessary to maintain a comfortable indoor environment. This introduction to occupant load estimation provides a systematic approach to calculating its contribution to the overall cooling load, ensuring that spaces are adequately cooled based on expected usage. Formula (1) is used to calculate the occupant load for cooling purposes.

$$Occupants\ Capacity = \frac{A}{D} \quad (1)$$

Where, A is room area (m^2), D is occupancy density (m^2/person).

$$A = 12(7.8) = 93.6\,m^2$$

Assuming ¼ of the room is used for the lecture stage, the area considered in the calculation is:

$$\mathrm{A_{STAGE}} = \frac{1}{4}(93.6) = 23.4\ \mathrm{M^2}$$

$$\mathrm{A_{NEW}} = 93.6 - 23.4 = 70.2\ \mathrm{M^2}$$

Assume that d = 1.5 m^2/person

$$\text{Occupants capacity} = \frac{70.2}{1.5} = 46.8 \approx 46\ \text{PEOPLE}$$

The occupancy load can be calculated using the values in Table 2 and the following formula:

Table 2. Heat gain [5]

Level of Activity	Typical	Heat Gain / Person btuh	
	Application	SHG (qs)	LHG (ql)
Seated at rest	Theater	245	105
Seated, light work	Office	245	155
Moderate office work	Office	250	200
Standing, walking slowly	Retail Sales	250	250
Light bench work	Factory	275	475
Dancing	Nightclub	305	545
Heavy work	Factory	580	870

$$SHG = \frac{245}{3.412} = 72W$$

$$\mathrm{Q_{occupants}} = \text{SHG x Occupants capacity} = 72(46) = 3312\text{W}$$

4.2 Equipment load

In the context of cooling load, equipment load refers to the heat generated by equipment or appliances operating within a room. The growth in energy use for HVAC systems is particularly significant [6].

This generated heat must be accounted for in the design of the room's cooling system to maintain a comfortable temperature and ensure efficient operation of the equipment.

Generally, the equipment load in cooling load can be calculated using the following formula (2):

$$Q_{eqp} = \sum (W_{in}\ x\ F_H\ x\ 3.412) \quad (2)$$

Where, Q_{eqp} is heat load generated by the equipment (BTU/hour), W_{in} is electrical power consumed by the equipment (watts), F_H is heat conversion factor, which depends on the equipment's, and Efficiency is conversion factor from watts to BTU/hour.

This calculation helps HVAC designers determine the cooling capacity required to counteract the heat from equipment, maintaining thermal comfort and energy efficiency within the space.

Handphone

Figure 1. Handphone

Assume:

- 46 phones, each consuming 10 watts.
- F(heat) = 1.0
- Power = 5V, 2A

Calculation Q for phones:

$$\mathrm{Q_{phones}} = 46(10W)(1.0)(3.412) = 1569.52\ \text{BTU/hr}$$

Laptop

Figure 2. Laptop

Assume:

- 1 laptop, consuming 60 watts
- F(heat) = 1.0
- Power = 19V, 3.16A

Calculation Q for laptop:

$$Q_{laptops} = 1(60W)(1.0)(3.412) = 204.72\ BTU/hr$$

Projector

Figure 3. Projector

Assume:

- 1 projector consuming 200 watts
- F(heat) = 1.0

Calculation Q for projector

$$Q_{projector} = 1(200W)(1.0)(3.412) = 682.4\ BTU/hr$$

Based on the calculation, total Q_{eqp} is:

$$Q_{eqp} = \left(Q_{phones} + Q_{laptops} + Q_{projector}\right)$$

$$Q_{eqp} = (1569.52 + 204.72 + 682.4)\ BTU/hr = 2456.64\ BTU/h$$

Table 3. Equipment load heat gain

Equipment	Heat Gain (W)	Qty	Heat gain total	
			(W)	(BTU/hr)
Phones	10	46	460	1569.52
Laptop	60	1	60	204.72
Projector	200	1	200	682.4
Heat Gain Total			720	2456.64

4.3 Lighting load

In cooling load calculations, the heat generated by lighting plays a critical role, occupant dynamic presence and characteristics associated with lighting loads [7]. Lighting fixtures, especially when they operate for extended periods, release a significant amount of heat, which the cooling system must counteract to maintain a comfortable indoor environment.

