Proceedings of the
International Conference on Mechanical Engineering and Renewable Energy 2019
(ICMERE2019) 11 – 13 December, 2019, Chittagong, Bangladesh

ICMERE2019-PI-152

DEVELOPMENT OF A COMPUTER PROGRAM FOR COOLING LOAD ESTIMATION

Rokib Ul Islam[1,*] and Prasanjit Das[2]

[1]Final year Student, Department of Mechanical Engineering, Chittagong University of Engineering & Technology (CUET), Bangladesh
[2]Assistant Professor, Department of Mechanical Engineering Chittagong University of Engineering & Technology (CUET), Bangladesh
[1,*] rokibulislam1997@gmail.com, [2] prasanjitd12@gmail.com, [2] prasanjitd11@yahoo.com

Abstract- *Since, day-by-day, increasing the atmospheric temperature and also improve the lifestyle, air conditioning is essential for human comfort. For proper air conditioning, accurate cooling load estimation is necessary. The manual cooling load calculation is time consuming, and judgment estimation is liable to error. Load estimation through a computer program is likely to make a positive impact on the dynamic nature and also reduce error and time consumption. This study develops a computer program in Python programming language to handle a simple and typical load estimation air-conditioning. Though this study deals with a simplified room, with a very little effort this program can be improved to calculate load on changing climate. The main objective of this study is to develop a simple computer program for estimating cooling load. This study also deals to calculate cooling load of a room and compare the result with manual calculation and excel spreadsheet calculation.*

Keywords: HVAC, CLTD method, Python programming language, Comparative analysis

INTRODUCTION

Air conditioning is mainly to be used as human comfort medium. Air conditioning can be form of cooling, heating, ventilation or disinfection. In generally air conditioning is defined as a system to cooling and dehumidification air in the surrounding system to achieve thermal comfort. Human civilization came to existence, human's need of comfort, satisfaction, and luxury increased manifolds. The advent of air-conditioning system played an important role in this direction of human need. There is definite range of temperature and humidity within which best human efficiency and comfort can be obtained. Air conditioning is used to provide these human comfort and controlled atmosphere to various buildings or the proper performance of certain industrial processes such as offices, halls, homes, and industries, etc. HVAC (Heating, Ventilating, and Air-Conditioning) engineers aim to provide these conditions with the optimum saving of energy by selecting the correct sized equipment with minimum cost. For any air conditioning system to perform satisfactorily, equipment of the proper capacity must be selected based on the instantaneous peak load requirements. The type of control used is dictated by the conditions to be maintained during peak and partial load. From engineering point of view, determining the cooling load of HVAC system is the most important task for equipment selections. Undersized equipment will not provide the required conditions while a greatly oversized one will lead to high operational cost and frequently breakdown. The estimation of the cooling load is the first step in controlling air conditioning. Load estimating in air-conditioning system design has been carried out manually in many quarters. It is very troublesome and time consuming to calculate the appropriate cooling load for any structure if the calculation is made manually. Because, many factors must be analyzed, judged and calculated before estimating the cooling load. A lot of time and energy are wasted when estimating the cooling loads in complex and intricate buildings of modern time. If a computer program is used to design an air conditioning system, then it will be very easy to analyze and calculate different parameters of cooling within less time. The calculation of such a lengthy and time consuming procedure will also be accurate and less time required by using a computer program. Cooling load estimation through computer application sounds reasonable to replace tedious and time consuming manual methods. To achieve this computer automation, a program is developed using "Python (PyCharm)" programming language tool. In addition, it is a flexible tool capable of handling this type of large and complicated issue.

2. LITERATURE REVIEW

M. K. Uddin et al. [2] had built up a framework structure that assessment cooling loads for ventilating framework for straightforward private and non-private structures. They used PC programming in C# .NET to developed the software. Cooling load for the seminar room was calculated by the software and also calculated manually. By software, the calculated value was 15.65

