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Analysis of Cooling Load Calculation 2nd Floor Building F, Engineering Faculty Widyatama University

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Abstract: The air conditioning system is the process of regulating air, which includes air temperature, humidity, and air quality. Air conditioning in the classroom is an important factor to support the teaching and learning process. On the second floor of Building F, there are 3 classrooms. Each classroom has 2 air conditioners of the split type. When room has a full number of students, the air temperature in the room is very uncomfortable due to the heat. This research purposes are to calculate the maximum cooling load for these three classrooms, and to provide recommendations to the relevant parties regarding the required cooling capacity. The research method used is the analysis of the cooling load calculations for the air conditioning system. The research results are the total heat load for classroom F200 is 6.081 PK, classroom F201 is 5.956 PK, and classroom F202 is 6.236 PK, while the existing cooling capacity for each classroom is 3 PK. Therefore, the cooling capacity in the three classrooms on the second floor of Building F does not meet the maximum cooling load requirements. The recommendation from this research is that an additional air conditioning capacity of 3 PK is needed for each room.

Keywords: *Air Conditioning System; Cooling Load; AC Split.*

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I. INTRODUCTION

The anomalies of natural conditions compared to their normal state represent climate change over a period of decades or centuries [1]. One sign of climate change is the significant change and increase in air temperature [2]. Between 1990 and 2019, the increase in air temperature in Indonesia was between 0.11 and 1.24°C [3]. Due to the continuously rising air temperatures, the use of air conditioning (AC) has increased along with the growing number of residences and public facilities in major cities in Indonesia [4]. Air conditioning in a room has become a necessity nowadays to ensure that the space is comfortable. This can support all activities taking place within that room [5]. Air conditioning is the process of regulating temperature, humidity, and distribution within a space to achieve the desired comfort [6].

One of the buildings/rooms that require air conditioning is the classroom. Air conditioning in the classroom is important to support the teaching and learning process. Widyatama University has one of the lecture halls for students on the second floor of Building F, Faculty of Engineering. On the second floor, there are 3 classrooms. Each classroom has 2 air conditioners of the split type. When the learning conditions have a full number of students, the temperature in the room is very uncomfortable due to the heat. The room temperature in the classroom was measured at 30°C, while the temperature setting was at 16°C; this certainly hinders the learning process. The facility's confirmation stated that there is no damage to the air conditioning units in those classrooms.

Based on the background above, the formulation of the problem in this study is whether the cooling capacity of the split AC units in the classrooms on the 2nd floor of Building F, Faculty of Engineering, meets the maximum cooling load. Therefore, the objective of this research is to calculate the maximum cooling load for three classrooms on the 2nd floor of Building F, Faculty of Engineering, Widyatama University Bandung, and to provide recommendations to the relevant parties regarding the required cooling capacity.

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II. LITERATURE REVIEW

A. Air Conditioning

Air conditioning is the process of treating air in an enclosed environment to establish and maintain the necessary standards related to temperature, humidity, cleanliness, and movement [7]. An air conditioner (AC) is a device that regulates temperature, humidity, cleanliness, and distribution simultaneously to create a comfortable atmosphere in a room, which is essential for people. The air conditioning machine uses a vapor compression cycle to cool the space. Refrigerant is the working fluid of this cycle [8]. Figure 1 is a diagram of the vapor compression cycle. The cycle of the air conditioning system is presented in Figure 2.

