LOGIC
Journal of Engineering Design and Technology
Vol. 25 No.1 March 2025 ; p. 45-53

p-ISSN : 1412-114X
e-ISSN : 2580-5649
http://ojs2.pnb.ac.id/index.php/LOGIC

DETERMINATION THE COOLING CAPACITY OF THE FAN COIL UNIT (FCU) IN A HOTEL ROOM BASED ON HEAT TRANSFER ANALYSIS

Luh Putu Ike Midiani[1], I Wayan Adi Subagia[1], I Made Angga Antara[2]

1) Mechanical Engineering Department, Politeknik Negeri Bali, Badung, Indonesia
2) Utilities Engineering Technology Study Programme, Mechanical Engineering Department, Politeknik Negeri Bali, Badung, Indonesia

Correponding email [1] :
putuikemidiani@pnb.ac.id

Abstract. Fan Coil Unit (FCU) with the appropriate cooling capacity is needed to obtain room thermal comfort. FCU installed based on the cooling load of the room. Cooling load is affected by room volume, material of : wall, floor, roof, equipment in a room, ventilation, infiltration, windows, outdoor air temperature and humidity, indoor air temperature and humidity. Appropriate and correct FCU installation will have an impact on the energy use of a building. Energy saving efforts are made when determining FCU capacity by calculating cooling load by analyzing heat transfer. This paper investigates and analyzes the amount of room cooling load using the CoolPack application. Calculation of cooling capacity using the CoolPack application is carried out after determining the thermal conductivity and material thickness, thermal resistance of the inner surface and outer surface of the wall, roof, floor, and heat transfer coefficient. Based on the results of calculations and analysis, it was concluded that the total cooling load was 3.58 kW. Furthermore, the FCU capacity to be installed must match the FCU capacity available on the market and be greater than the total cooling load in order to achieve the expected comfort. Proper and correct installation of FCUs will have an impact on energy use in a building is an effort to implement energy saving.

Keywords : Cooling capacity, cooling load, Fan Coil Unit, heat transfer analysis, thermal comfort

1. INTRODUCTION

Thermal comfort in the hospitality industry is urgently needed. to obtain thermal comfort and good environmental air quality, air conditioning equipment is needed. Air conditioning equipment is a system that can provide ventilation, reduce air infiltration, and maintain pressure relationships between spaces [1][2].

One of the air conditioning equipment that are widely used in hotels is Central Air Conditioning, where this system provides a large cooling capacity. The system operates with two types of refrigerants, which are differentiated into primary refrigerants and secondary refirgerants. The primary refrigerant circulated on the vapor compression system and the secondary refrigerant cool the supply air. The main components of this system are: chiller, Air Handling Unit (AHU) or Fan coil Unit (FCU) and cooling tower [3][4].

The chiller is the main cooling equipment in the central air conditioning (AC) system. In the chiller occurs the process of dissipating the heat of the working medium and subsequently distributing it throughout the room. FCU is a device consisting of a fan and cooling coil. The cooling coil dissipates air heat through heat transfer. The cooling tower is a heat exchanger with the working principle of releasing and transferring the heat of cooling water to the air [5][6][7].

In hotel buildings, FCU is one of the room air distribution equipment used for intensive and long operating hours. The FCU structure can be vertical or horizontal (airflow path) and open or recessed (stand), and can optionally use hydronic or direct expansion to perform filtration cycle and room temperature control of indoor air. In FCU, hot environmental air is passed on the cooling coil. The cooling coil gets cold water from the chiller will dissipate the heat of the air through the heat transfer process. FCU can be controlled by thermostat or remote [8].