and in manual the value was 15.62 and difference between software and manual calculation was 0.19%. Z. Noranai et al. [3] developed a program to calculate the cooling load using MATLAB. They studied several of limitation of the case study that judge to sure the program's meeting to Malaysia building specification. Finally, their validation was done by comparison manual calculation and by the developed program. The developed software results and manual calculation had less than 1% error and the average percentage error was 0.901%. S. Zaphar and T. Sheworke [4] designed a computer program for cooling load estimation which is user friendly and minimum data input with accurate results obtained. The software was based on the carrier data book used for cooling load estimation based on the cooling load transfer and solar heat gain factor method. The programming language has been done in Visual Basic 6.0 and the database was created using Microsoft Access. Step by step data input was provided according to the architecture layout in the developed program and finally, the result sheet appeared after all data input was completed. In order to test the established software, one sample project was tested with the software and solved by hourly program evaluation software (HAP v 4.90) and the precision level of the current software was 98.1%. Tousif Ahmed [5] developed a computer software followed CLTD method in C#.NET (C sharp dot. NET) to handle simple and typical load estimation for air conditioning. To developed the software, there has some limited weather information. Used dry blub of 2.5% in summer and 97.5% in winter. For testing the software, used a model room. And the output results compared to "TRACE 700" and the result is very close to "TRACE 700" and HVAC design software. B. Kareem [6] has developed a system framework that estimates cooling loads for air-conditioning system for both sample and complex non-residential buildings. The system developed was able to estimate various loads in buildings which are sensible, latent and total load. The load computation was computer automated for easy application in industries. The computer software developed for the load estimation named Computer Aided Load Estimating for Air- Conducting-CALAC-2004 in "QBasic" ran effectively in windows and was able to estimate cooling loads for different rooms in the ground, middle and last floors based on the input parameters related to loads through windows, doors, floors, partition, infiltration, and others mentioned previously based on ASHRAE 2001.

3. METHODOLOGY

Different methods are used to estimate the cooling of the air-conditioning and some assumption is needed to simplify the calculation method. Several equations are used to calculate the design space load.

3.1 Cooling Load Calculation Techniques

One of the following three techniques should be used for a complete calculation of the zones and entire building loads.

3.1.1 Transfer Function Method (TFM):

Two steps are used to calculate the space cooling load using the transfer function method. First, heat gains from outside walls, roofs, and floors are calculated using the coefficients of the conductive transfer function; and the solar and internal heat gains are calculated directly for the scheduled time. Second, coefficients of the room transfer function are used to transform heat gains into loads of cooling. The TFM is confined because the cooling loads thus calculated depend on the value of the coefficients of the transfer function as well as the space characteristics and how they vary from those used to produce the coefficients of the transfer function. Furthermore, TFM presumes that the complete cooling load could be calculated by merely adding the individual components. This hypothesis, however, may trigger some errors. This is the complex methods proposed by ASHRAE and requires a computer program or advanced spreadsheet to be used.

3.1.2 Cooling Load Temperature Difference/ Cooling Load Factors (CLTD/CLF) Method:

CLTD is a theoretical difference in temperature that stands for the combined effects of variation in indoor and outdoor air temperature, daily temperature range, solar radiation, and building heat storage. The orientation, tilt, month, day, hour, latitude, and so on affects it. CLF accounts for the radiant energy that at a particular time enters the conditioned space. CLF factors are used to adjust the heat gains from inner loads. Information derived through the use of TFM was used to obtain cooling load temperature differential (CLTD) data, to calculate cooling load from conduction heat gain through sunlit walls and roofs, and conduction through exposed glass zones.

3.1.3 Total Equivalent Temperature Difference/ Time-Averaging (TETD/TA) Method:

Before the advent of the CLTD / CLF technique, this method was the preferred technique for manual or simple spreadsheet calculation.The most practical method to use is the CLTD / SCL / CLF method as described in the 1997 ASHRAE Fundamentals for strictly manual cooling load calculation method. This technique, although not optimal, will produce the most conservative outcomes to be used in sizing equipment based on peak load values. In this study, CLTD method was used to develop the computer program.

3.2 Considerations and Assumptions

Under some assumed condition, the design cooling load takes into account all the loads of a building. Following assumptions are considered behind the cooling load design.

- Design weather conditions are chosen from a long-term statistical weather database. The conditions are the representative of the building locations, but will not necessarily represent any actual day.
- The solar loads on the building are expected to happen on a clear day (i.e. no haze in the air) in the month selected for the calculations.