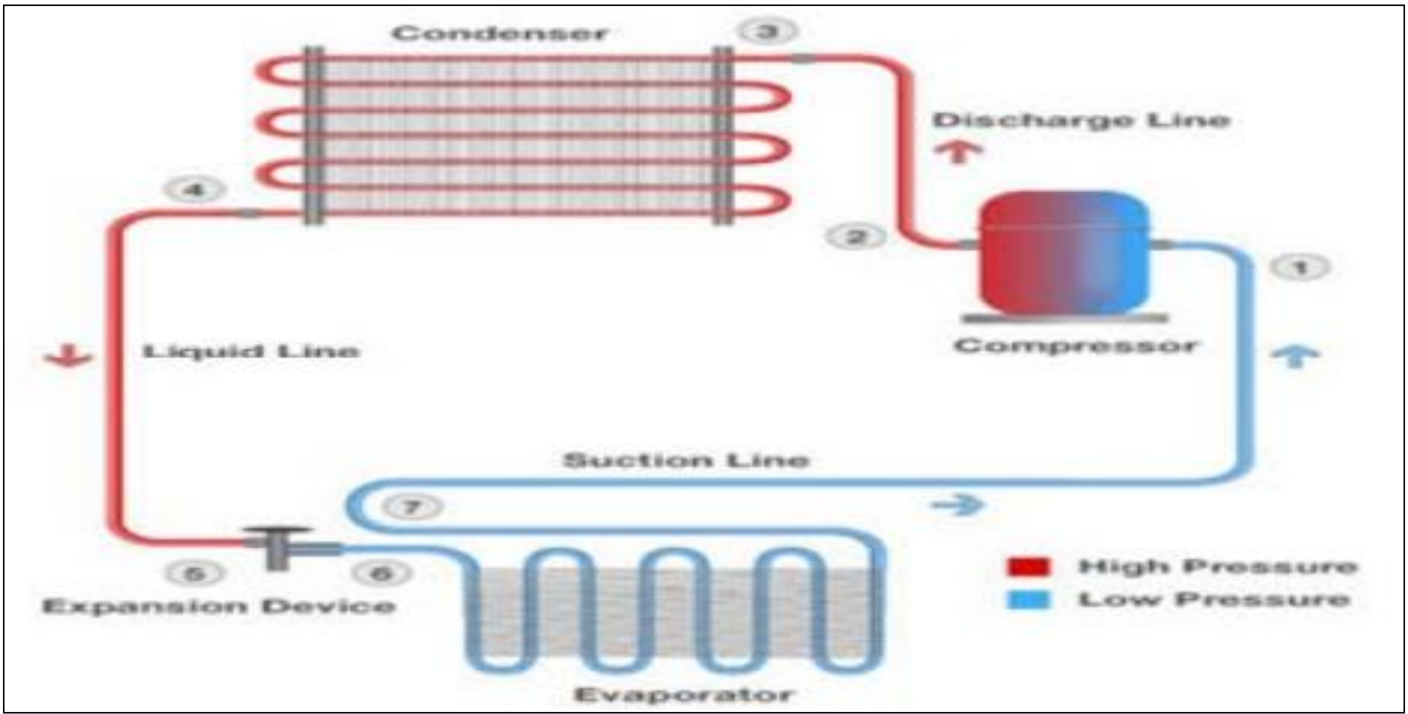

Fig 1: Diagram of the Vapor Compression Cycle [9]

The air conditioning system consists of four main components: the compressor, condenser, expansion pipe or capillary valve, and evaporator. The compressor increases the refrigerant pressure. The function of the condenser is to change the state of the refrigerant from gas to liquid. The capillary tube or expansion valve significantly reduces the refrigerant pressure. The evaporator, also known as the indoor unit of the air conditioning system, absorbs heat from the indoor air, making the air inside cooler while the refrigerant in the evaporator becomes warmer. The function of the evaporator is as a heat exchanger [11].