Accurately assessing the lighting load involves calculating the total lighting power, adjusting for use factors and any additional ballast heat if applicable. This lighting heat gain is then incorporated into the overall cooling load calculation.

Properly accounting for lighting load helps ensure that cooling systems are correctly sized to handle the cumulative heat from various internal sources, thereby enhancing energy efficiency and occupant comfort.

Figure 4. Classroom GK103

Here is the calculation format for determining the lighting load in a cooling load calculation:

$$Q = (W \times 3.412) \times Fu \times Fs \times CLF \tag{3}$$

Where, Q is total heat gain from lighting (BTU/hr), W is total lighting power (watts), number 3.412 is conversion factor from watts to BTU/hr (1W = 3.412 BTU/hr), F_u is lighting use factor, F_s is Ballast Factor, and CLF is cooling load factor.

Known data from classroom GKU1 103, W = 24 bulb x 8W = 192W, F_u =1, F_s = 1.2, CLF = 1. So, the Q for lighting load is:

$$Q = (192W \times 3.412) \times 1 \times 1.2 \times 1 = 786.12\,\frac{BTU}{hr} = 230.4W$$

4.4 Transmission load

The envelope heat transmission contributes to the cooling and heating loads [8]. Transmission load is heat that comes from outside the room that flows into the room, this occurs based on the second law of thermodynamics, namely heat moves from a place with a high temperature to a place with a lower temperature.

In this room, the rate of heat transfer (Q) is hampered by the walls that act as thermal resistance. The part of the room that is directly exposed to the sun has a greater rate of heat transfer due to the fairly high temperature difference between the outside and inside of the room.

The transmission load equation can be written as follows:

$$Q = -\frac{K \cdot A \cdot (T_2 - T_1)}{d} \tag{4}$$

Where, Q is heat flow rate (Watt), K is thermal conductivity (W/m.K), T_2 is low-temperature region (K), T_1 is high-temperature region (K), d is thickness (m).

Here area data that we get from measured a GKU1 room 103.

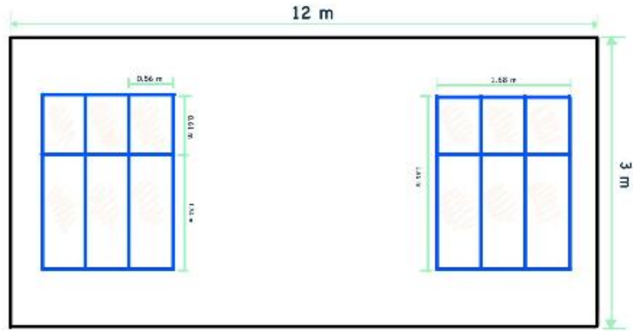

Figure 5. Dimension of GKU1 room 103

$$A_{\text{total wall}} = 12\text{m x } 3\text{m} = 36\text{m}^2$$

$$A_{\text{window}} = (1.95\text{m x } 1.68\text{m}) \text{ x } 2 = 6.55\text{m}^2$$

$$A_{\text{calculated wall}} = 36\text{m}^2 - 6.55\text{m}^2 = 29.45\text{m}^2$$

In 4th November 2024, GK1-103 room has specification about this:

Table 4. Thermal Conductivity

		Fluid	Air	Silicone fluid	Magnetic fluid	Water
	W m^{-1} K^{-1}	k_f	0.026	0.15	0.59	0.61
Wall	k_w	k^*				
Plywood	0.12		4.6 [4]	0.8	0.20	0.20
PVC	0.16		6.2 [1]	1.07	0.27	0.26
Silicone fluid	0.15		5.8		**0.25**	0.25
Perspex	0.19		7.3	**1.27**	**0.32**	0.31
Magnetic fluid	0.59		23	**3.9**		0.97
Glass	0.8		31	5.3	1.36	1.31
Concrete	1.0		38	6.7	1.69	1.64
Steel	46		1770	310	78	75
Aluminium	237		9100 [14]	1580	400	390
Copper	400		15400 [1]	2700	680	660

Table 5. Data of transmission load

Type	Value	Unit
Temperature Outside (T1)	304	Kelvin
Temperature Inside (T2)	297	Kelvin
Thermal Conductivity (Wall)	1	W/m^2.K
Thermal Conductivity (Glass)	0.8	W/m^2.K
Area (Wall)	29.45	m^2
Area (Glass)	6.55	m^2
Thickness (Wall)	0.1	m
Thickness (Glass)	0.05	m

With data above, we can calculate Heat Flow Rate (Q) from the outside of the room of GK1-103, the calculation:

$$Q_{\text{wall}} = -\frac{(1)(29.45)(297-304)}{0.1} = 2061.5\text{W}$$

$$Q_{\text{window}} = -\frac{(0.8)(6.55)(297-304)}{0.005} = 7336\text{W}$$

$$Q_{\text{transmission}} = 2061.5\text{W} + 7336\text{W} = 9397.5\text{W}$$

After calculation, we know the heat flow rate in GK1-103 room from the outside to the inside through the concrete wall is 9397.5 W.

5. ANALYSIS

All forms of load in the GKU1 room 103, namely the form of occupant load, lighting load, equipment load, and transmission load which have a Q total after knowing the data from the data that has been obtained, below is the total Q for all forms of load in the GKU1 room 103:

$$Q_{total} = Q_{occupants} + Q_{equipment} + Q_{lighting} + Q_{transmission}$$

$$Q_{total} = 3312\ W + 720\ W + 230.4\ W + 9397.5\ W$$

$$Q_{total} = 13659.9\ W$$

However, in normal day, we do not use lights in classroom so if lighting load is neglected, the total load will be:

$$Q_{total} = Q_{occupants} + Q_{equipment} + Q_{transmission}$$

$$Q_{total} = 3312W + 720W + 9397.5W$$

$$Q_{total} = 13429.5\ W$$

In GKU-1 room 103 there are 2 Daikin air conditioning (AC) units each with a capacity of 5020 W and the following is the total calculation of the cooling capacity in GKU1 room 103:

$$\text{Daikin AC Capacity} = 5020\text{W x } 2 = 10040\text{W}$$

Recapitulating the cooling load calculations and cooling capacity data, the following can be used for the basis of evaluation:

1. Full lighting load

   $Q_{\text{total}} = 13659.9\text{W}$

   Capacity of 2 AC = 10040W

   Q_{total} > Capacity of 2 AC

   13659.9 > 10040W

2. Without lighting load

   $Q_{\text{total}} = 13429.5\text{W}$

   Capacity of 2 AC = 10040W

   Q_{total} > Capacity of 2 AC

   13429.5W > 10040W

In both cases, the cooling loads are larger than the cooling capacity of the installed air conditioning system. This suggests the need to add capacity of the system, which can be achieved by adding another unit.

6. CONCLUSION

The analysis of GKU-1 Classroom 103 shows that the actual cooling load, with or without lighting, are at least 13429.5W, exceeding the installed AC capacity 10040W, indicating the system is undersized for current usage. Results are based on real measurements with additional observation-based assumptions for occupancy, equipment use, and thermal properties, to obtain a close figure to the actual operational conditions. Future work will extend monitoring, refine load modelling, and evaluate alternative cooling or load-reduction strategies. Finally, the approach demonstrated here can be adapted for other itera rooms and similar buildings to improve HVAC sizing and energy efficiency planning.

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