- It is regarded that all the building equipment and appliances are working at a fairly representative capability.
- Ventilation rates are presumed either on air changes or on the basis of the expected peak occupancy.
- It was assumed that there was no moisture gain from the equipment.
- It was assumed that the windows were made of ordinary glass and fitted with walls without shade. That's why glass factor 1 was used.

3.3 Equations

The space heat gain sources, types of equations to be used in the calculations, are provided as follows:

3.3.1 Transmission Heat Gain:

Transmission heat gain occurs in the conditioned space due to conduction of heat through walls, roof, floor, windows, and doors, etc.

i. Wall:

The walls that are exposed to direct sunlight on the outside, heat gain through the walls can be calculated using equation (1)

$$Q = U \times A \times CLTD\,c \tag{1}$$

where, Q = Heat flow rate through wall (Btu/hr.), U = Wall heat transfer coefficient (Btu/hr. ft^2 / °F), A = Area (ft^2), $CLTD_C$ = Corrected cooling load temperature difference (°F).

Transmission heat gain through the partition walls can be determined using equation (2)

$$Q = U \times A \times (t_o - t_i) \tag{2}$$

where, Q = Heat flow rate through partitions (Btu/hr.), U = Partition heat transfer coefficient (Btu/hr. ft^2 / °F), A = Area (ft^2), t_o = Adjoining unconditional room temperature (°F), t_i = Indoor design room temperature (°F).

ii. Roof:

Roof is exposed to direct sunlight on the outside, hence, transmission heat gain through roof will be calculated using equation (3)

$$Q = U \times A \times CLTD \tag{3}$$

where, Q = Heat flow through roof (Btu/hr.), U = Roof heat transfer coefficient (Btu/hr. ft^2 / °F), A = Roof Area (ft^2), $CLTD$ = Corrected cooling load temperature difference (°F).

iii. Floor:

Heat gain in the room through the floor can be obtained using equation (4)

$$Q = U \times A \times (t_o - t_i) \tag{4}$$

where, Q = Heat flow rate through the floor (Btu/hr.), U = Heat transfer coefficient of floor (Btu/hr. ft^2 / °F), A = Area of floor (ft^2), t_o = Adjoining unconditional temperature with floor (°F), t_i = Indoor design room temperature (°F).

iv. Windows and Doors:

The windows or doors those are exposed to direct sunlight on the outside, heat gain through the windows or doors can be calculated using equation (5), and heat gain through unexposed to sunlight windows or doors can be calculated using equation (6)

$$Q = U \times A \times CLTD\,c \tag{5}$$

$$Q = U \times A \times (t_o - t_i) \tag{6}$$

where, Q = Heat flow rate through windows or doors (Btu/hr.), U = Heat transfer coefficient of windows or doors (Btu/hr. ft^2 / °F), A = Total area of all windows or doors (ft^2), $CLTD_C$ = Corrected cooling load temperature difference (°F). t_o = Outdoor temperature (°F), t_i = Indoor room temperature (°F).

3.3.2 Solar Heat Gain:

Solar heat gain occurs in the conditioned space due to radiation of heat through the glasses can be estimated using equation (7)

$$Q = A \times q \tag{7}$$

where, Q = Solar heat flow rate through glass (Btu/hr.), A = Total glass area (ft^2), q = Solar heat gain through per square feet of glass (Btu/hr. ft^2).

3.3.3 Internal Heat Gain:

Occupants, equipment, ventilation and infiltration, etc. also the major parts of heat source of a room. The internal heat gain of a room can be calculated using following equations.

- **Ventilation:**

The fresh air circulation from outside to inside of the rooms is ventilation. Heat gain in the space due to ventilation can be determined by equation (8)

$$Q_v = \frac{60 \times (cfm/person)_v \times n \times (h_o - h_i)}{v} \tag{8}$$

where, Q_v = Heat gain due to ventilation (Btu/hr), $(cfm/person)_v$ = Volumetric air flow per person (ft^3/min./person), n = Number of people, h_o = Enthalpy at outdoor temperature (Btu/lb), h_i = Enthalpy at inside temperature (Btu/lb), v = Specific volume of air (ft^3/lb).