To obtain room thermal comfort, a FCU with the appropriate cooling capacity is needed. FCU is installed based on the cooling load of the room. Cooling load is the heat or heat load released and absorbed by the evaporator. Cooling load is affected by various factors, namely: room volume, material of : wall, floor, roof, equipment in a room, ventilation, infiltration, windows, outdoor air temperature and humidity, indoor air temperature and humidity [9]. Appropriate and correct FCU installation will have an impact on the energy use of a building. Based on research that has been done, energy consumption for air conditioning systems represents about 60% of all consumption of a building [10][11][12]. Thus building energy savings are the objective in installing FCU. Efforts to improve the energy efficiency of air conditioning equipment in commercial buildings have been widely carried out such as the application of energy-saving control methods for FCU carried out with fuzzy models, intelligent control methods with Stepless Variable Speed Drive Technology, optimizing fan coils by using high supply cold water temperature, using ice slurry as coolant in standard terminal fan coil units [13][14][15]. Energy saving efforts are made when determining FCU capacity by calculating cooling load by analyzing heat and mass transfer as done by Ma [16]. Based on the descriptions of these preliminary studies, this article investigates and analyses the amount of space cooling load by analysing heat and mass transfer using the new CoolPack application.

2. METHODS

Calculation of cooling capacity based on heat transfer analysis is carried out based on the steps as shown in Figure 1 and the room that will be calculated for cooling load is shown in Figure 2.