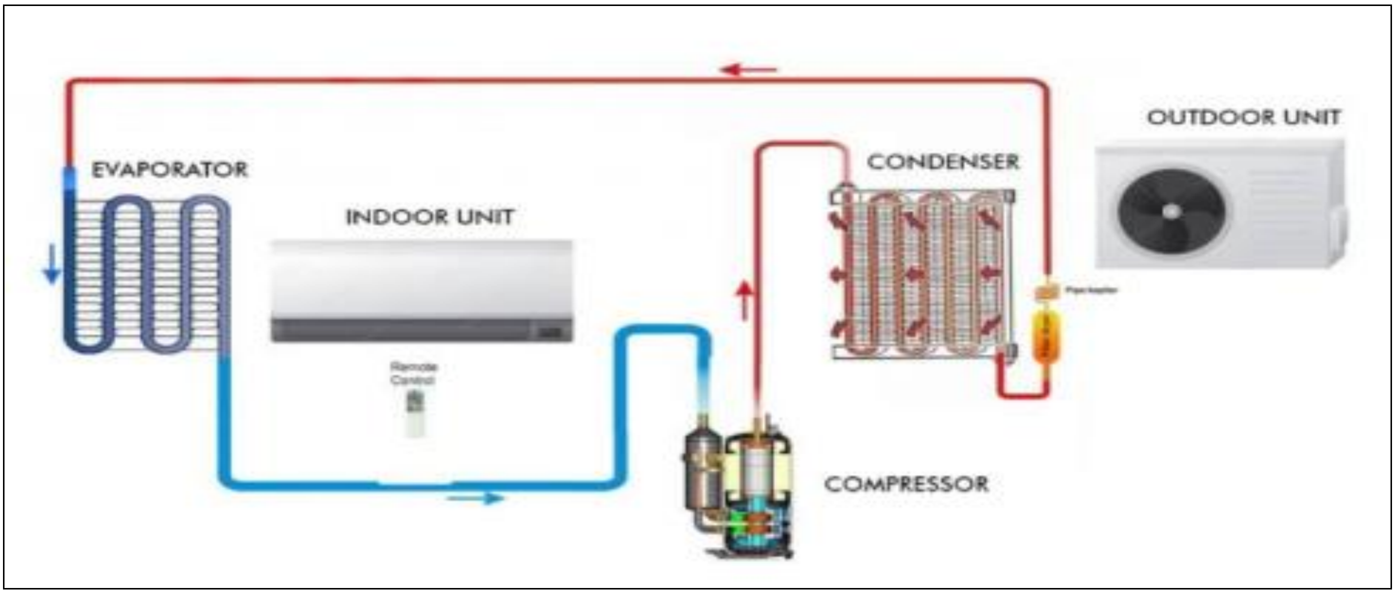

Fig 2: Diagram of the Air Conditioning Cycle [10]

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B. Cooling Load

The calculation of cooling load for air conditioning system design is primarily used to determine the volumetric flow rate of the air system as well as the coil load and cooling from equipment to determine the size of HVAC&R equipment and provide input to the system for energy usage calculations in order to select the optimal design alternative. The cooling load is usually classified into two categories: external and internal [12].

The external load required for cooling load calculations consists of heat loads from the walls, heat loads from the windows, heat loads from the roof, and heat loads from the floor. Meanwhile, the internal load required for cooling load calculations consists of heat loads from people, heat loads from lighting, and heat loads from equipment. In addition to these two loads, there are other factors such as radiation, infiltration load, and ventilation load [7]. The supporting image for the cooling load of a room is shown in Figure 3.