- **Infiltration:**

Infiltration is the volume of air that enters the conditioned space through cracks, and through the opening and closing of doors, it is calculated as equation (9)

$$Q_i = \frac{60 \times (cfm/person)_i \times n \times (h_o - h_i)}{v} \quad (9)$$

where, Q_i = Heat gain due to infiltration (Btu/hr), $(cfm/person)_i$ = Air flow rate per person for infiltration (ft^3/min./person), n = Number of people, h_o = Enthalpy at outdoor temperature (Btu/lb), h_i = Enthalpy at inside temperature (Btu/lb), v = Specific volume of air (ft^3/lb).

- **People:**

Heat gain due to people depends upon their activity and calculated by the equation (10 & 11)

$$Q_S = N \times S \quad (10)$$

$$Q_L = N \times L \quad (11)$$

where Q_S = Total sensible heat gain (Btu/hr), Q_L = Total latent heat gain (Btu/hr), N = Number of people, S = Sensible heat gain per person (Btu/hr), L = Latent heat gain per person (Btu/hr).

- **Light and Equipment**

Electrical lights and equipment emit heat equal to the amount of electrical power consumed. Heat gain from lights and equipment are calculated using equation (12 & 13)

$$Q_{Light} = W_L \times 1.25 \times 3.41 \quad (12)$$

$$Q_{Equip} = W_E \times 3.41 \quad (13)$$

Where, Q_{Light} = Heat gain from light (Btu/hr), Q_{Equip} = Heat gain due to equipment (Btu/hr), W_L = Total lights watts, W_L = Total equipment watts.

3.3.4 Total Cooling Load:

The total heat gain in the designed space is the sum of transmission heat gain, solar heat gain, and internal heat gain of the space. The total cooling load of a space can be determined by adding the safety factor with the total heat gain. Where safety factor is the 10% of total heat gain in the design space.

3.4 Flow Chart of the Program:

The procedure of developing the computer program of cooling load calculation is given as flow chart representing in Fig. 1.

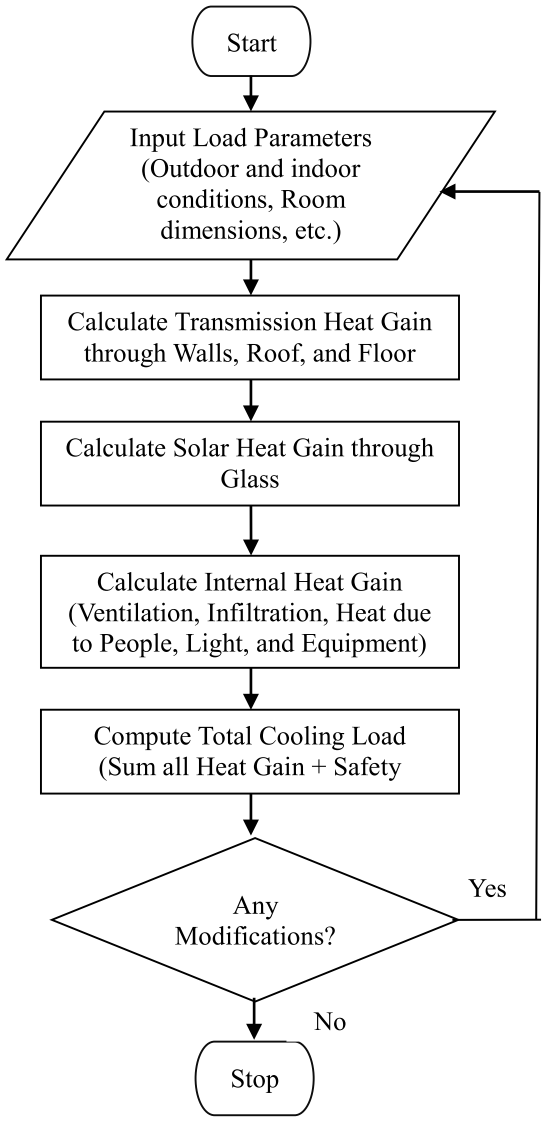

Fig. 1: Flow Chart of the Program

4. RESULTS AND DISCUSSIONS

Environmental condition of a room depends on outdoor and indoor design condition. Geographical position also influences on cooling load of air conditioning system such as latitude. The input of my own computer program for location, environmental conditions of the design room, and design time are shown in figure 2.