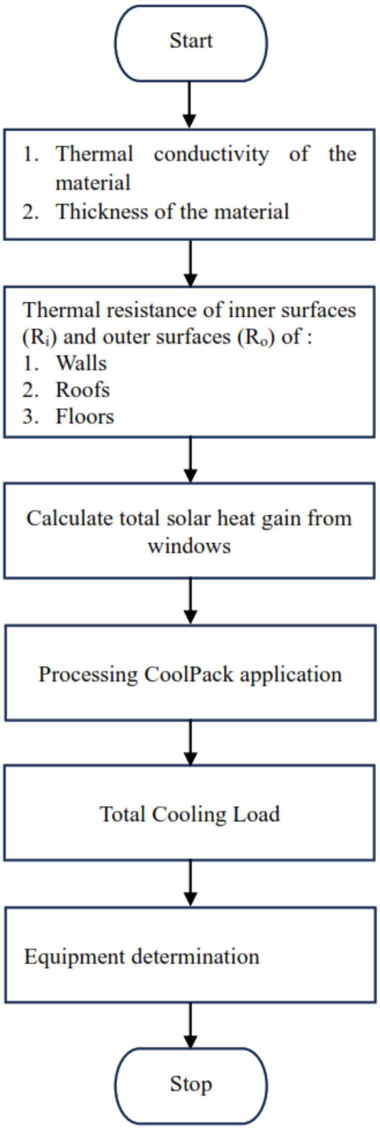


Figure 1 Flowchart of cooling capacity calculation

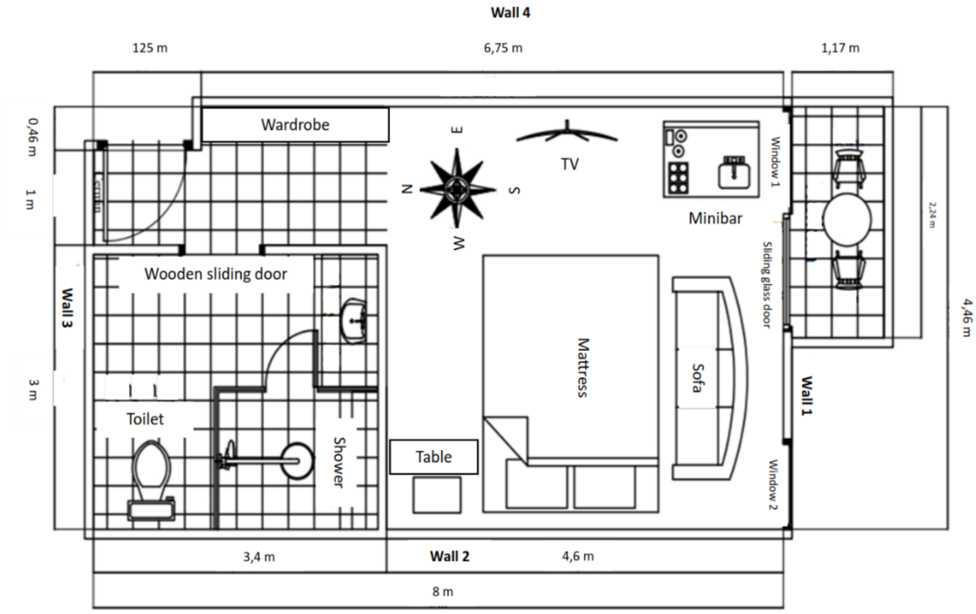


Figure 2. Room area

2.1. Thermal Conductivity and Thickness of The Material

Thermal conductivity is a value that indicates how fast heat will flow in a particular material [17]. Thermal conductivity has units of W/m.˚C, where thermal conductivity is affected by the thickness of the material (m), temperature (˚C) and heat flow rate (W).

2.2. Thermal Resistance of Inner (R_i) and Outer (R_o) Surfaces of Walls, Roofs and Floors

Thermal resistance is the resistance of a material to heat. The thermal resistance of a material depends on the geometry and thermal properties of the material [18]. Resistance to heat flow is represented by the letter R. Thermal resistance is indicated by determining several directions of heat flow, namely upward (roof), sideways (wall), and downward (floor), as shown in Table 1.

Table 1. Thermal Resistance of Inner and Outer Surfaces of Walls, Roofs and Floors

Surface Resistance ($m^2.K/W$)	Directions of heat flow		
	Upwards	Sideways	Down
R_i	0,10	0,13	0,17
R_o	0,04	0,04	0,04

2.3. Calculating the heat transfer coefficient of the walls, roof and floor [17]

$$U_{value} = \frac{1}{R_{total}} = \frac{1}{R_i + \frac{x_1}{k_1} + R_o} \tag{1}$$

where:

U_{value} = Coefficient of heat transfer from walls, roofs, and floors ($W/m^2.K$)
R_{total} = Total thermal resistance of wall, roof and floor ($m^2.K/W$)
R_i = Thermal Resistance of inner surfaces of wall, roof and floor ($m^2.K/W$)
R_o = Thermal Resistance of outer surfaces of wall, roof and floor ($m^2.K/W$)
x_1 = Thickness of wall, roof, and floor materials (m)
k_1 = Thermal conductivity of wall, roof, and floor materials (W/m. K)

If there are windows, doors, etc. on the walls, the overall heat transfer coefficient, obtained using the values of individual U_{value} and surface area respectively as follows [17]:

$$U_{mean} = \frac{(U_{wall} x A_{wall} + U_{door} x A_{door} + U_{window} x A_{window}}{A_{total}} \quad (2)$$

where:
U_{mean} = Average heat transfer coefficient (W/m^2. K)
U_{wall} = Wall heat transfer coefficient (W/m^2. K)
A_{wall} = Total wall area (m^2)
U_{door} = Door heat transfer coefficient (W/m^2. K)
A_{door} = Total width of doors (m^2)
U_{window} =Window heat transfer coefficient (W/m^2. K)
A_{window} = Total window area (m^2)

2.4. Calculating total solar heat gain window

To determining the total solar heat gain of glass windows used the formula (3) and the results of the calculation are shown in Table 2 [1]:

$$q_{win} = SC \ x \ SCL \quad (3)$$

where:
q_{win} = Solar heat gain (W/m^2)
SC = Solar radiation factor through glass
SCL = Solar cooling load factor (W/m^2)

Table 2. Solar Heat Gain

Glass Window Position	Solar Radition Factor Through Glass (SC)	Solar Cooling Load Factor / SCL (W/m^2)	Solar Heat Gain Factor (SHGF) Building Envelope
North	0,48	43,24	1,04
Northeast	0,13	96,14	1,34
East	0,11	144,58	1,45
Southeast	0,14	131,50	1,45
South	0,22	79,38	1,16
Southwest	0,52	131,57	1,45
West	0,52	144,58	1,45
Northwest	0,47	96,14	1,34

2.5. Enter the data obtained into the CoolPack application

The final step to get the room cooling load is to enter the load calculation data of each floor, door and window into the CoolPack application.