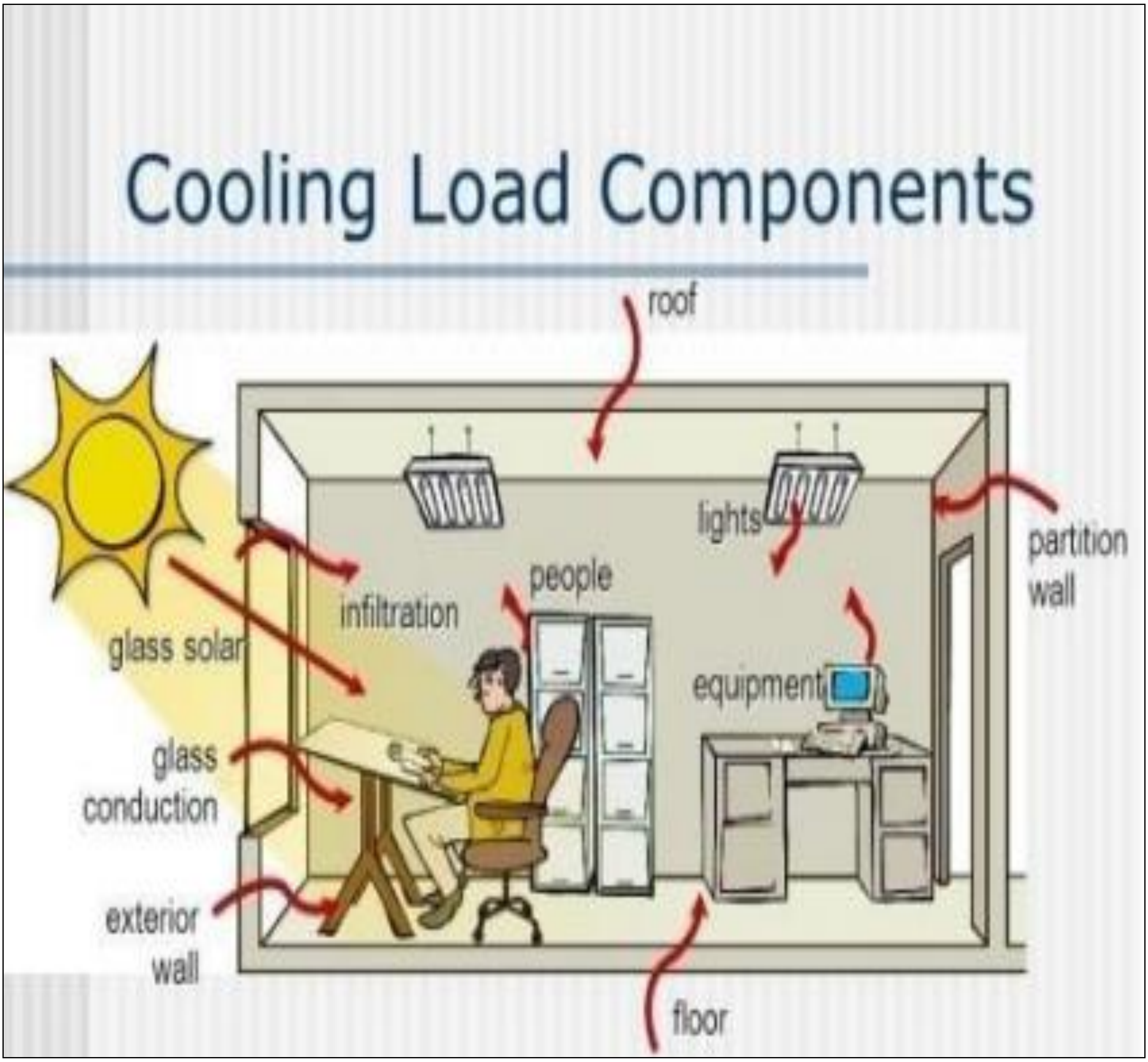

Fig 2: Cooling Load Variables [13]

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III. RESEARCH METHODOLOGY

The research flow diagram can be seen in figure 4.