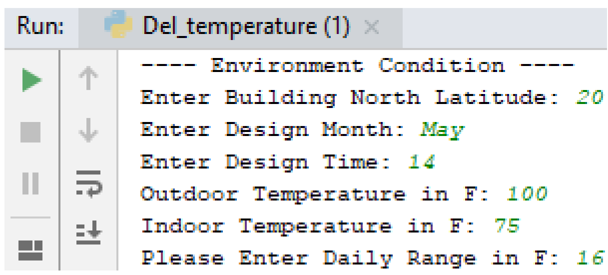

Fig. 2: Input of Computer Program for Design Condition

Room parameters are important factor for estimating the cooling load of air-conditioning system. Room parameters includes the length, width, height of the room with materials of walls, roof, and floor.

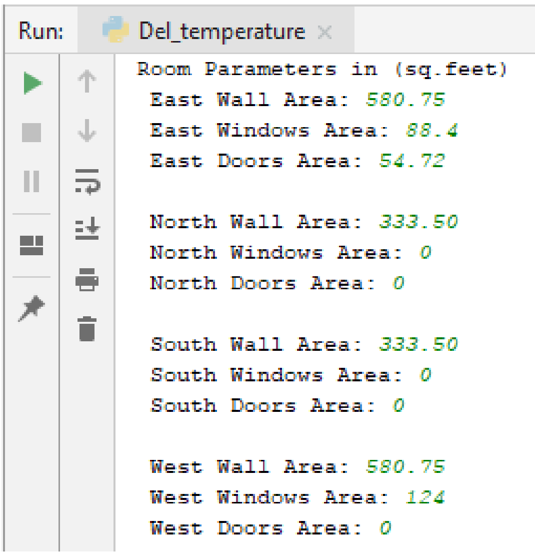

Fig. 3: Input of the Computer Program for room parameters

The position of the walls, roof, and floor are also an important factor for solar heat gain. If a wall exposed to the sun gain more heat than it is in a shaded position. The design room walls are exposed to sun or not which also affects the cooling load of air conditioning system.

Fig. 4: Input of Computer program for the walls exposer

Internal heat gains also the major parts of cooling load. It occurs due to occupants, lights, equipment, etc. Heat gain due to people in the room depends on their activities.

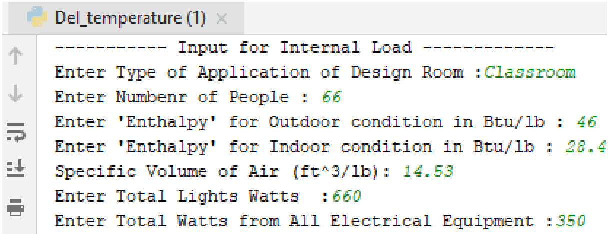

Fig. 5: Input of the Computer Program for Internal Load

Estimated cooling load determined by using my own computer program first in Btu/hr units, then the program converts the load and also displayed in Ton.

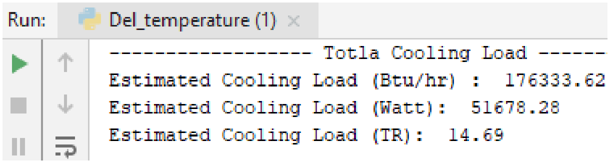

Fig. 6: Output Screen of the Computer Program

To test the computer program and compare the results, a classroom of mechanical building of CUET was assumed. Estimated cooling load of the computer program was 14.69 TR. This result is close to the manual hand calculation which gives 15.61 TR and Excel spreadsheet value as 15.7 TR. Table 1 and Figure 7 shows the comparative results between different calculating process of cooling load calculation for the designed room.