3. RESULTS AND DISCUSSION

3.1 Room Size

V = P x L x T
= 4,46 x 8 x 2,5
= 89,2 m^3

3.2 Determining Wall, Roof, and Floor Specifications

3.2.1 Wall 1

Total wall area 1 ($A_{wall\ tot}$) = P x L = 4,46 x 2,5 = 11,15 m^2

a. Glass door

- Total glass door area (A_{tot1})
  = P x L = 1,24 x 2,04 = 2,52 m^2
- Glass door area (A_1)
  = P x L = 0,97 x 1,72 = 1,66 m^2
- Wooden frame area of glass doors (A_2)
  = total glass door area – glass door area = 2,52 – 1,66 = 0,86 m^2
- Thermal conductivity of glass (k_1) = 5,1 W/m.K , Thick (x_1) = 0,01 m

- Thermal conductivity of wooden frame (k_2)
  = 0,18 W/m.K , Thick (x_2) = 0,15 m

b. Window 1

- Total Window Area 1 (A_{tot2})
  = P x L = 1,13 x 2,04 = 2,3 m^2
- Window glass area 1 (A1)
  = P x L = 1,1 x 1,92 = 2,11 m^2
- Wooden window frame area 1 (A_2)
  = total windows frame area 1 – windows glass area = 2,30 – 2,11 = 0,19 m^2
- Thermal conductivity of glass (k_1) = 5,1 W/m.K , Thick (x_1) = 0,01 m
- Thermal conductivity of wooden frame (k_2) = 0,18 W/m.K , Thick (x_2) = 0,15 m

c. Window 2

- Total Window Area 2 (A_{tot3})
  = P x L = 0,95 x 1,64 = 1,55 m^2
- Window glass area 2 (A_1)
  = P x L = 0,75 x 1,44 = 1,08 m^2
- Wooden window frame area 2 (A_2)
  = total windows area 2 – window glass area 2 = 1,55 m^2 – 1,08 m^2 = 0,47 m^2
- Thermal conductivity of glass (k_1) = 5,1 W/m.K , thick (x_1) = 0,01 m
- Thermal conductivity of wooden frame (k_2) = 0,18 W/m.K , thick (x_2) = 0,15 m

d. GRC + Glasswool Carpet (A_{tot4})

= total wall area 1 – total glass doors area – total window area 2
= 11,15 – 2,52 – 2,3 – 1,55 = 4,78 m^2

- Thermal conductivity of GRC (k_1) = 0,9 W/m. K, thick (x_1) = 0,009 m
- Thermal conductivity of glasswool carpets (k_2) = 0,03 W/m. K, thick (x_2) = 0,002 m
- In direct contact with outside air = 32 °C

3.2.2 Wall 2

a. Total wall area 2 ($A_{wall\ tot}$)

= P x L = 8 m x 2,5 m = 20 m^2

- GRC area + Glasswool carpet (A_{tot1}) = P x L = 4,6 x 2,5 = 11,5 m^2
- Thermal conductivity of GRC (k_1) = 0,9 W/m. K, thick (x_1) = 0,009 m
- Thermal conductivity of glasswool carpets (k_2) = 0,03 W/m. K, thick (x_2) = 0,002 m

b. Plastering 1 + concrete brick + plastering 2 + ceramic

= Total wall area 2 – GRC area + glasswool carpets (A_{tot2}) = 20 – 11,5 = 8,5 m^2

- Thermal conductivity of plastering 1 (k_1) = 0,94 W/m. K, thick (x_1) = 0,01 m
- Thermal conductivity of concrete brick (k_2) = 0,77 W/m. K, thick (x_2) = 0,1 m
- Thermal conductivity of plastering 2 (k_3) = 0,88 W/m. K, thick (x_3) = 0,01 m
- Thermal conductivity of ceramics k_4 = 1,3 W/m.K , thick (x_4) = 0,01 m
- In direct contact with outside air = 22 °C