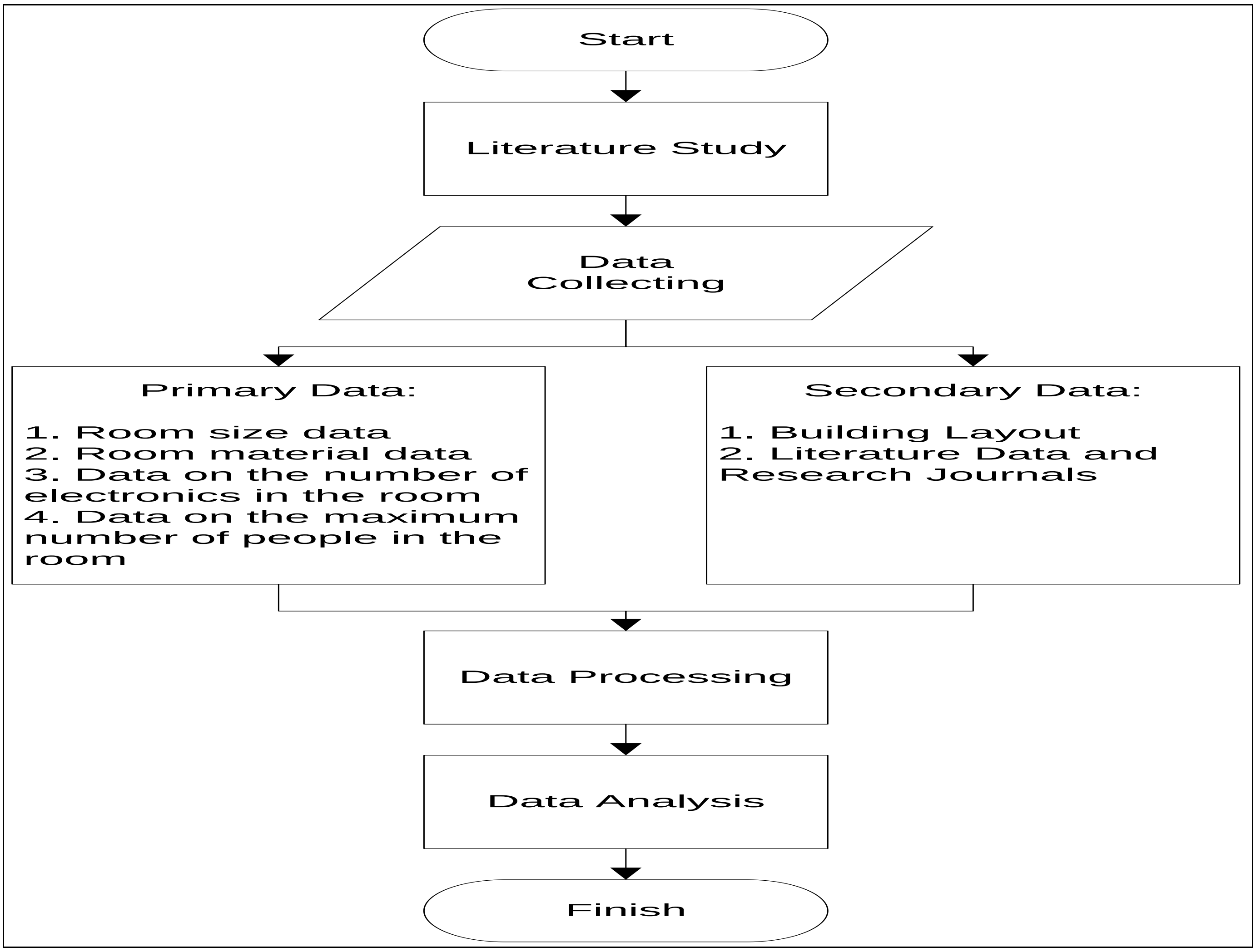

Fig 4: Research Flow Diagram

A. *Literature Study*

At this stage, it is necessary to have literacy in references that are relevant to research on calculating the maximum load of a room from various sources such as scientific articles in research journals, books, and other sources.

B. *Data Collecting*

Data collection consists of gathering two types of data, namely primary data and secondary data. Secondary data consists of images or layouts of the second floor of Building F. Primary data includes room dimensions, building materials, the number of electronic devices, and the number of people in the room to be studied.

C. *Data Processing*

At this stage, data processing is carried out in the form of calculations on the collected data. The data calculations used refer to ASHRAE standards. The cooling load calculations are influenced by external load factors and internal load factors. The calculations and equations used are as follows [7]:

- *Heat Load on the Wall*

The design description is as follows:

$$q = U \times A \times CLTDc \qquad (1)$$

Where:

q = heat load from the wall (Btu/hr)
U = 0.490 Btu/hr.ft². °F
A = Area of the wall that is radiating (ft^2)

$$CLTDc = (CLTD + LM) + (78 - TR) + (To - 85) \qquad (2)$$

Where:

K = Wall color adjustment factor
TR = Design room air temperature, °F.
CLTD = Cooling Load Temperature Difference.

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To = Outside air temperature at specific times, which can be calculated using the equation:
To = T outdoor – (0.5 x daily range) …….................... (3)

Where:

Ta	= 30˚C (86˚F), 70%
Unconditioned TR	= 28˚C (82.4˚F), 70%
Conditioned TR	= 24˚C (75.2˚F), 50%
Daily Range (DR)	= 11˚F (table A.9)
U	= 0.490 Btu/hr.ft². °F (table 6.3)
LM	= table 6.4
CLTD	= table 6.2

➢ *Heat Load from Windows*

The load from the windows can be calculated using the equation:
q = SHGF x A x SC x CLF .... (4)

Where:

q = load from the window, Btu/hr
SHGF = maximum heat factor, Btu/hr.ft^2 (table 6.6)
A = area of the window, ft^2
SC = Shading Coefficient (table 6.7)
CLF = Cooling Load Factor through glass (table 6.8)

➢ *Heat Load on the Roof*

The load from the roof can be calculated using the equation:
q = U x A x CLTD .... (5)

Where:
q = Load from the roof, Btu/hr
U = 0.093 Btu/hr.ft². °F (table 6.1)
A = Area of the roof, ft²
CLTD = 15 °F

➢ *Radiation Factor*

The radiation load can be calculated using the equation:

q = SHGF x A x SC x CLF.. (6)

Where:

Q = heat load from radiation
SHGF = maximum heat factor, Btu/hr.ft² (table 6.6)
SC = Shading Coefficient (table 6.7)
CLF = Cooling Load Factor through glass (table 6.8)
A = Area of glass/window.

