

# Cooling Load Estimation for Laboratory at School of Manufacturing, UniMAP.

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**Keywords:** Heat gain, air conditioning, and cooling load

**ABSTRACT** – Performance of air conditioning system is closely related to heat gain that is generated inside a room. The amount of heat in the room depended on three factors, including of temperature difference ( $\Delta T$ ), area ( $A$ ), and heat transfer coefficient ( $U$ ). Apart from that, other factors such as location, time of data collection, material of wall, electrical appliances and activity of people are also affected the heat gain in the room. In this present study, one of the laboratories at School of Manufacturing is chosen. Total heat (TH) gain is calculated using cooling load temperature different (CLTD) method. As the results, it was found that the TH gain for the computer laboratory is 168,158 W.

## 1. INTRODUCTION

Cooling system is very important especially for tropical countries (*e.g.* Malaysia, Indonesia and Singapore) [1]. To stay in space with comfort conditions for long time, air conditioning is one of important factor for human comfort [2]. In Malaysia, air conditioning system consumes around 70% of the overall energy intake per year for most industrial sectors [1]. Exact prediction of the cooling load is crucial in order to reduce energy consumption. Several factors affect the cooling loads, including of temperature, heat transfer coefficient, and surface area.

The major electricity consumption is generated from building heating, ventilation and air conditioning (HVAC) system [3]. By using HVAC system precisely, the amount of energy consumption can be estimated [4].

Cooling load temperature different (CLTD) is one of the tools to calculate the heat gain [5-8]. This method is widely applied due to its simplicity and the calculation can be performed manually. By knowing the heat gain, the electricity consumption could be wisely utilised.

Up to now, no previous studies has been done to estimate the TH for the laboratory. The objective of this present study is to estimate the cooling load for the manufacturing laboratory using CLTD method.

## 2. METHODOLOGY

The internal heat gain was normally generated within a conditional space. Sensible and latent heat gain are two component of internal heat gain, generating from several loads such as occupants, lightings, appliances, machines, as described by Arora [9]. In general, heat gain is calculated using the following equation:

$$Q = A \times \Delta T \times U \quad \text{Equation 1}$$

where;  $Q$  is heat gain,  $A$  is surface area,  $\Delta T$  is temperature difference, and  $U$  is heat transfer coefficient.

Meanwhile, the equation for  $U$  is expressed as follows:

$$\frac{1}{U} = \frac{1}{f_o} + \sum \frac{x_n}{k_n} + \frac{1}{f_i} \quad \text{Equation 2}$$

where;  $f_o$  is outdoor film coefficient ( $23 \text{ W m}^{-2} \text{ K}^{-1}$ ),  $f_i$  is indoor film coefficient ( $7 \text{ W m}^{-2} \text{ K}^{-1}$ ),  $x_n$  is thickness of specified material, and  $k_n$  is thermal conductivity of specified material.

## 3. RESULTS AND DISCUSSION

The dry-bulb, and wet-bulb temperature for an outdoor condition are 33, and 29°C, respectively. Meanwhile, the dry-bulb temperature and humidity for indoor condition are 28°C, and 50%, respectively. The laboratory located at 6° north latitude and 100° east longitude. Floor area and volume of the laboratory are 466 and 1864 m<sup>3</sup>, respectively. Each wall of the laboratory is assigned according to its direction; namely west, north, and east wall with the wall surface areas of 124.2, 46.0, and 151.2 m<sup>2</sup>, respectively. The laboratory also had a partition wall at the south direction with the wall surface area of 40.6 m<sup>2</sup>. Glass windows located at three different directions, including of west, south and east glasses. The glass area for the west, south, and east directions were 37.8, 5.4, and 10.8 m<sup>2</sup>, respectively.

The data of equivalent temperature differentials and solar gain through wall and glass of the laboratory, respectively, were obtained from the tables, as discussed by Arora [9]. However, in this present study, the correction of data equivalent temperature differentials has not been considered. The data were collected on 27<sup>th</sup> March 2019. Thus, the equivalent temperature differential and solar gain data for both wall and glass, respectively, are summarised in Table 1 and 2. Meanwhile, the  $U$  values for various structures of the laboratory are summarised in Table 3, which were calculated using Equation 2.

It is observed that the roof load is maximum at 6.00 p.m with the equivalent temperature differential of 21.3 °C (Table 1). Meanwhile, the solar gain through the west glass has the maximum value of 498 W/m<sup>2</sup> at 4.00 p.m (Table 2). A higher solar gain through the west glass is

observed as compared to the east glass. This result is expected due to a larger surface area of the glass in the west as compared to the east. The solar gain in the south glass is higher than the east glass although having a unit of glass in the south partition. This is due to a higher glass surface area in the south than the east. Therefore, the time of maximum load is likely to occur near 5.00 p.m.

Table 1 Equivalent temperature differentials for wall and roof (unit in °C)

Position	2 pm	3 pm	4 pm	5 pm	6 pm	7 pm
West	4.9	8.0	10.4	14.0	16.5	18.2
North	2.2	3.0	3.8	4.4	4.7	4.7
East	10.6	9.2	8.4	8.1	7.8	7.5
Roof	14.8	16.6	18.8	20.5	21.3	20.9

Table 2 Solar gains through glass (unit in W/m<sup>2</sup>)

Position	2 pm	3 pm	4 pm	5 pm
West	325	454	498	391
South	259	189	57	28
East	41	38	32	16

Table 3 Heat transfer coefficients for various structures

Type of structures	$U$ (Wm <sup>-2</sup> K <sup>-1</sup> )
Outer wall	3.31
Partition wall	2.49
Roof	2.13
Floor	6.05
Glass	4.94
Door	0.69

By using Equation 1, room sensible heat (RSH) and room latent heat (RLH) are found to be 112,308 and 55,850 W, respectively. A higher heat gain was observed in the RSH as compared to RLH which was due to a larger contribution of heat gain through the wall, roof, glass, and etc. Effective room sensible and latent heat have not been considered due to the no supply or return ducts were observed in the laboratory. The summation of RSH and RLH will contribute to the TH gain. As the result, TH of 168,158 W was observed for the laboratory.

#### 4. CONCLUSIONS

As a conclusion, the TH for computer laboratory is 168,158. The highest contribution of the TH is generated from sensible heat gain, sourcing from roof, wall, floor, and internal heat gain (e.g. electrical appliances, and people). It was then followed by the latent heat gain generating from electrical appliances, and people. It is observed that electrical appliances, and people produced two heats: (i) sensible, and (ii) latent heats that affected the TH for the laboratory. In addition, a larger surface area from the roof, wall, and floor has also influenced the increasing TH, although having a smaller  $k$ .

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