3.2.3 Wall 3 ($A_{wall\ tot}$)

a. Total wall area 3

= P x L = 4,46 x 2,5 = 11,15 m^2

b. Plastering 1 + concrete brick + plastering 2 + glass

A_{tot1} = P x L = 1 x 2,5 = 2,5 m^2

- Thermal conductivity of plastering 1 (k_1) = 0,94 W/m . K , thick (x_1) = 0,01 m
- Thermal conductivity of concrete brick (k_2) = 0,77 W/m . K, thick (x_2) = 0,1 m
- Thermal conductivity of plastering 2 (k_3) = 0,88 W/m . K , thick (x_3) = 0,01 m
- Thermal conductivity of glass (k_4) = 5,1 W/m . K , thick (x_4) = 0,01 m
- Thermal conductivity of concrete brick (k_5) = 0,77 W/m . K, thick (x_5) = 0,1 m
- Thermal conductivity of plastering 2 (k_6) = 0,88 W/m . K, thick (x_6) = 0,01 m
- Thermal conductivity of glass (k_7) = 5,1 W/m . K , thick (x_7) = 0,01 m

c. Plastering 1 + concrete brick + plastering 2 + ceramic

A_{tot2} = P x L = 3 x 2,5 = 7,5 m^2

- Thermal conductivity of GRC (k_1) = 0,9 W/m . K, thick (x_1) = 0,009 m
- Thermal conductivity of glasswool carpets (k_2) = 0,03 W/m . K, thick (x_2) = 0,002 m

d. GRC + glasswool carpets

= 11,15 – 2,5 – 7,5 = 1,15 m^2

- Thermal conductivity of GRC (k_1) = 0,9 W/m . K, thick (x_1) = 0,009 m

- Thermal conductivity of glasswool carpets (k_2) = 0,03 W/m . K, thick (x_2) = 0,002 m
- In direct contact with outside air = 26 °C

3.2.4 Wall 4

a. Total wall area 4 ($A_{wall\ tot}$)
= P x L = 8 x 2,5 = 20 m^2

b. GRC + glasswool carpet (A_{tot1})
= 6,75 x 2,5 = 16,875 m^2
- Thermal conductivity of GRC (k_1) = 0,9 W/m . K, thick (x_1) = 0,009 m
- Thermal conductivity of glasswool carpets (k_2) = 0,03 W/m . K, thick (x_2) = 0,002 m

c. Wooden Door
- Wooden door area (A_{tot2}) = Total wall area 4 – GRC area + glasswool carpets = 20 – 16,875 = 3,125 m^2
- Thermal conductivity of wooden doors (k_1) = 0,18 W/m . K, thick (x_1) = 0,05 m
- In direct contact with outside air = 22 °C

3.2.5 Ceiling

a. Total roof area ($A_{roof\ tot}$)
= P x L = 4,46 x 8 = 35,68 m^2

b. Gypsum + rooftile
- Thermal conductivity of Gypsum (k_1) = 0,18 W/m . K, thick (x_1) = 0,009 m
- Thermal conductivity of rooftile (k_2) = 1 W/m . K, thick (x_2) = 0,01 m
- In direct contact with outside air = 32 °C