Table 1: Comparative result between the cooling loads determined by various process

Load estimated by the computer program (TR)	Load estimated by excel spreadsheet (TR)	Load estimated manually (TR)
14.69	15.7	15.61

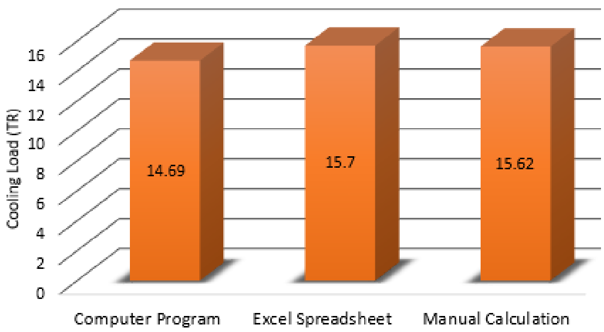

Fig. 7: Graphical Comparison of the Cooling Loads

5. FUTURE WORK AND IMPROVEMENTS

Construction orientation (location), space used, dimensions, columns and beams, construction materials, floor, doors, windows, people, ventilation, lighting, and thermal storage are the variables that must be critically examined during the load estimation process. But some values were assumed for simplicity rather than reading accurate values from the database. Following improvements can be made:

- Due to unavailability of data, only 20° N and 40° N latitude data were used for the development of the computer program. But others latitude data can be included for more precise results on the basis of data availability.
- Only a few predefined walls structure and materials are available in this computer program. Vast different walls construction materials and their properties can be included in the database.
- This program was developed used only the roof data, there have no data included for the ceiling. In the future, the ceiling data can be included in the database for vast use.
- In this computer program to determine the U-factor for every material, the resistance, and thickness were inputted manually. In the future, if this manual inputs method will be eliminated, then less time will require in the calculation and, provide simplicity to the user.
- Although this program was developed in the Python programming language, anyone using C ++, or the MATLAB programming language, can develop a computer program for cooling load calculations. It can be easy to develop the graphical user interface (GUI) of a computer program using C ++, which will provide a more general calculation method.

6. CONCLUSIONS

This research developed a system framework for estimating cooling loads for buildings air-conditioning system. Using the PyCharm programming environment, this computer program was developed in Python programming language. While this computer program's features may be less effective, it provides the users with a convenient and user-friendly way to introduce a cooling load calculation program. This reduces time consumption as well as manual computation errors. If more time and resources are given, this program can incorporate the design of the air distribution system. Compared to the manual tabulation method, the results obtained by the computer program calculations are faster, more efficient and more accurate. Furthermore, this program saves the user time and can eliminate possible errors in the manual calculation. In addition, this computer program can be used for educational purposes as a reference.

7. ACKNOWLEDGEMENT

I would like to express thanks to honorable supervisor DR. PRASANJIT DAS, Assistant Professor of the Department of Mechanical Engineering, CUET, under his cordial guidance and proper instruction, the project work was carried out and presented in this form. I also acknowledge my family, especially my father and mother, and my elder brother for their cordial support to reach this stage. And special thanks to my friend Zaber-Al-Hasan for help me to understood the python programming language.

8. REFERENCES

[1] Carrier Air Conditioning Company, “Handbook of Air Conditioning System Design”, McGraw-Hill Book Company, Ltd, New York, 1965.

[2] M. K. Uddin, D. Mondal and S. Bin Manjur, “Design and Development of Software for Estimation of Cooling Load of A-C System,” in *Int. Conference on Mechanical, Industrial and Energy Engineering,* Khulna, Bangladesh, Dec 26-27, 2016, pp. 1–5.

[3] Z. Noranai, D. S. Z. Abang Bujang, R. Asmawi, H. Salleh, and M. Z. Md Yusof, “Development of Cooling Load Demand Program for Building in Malaysia,” *International Journal of Mechanical and Mechatronics Engineering*, vol. 6, no. 3, pp. 582–585, 2012.

[4] S. Zaphar, and T. Sheworke, “Computer Program for Cooling Load Estimation and Comparative Analysis with Hourly Analysis Program (HAP) Software,” *International Journal of Latest Technology in Engineering, Management & Applied Science,* vol. VII, no. Vi, pp. 53–61, 2018.

[5] T. Ahmed, “Software Development for Cooling Load Estimation by CLTD Method,” *IOSR Journal of Mechanical and Civil Engineering*, vol. 3, no. 6, pp. 01–06, 2012.

[6] B. Kareem, “Load Estimating for Air Conditioning using Computer Software Approach,” *Int. J. Comput. Internet Manag. Vol. 16. No 2 (May-August, 2008)*, vol. 16, pp. 35–43, 2002.

[7] https://www.accuweather.com/en/bd/chittagong. (DOA: 26 July, 2019)