➢ *Heat Load from People*

For the calculation of heat load from people, it is divided based on the type of room. The design specifications are as follows:

qs = qs/person x number of people x CLF .... (7)
qL = ql/person x number of people x CLF.............. (8)

Where:

qs/person = 250 Btu/h (table 6.13)
ql/person = 200 Btu/h (table 6.13)
CLF = 1.0 (table 6.14)

➢ *Load from Lighting*

The load from lighting can be calculated using the following formula:
q = 3.4 x W x BF x CLF .... (9)

Where:

q = heat load from the lamp
W = lamp power
BF = Ballast factor (1.25)
CLF = Cooling Load Factor for lighting (1)

➢ *Load from Equipment*

For the calculation of heat load from equipment, it is categorized based on the type of equipment. The design specifications are as follows:

q = 3.41 x n x Heat Gain x CLF .... (9)

Where:

n = Number of devices
Heat Gain = power of the device
CLF = 1.0

➢ *Infiltration Load*

For the calculation of the heat load from infiltration, it is divided based on the type of room. To calculate the infiltration load, the following formulas are used:

qs = 1.1 x CFM x Tc .... (10)
qL = 0.68 x CFM x (Wi – Wo) .... (11)

Where:
qs = sensible heat load of air infiltration, Btu/hr
qL = latent heat load of air infiltration, Btu/hr
CFM = air ventilation rate, ft³/min (Table 3.4)
CFM Window = 0.37 CFM per ft.
CFM Door = 1.0 CFM per ft².
TC = temperature difference between outside and inside, °F
ΔW = difference between the humidity ratio outside and inside, gr.w./kg. d.a.
Wo = gr.w./kg. d.a.
Wi = gr.w./kg. d.a.

➢ *Ventilation Load*

For the calculation of the heat load from ventilation, it is divided based on the type of room. To calculate the infiltration load, the following formulas are used:

qs = 1.10 x CFM x TC x NO .... (12)
qL = 0.68 x CFM x (Wi – Wo) x NO .... (13)

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Where:

qs = sensible heat load of air infiltration, Btu/hr
qL = latent heat load of air infiltration, Btu/hr
CFM = 15 CFM air ventilation rate, ft³/min (Table 6.15)
TC = temperature difference between outside and inside, °F
ΔW = difference between the humidity ratio outside and inside, gr.w./kg. d.a.
NO = Number of people

D. Data Analysis

At this stage, data analysis is conducted to conclude whether the existing cooling capacity meets the maximum cooling load requirements of the room.

IV. RESULT AND DISCUSSION

A. Cooling Load Calculation Result

The results of the cooling load calculation are as follows:

- *Heat Load on the Wall*

Table 1: Heat Load on the Wall Class F200

Directions	**U (Btu/hr.ft^2)**	**A (ft^2)**	**CLTDcor (°F)**	**Q (Btu/hr)**
West	0,49	271,250	8,05	1069,946
East	0	271,250	0	0,000
North	0,49	291,432	14,05	2006,364
South	0,49	255,750	2,05	256,901
Total Heat Load on the Wall				3333,210

Table 2: Heat Load on the Wall Class F201

Directions	**U (Btu/hr.ft^2)**	**A (ft^2)**	**CLTDcor (°F)**	**Q (Btu/hr)**
West	0	271,250	0	0,000
East	0	271,250	0	0,000
North	0,49	291,432	14,05	2006,364
South	0,49	255,750	2,05	256,901
Total Heat Load on the Wall				2263,264

Table 3: Heat Load on the Wall Class F202

Directions	**U (Btu/hr.ft^2)**	**A (ft^2)**	**CLTDcor (°F)**	**Q (Btu/hr)**
West	0	271,250	0	0,000
East	0,49	271,250	18,05	2399,071
North	0,49	291,432	14,05	2006,364
South	0,49	255,750	2,05	256,901
Total Heat Load on the Wall				4662,335

- *Heat Load from Windows*

Table 4: Heat Load from Windows Class F200, F201, F202

Directions	**SHGF (Btu/hr.ft^2)**	**A (ft^2)**	**SC**	**CLF**	**n**	**Q (Btu/hr)**
West	0	0	0	0	0	0,000
East	0	0	0	0	0	0,000
North	48	13,723	0,39	0,89	2	457,272
South	43	49,406	0,39	0,8	3	1988,493
Total Heat Load from Windows						2445,765