3.2.6 Floor

a. **Total wall area ($A_{floor\ tot}$)**
= P x L = 4,46 x 8 = 35,68 m^2

b. Concrete + Wood
- Concrete Area + wood (A_{tot1}) = P x L = 4,46 x 4,6 = 20,516 m^2
- Thermal conductivity of concrete (k_1) = 1,13 W/m . K, thick (x_1) = 0,2 m
- Thermal conductivity of wood (k_2) = 0,13 W/m . K, thick (x_2) = 0,003 m

c. Concrete + plastering + ceramic
- Concrete Area + plastering + ceramic (A_{tot2}) = 35,68 - 20,516 = 15,16 m^2
- Thermal conductivity of concrete (k_1) = 1,13 W/m . K, thick (x_1) = 0,2 m
- Thermal conductivity of plastering (k_2) = 0,88 W/m . K, thick (x_2) = 0,01 m
- Thermal conductivity of ceramic (k_3) = 1,3 W/m . K, thick (k_3) = 0,01 m
- In direct contact with outside air = 22 °C

3.3 Calculating U value

The results of the calculation of U value using formula 2 are shown in Table 3:

Table 3. U Value Calculation

Wall 1	
Glassdoor (U_1)	5,84 W/m^2. K
Wooden frame of the door (U_2)	1 W/m^2. K
U average (U_{rtot})	4,18 W/m^2. K
Wall 2	
GRC + glasswool carpet (U_1)	4,16 W/m^2. K
Plastering 1 + concrete brick + plastering 2 + ceramic (U_2)	3,14 W/m^2. K
U average (U_{rtot})	3,72 W/m^2. K
Wall 3	
Plastering 1 + concrete brick + plastering 2 + glass (U_1)	3,2 W/m^2. K
Plastering 1 + concrete brick + plastering 2 + ceramic (U_2)	3,14 W/m^2. K
GRC + glasswool carpet (U_3)	4,16 W/m^2. K
U average (U_{rtot})	3,25 W/m^2. K
Wall 4	
GRC + glasswool carpet (U_1)	4,16 W/m^2. K
Plastering 1 + concrete brick + plastering 2 + ceramic (U_2)	2,27 W/m^2. K
U average (U_{rtot})	3,86 W/m^2. K
Roof	
Gypsum + rooftile (U_1)	5 W/m^2. K
Floor	
Concrete + wood (U_1)	2,47 W/m^2. K
Concrete + plastering + ceramic (U_2)	2,47 W/m^2. K
U average (U_{rtot})	2,45 W/m^2. K

There are 2 windows on the wall and the wall faces south, so that the total solar heat gain:
1. Window area 1 = 2,3 m^2
2. Window area 2 = 1,55 m^2
3. Total area = 3,85 m^2

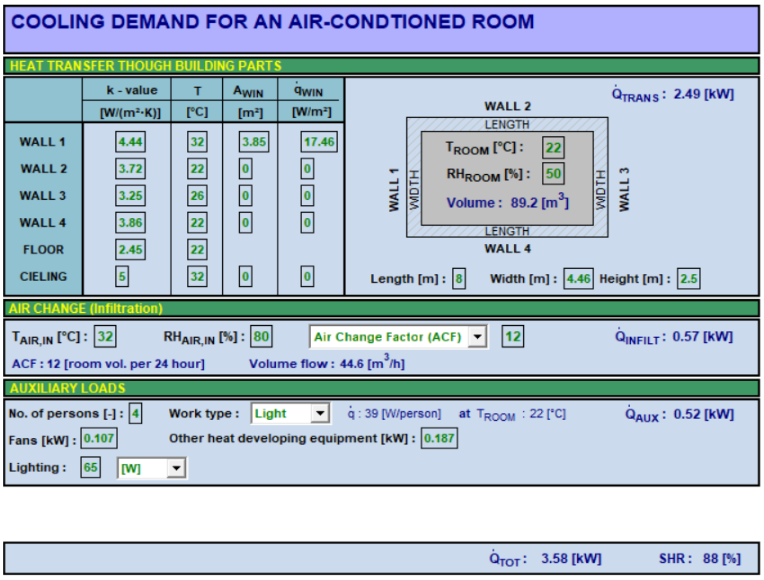
The estimated for equipment and occupant loads:
1. Occupant = 4 orang
2. Lamp = 13 × 5 Watt = 65 Watt
3. TV 150 Watt = 1 piece
4. Fan blower FCU = 107 Watt
5. Minibar 37,4 Watt = 1 piece
6. Activities = light

The infiltration load is differentiated as follows:
1. Infiltration air temperature = 32 ℃
2. Infiltration air humidity = 80 %

Air Change = 0,5 AC/Hr = 12 ACF (Air Change Factor), because only 1 wall includes an exterior wall, namely wall 1, and the rest is an interior wall.

Other parameters that must be considered are:
1. Room Air Temperature = 22 °C
2. Room Air Humidity = 50 %

Next, the data obtained above is entered into the CoolPackprogram, as shown in Figure 3.



COOLING DEMAND FOR AN AIR-CONDTIONED ROOM

HEAT TRANSFER THOUGH BUILDING PARTS

	k - value [W/(m²·K)]	T [°C]	A_{WIN} [m²]	$\dot{q}_{WIN}$ [W/m²]
WALL 1	4.44	32	3.85	17.46
WALL 2	3.72	22	0	0
WALL 3	3.25	26	0	0
WALL 4	3.86	22	0	0
FLOOR	2.45	22		
CIELING	5	32	0	0

$\dot{Q}_{TRANS}$: 2.49 [kW]

T_{ROOM} [°C] : 22

RH_{ROOM} [%] : 50

Volume : 89.2 [m³]

Length [m] : 8 Width [m] : 4.46 Height [m] : 2.5

AIR CHANGE (Infiltration)

$T_{AIR,IN}$ [°C] : 32 $RH_{AIR,IN}$ [%] : 80 Air Change Factor (ACF) 12 $\dot{Q}_{INFILT}$: 0.57 [kW]

ACF : 12 [room vol. per 24 hour] Volume flow : 44.6 [m³/h]

AUXILIARY LOADS

No. of persons [-] : 4 Work type : Light $\dot{q}$: 39 [W/person] at T_{ROOM} : 22 [°C] $\dot{Q}_{AUX}$: 0.52 [kW]

Fans [kW] : 0.107 Other heat developing equipment [kW] : 0.187

Lighting : 65 [W]

$\dot{Q}_{TOT}$: 3.58 [kW] SHR : 88 [%]

Figure 3. Results of Total Cooling Load using the CoolPack Application

Based on the CoolPack application calculation, the total cooling load is:

Q_{TOT} = 3,58 kW. It is known that 1 kW = 3.412 Btu/h, so

Q_{TOT} = 3,58 kW x 3.412 Btu/h

= 12.214,96 Btu/h

The total cooling load in the room is 3.58 kW, so the capacity of the FCU to be installed should be equal to or slightly greater than the total cooling load. If the FCU capacity is smaller than the cooling load, the FCU performance will be heavier and less efficient. However, if the FCU capacity is too large, there will be a waste of energy. FCU selection must consider the appropriate airflow so that the air can circulate properly. Airflow is expressed in CFM (Cubic Feet per Minute) or m³/h (cubic metres per hour). The installation location of the FCU will affect efficiency and power consumption. Therefore, FCUs with high energy efficiency and low power consumption are selected. Energy saving efforts are made when determining FCU capacity by calculating cooling load by analyzing heat and mass transfer as done by Ma [16]. Where the large air flow rate is the main factor that causes high energy consumption. Therefore, calculations using the CoolPack application help the data processing process to get the correct total cooling load.

4. CONCLUSIONS

Calculation of cooling capacity using the CoolPack application is carried out after determining the thermal conductivity and material thickness, thermal resistance of the inner surface and outer surface of the wall, roof, floor, and heat transfer coefficient. The result of the cooling capacity is 3.58 kW. Furthermore, the FCU capacity installed must be in accordance with the FCU capacity available on the market. If no suitable capacity is found, an FCU capacity that is slightly larger than the total cooling load can be installed in order to achieve the expected comfort. An FCU with too large a capacity will cause large energy usage and cause energy waste. Furthermore, for the future, the use of the CoolPack application provides precise and accurate results.