- *Heat Load on the Roof*

Table 5: Heat Load on the Roof Class F200, F201, F202

U (Btu/hr.ft^2)	**A (ft^2)**	**CLTD (°F)**	**Q (Btu/hr)**
0,093	775,001	15	1081,126
Total Heat Load on the Roof			1081,126

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➢ *Radiation Factor*

Table 6: Radiation Factor Class F200, F201, F202 Heat

Directions	SHGF (Btu/hr.ft^2)	A (ft^2)	SC	CLF	n	Q (Btu/hr)
North (Glass)	48	2,079	0,94	0,3	1	28,141
South (Glass)	43	8,417	0,94	0,58	1	197,325
North (Glass)	48	3,164	0,94	0,3	1	42,828
South (Glass)	43	6,867	0,94	0,58	1	160,987
North (Window)	48	13,723	0,39	0,89	2	457,272
South (Window)	43	49,406	0,39	0,8	3	1988,493
Total Radiation Factor						2875,046

➢ *Heat Load from People*

Table 7: Heat Load from People Class F200, F201, F202

qs/person (Btu/h)	ql/person (Btu/h)	No people	CLF	Qs (Btu/hr)	Ql (Btu/hr)
250	200	37	1	9250	7400

➢ *Load from Lighting*

Table 8: Heat Load from Lighting

Type	W (Watt)	BF	CLF	n	Q (Btu/hr)
Light bulb	49,476	1,25	1	9	1892,457
Fluorescent lamp	54,594	1,25	1	18	4176,441
Total Load from Lighting					6068,898

➢ *Load from Equipment*

Table 9: Heat Load from Equipment

Type	Heat Gain (Btu/h)	n	CLF	Q (Btu/hr)
Laptop	511,821	1	1	511,821
Infocus	853,035	1	1	853,035
Total Load from Equipment				1364,856

➢ *Infiltration Load*

Table 10: Infiltration Load Class F200, F201, F202

Type	CFM (ft^3/min)	Tc (ºF)	Wi	Wo	n	Qs (Btu/hr)	Ql (Btu/hr)
Window	0,00888	10,8	41	72	3	0,105	
Door	0,43	10,8	41	72	2		9,064

➢ *Ventilation Load*

Table 11: Ventilation Load Class F200, F201, F202

CFM (ft3/min)	Tc	No	Wi	Wo	Qs (Btu/hr)	Ql (Btu/hr)
15	10,8	37	41	72	6593,4	11699,4

B. *Cooling Load Analysis Result*

Based on the calculation results, the total cooling load is presented in Table 12. The existing capacity of the air conditioning units used on the second floor of Building F is shown in Table 13. When compared to the results obtained from the calculations, the findings are presented in Table 14.

Table 12: Total Cooling Load

Load	Q_{F200} (Btu/h)	Q_{F201} (Btu/h)	Q_{F202} (Btu/h)
Total Sensible Load	33012,407	31942,462	34341,532
Total Latent Load	19108,464	19108,464	19108,464
Total Load	52120,872	51050,926	53449,997
Safety factor	2606,043	2552,546	2672,499
Total Cooling Load	54726,915	53603,472	56122,496
	6,081 PK	5,956 PK	6,236 PK

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Table 13: Existing Capacity AC

No	Class	AC Capacity (PK)	Quantity	Total AC Capacity (PK)
1	F200	1,5	2	3
2	F201	1,5	2	3
3	F202	1,5	2	3

Table 14: Comparison of the Air Conditioning Capacity

No	Class	Existing AC capacity (PK)	The required AC capacity according to calculations (PK)
1	F200	3	6,081
2	F201	3	5,956
3	F202	3	6,263

The comparison of the air conditioning capacity in Table 14 indicates that the existing AC capacity is insufficient to cool the room under maximum load. The cooling load requirement for the room is twice as large as the capacity of the existing air conditioner. This supports the background stating that the classroom feels hot during lectures due to insufficient cooling capacity.

V. CONCLUSION

The conclusion of this study is as follows: the total heat load for classroom F200 is 54,726.915 Btu/h = 6.081 PK, while the air conditioning capacity in the room is 3 PK. The total heat load for classroom F201 is 53,603.472 Btu/h = 5.956 PK, while the air conditioning capacity in the room is 3 PK. The total heat load for classroom F202 is 56,122.496 Btu/h = 6.236 PK, while the air conditioning capacity in the room is 3 PK. The cooling capacity in the three classrooms on the second floor of Building F does not meet the maximum cooling requirements.

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