5. REFERENCES

[1] S. K. Wang, "Handbook Of Air Conditioning And Refrigeration," New York: Mc Graw Hill, 2001.
[2] K. Noh, J. Jang, And M. O. Ã, “Thermal Comfort And Indoor Air Quality In The Lecture Room With 4-Way Cassette Air-Conditioner And Mixing Ventilation System,” Vol. 42, Pp. 689–698, 2007, Doi: 10.1016/J.Buildenv.2005.10.033.
[3] S. Nicklas, G. Strehlow, S. W. Duda, And P. Simmonds, "Ashrae-Handbook-2016-Hvac-Systems-And-Equipment," No. 28, 2016.
[4] L. S. Peris, “Performance Evaluation Of A Hvac System In A Pharmaceutical Plant,” No February, 2019.
[5] J. C. Hensley, “Cooling Tower Fundamentals,” 2009.
[6] A. A. R. Hakim And E. A. Kosasih, “Analysis Of Heat And Mass Transfer On Cooling Tower Fill,” No. December, 2020, Doi: 10.17146/Jfn.2020.14.1.5812.
[7] L. P. I. Midiani, I. W. Temaja, I. P. M. Adnyana, I. K. Dwiana, I. Made, And P. Yoga, “Analisa Kinerja Cooling Tower Tipe Counter Flow Induced Draft,” Vol. 2, Pp. 72–77, 2021.

[8] H. Chuang, J. Chi, K. Chang, And C. Lee, “Study On A Fan Coil Unit And Chiller By An Intelligent Control Method With A Stepless Variable Speed Driving Technology,” Vol. 132, No. January, Pp. 137–146, 2018.

[9] S. I., "Ashrae Handbook Fundamentals," Vol. 30329, No. 404, 2009.

[10] A. D. Althouse And H. Cari, “Modern And Refrigeration And Air Conditioning,” 2004.

[11] V. Vakiloroaya, B. Samali, A. Fakhar, And K. Pishghadam, “A Review Of Different Strategies For Hvac Energy Saving,” Vol. 77, Pp. 738–754, 2014.

[12] M. Kameni *Et Al.*, “A Review On Energy Consumption In The Residential And Commercial Buildings Located In Tropical Regions Of Indian Ocean : A Case Of Madagascar Island,” Vol. 24, No. April, 2019, Doi: 10.1016/J.Est.2019.04.022.

[13] X. Li, T. Zhao, And J. Zhang, “Development Of Network Control Platform For Energy Saving Of Fan Coil Units, A Computationally Efficient Method For Fault Diagnosis Of Fan-Coil Unit Terminals In Building Heating Ventilation And Air Conditioning Systems,” *J. Build. Eng.*, 2017.

[14] M. Bai, F. Wang, J. Liu, And Z. Wang, “Experimental And Numerical Studies Of Heat And Mass Transfer Performance And Design Optimization Of Fan-Coil With High Supply Chilled Water Temperature In Air-Conditioning System,” *Sustain. Energy Technol. Assessments*, Vol. 45, No. March, P. 101209, 2021, Doi: 10.1016/J.Seta.2021.101209.

[15] F. J. Uhı And J. A. Dopazo, “Experimental Analysis On Pressure Drop And Heat Transfer Of A Terminal Fan-Coil Unit With Ice Slurry As Cooling Medium,” Vol. 3, 2010, Doi: 10.1016/J.Ijrefrig.2010.04.013.

[16] Z. Ma, X. Liu, And T. Zhang, “Measurement And Optimization On The Energy Consumption Of Fans In Semiconductor Cleanrooms,” *Build. Environ.*, Vol. 197, No. December 2020, P. 107842, 2021, Doi: 10.1016/J.Buildenv.2021.107842.

[17] J. P. Holman, "*Heat Transfer," 10th Edition*, 2010.

[18] Y. A. Cengel, "*Heat And Mass Transfer A Practical Approach," 3rd Edition*. 2005.