Load Estimating for Air Conditioning using Computer Software Approach

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Abstract

Traditionally, load estimating for air conditioning systems is done either by manual calculation or judgmental estimation based on experience of the air conditioning practitioner. While manual calculation is laborious, estimate based on judgment is liable to error due to gigantic, complex and dynamic nature of present day architectural designs.

Load estimating through computer automation is likely to make a positive impact in the dynamic nature of air conditioning applications. This study develops computer software in Basic computer programming language named Computer Aided Load Estimating for Air Conditioning- CALAC-2004 to handle simple, intricate and dynamic nature of load estimate for air conditioning in developing country. Application of the developed software to FUTA Library showed that a total load of 806.26kW was estimated for the three floors it contained. With this load it will be uneconomical and ineffective the use of window or split type of air-conditioner (a-c), instead, central a-c unit is preferable in the FUTA Library.

Keywords: CALAC-2004, Computer Automation, Load Estimating, Air-Conditioning, FUTA Library.

1. Introduction

Air-conditioning is utilised to supply a controlled atmosphere to public buildings such as offices, halls, homes, and industries for the comfort of human being or animals or for the proper performance of some industrial processes. Full air-conditioning implies that the purity, movement, temperature and relative humidity of the air be controlled within the limits imposed by the design specification.

In tropical and subtropical countries, cooling by means of air-conditioning is a necessary feature of modern development as the new and emerging industries and households need it to retain reliability of some industrial and home based appliances. Air-conditioning system is designed with ability to subdue most common heat loads such as sensible and latent heat (Adeyemo, 2000; James, 1995). The ability of air-conditioning system to maintain condition of comfort or condition required by a product or process has made its use inevitable for sustainable development especially in developing countries. The system will finds application in other areas of endeavours as diverse is automobile, pharmaceutical industry, cocoa processing industry and textile industry.

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. Undersized equipment will not provide the required conditions while a greatly oversized one will lead to operating problems such as "hunting". However, actual peak or partial load cannot be measured in space, instead, the loads are estimated. The load estimate establishes the amount of air required to cope with the cooling load as well as the piping requirement for water or refrigerants (Trane, 1999; William and Williams, 1995; Jones, 1989). Before the load is estimated, it is important that a comparative survey be made to ensure accurate evaluation of the load components (latent and sensible) especially in the areas of mechanical, architectural and structural drawing or field sketches. The factors that must be critically looked into during load estimation process include orientation of building (location), space used, dimensions, column and beams, construction materials, surrounding conditions, windows, doors, people, lighting, ventilation, thermal storage and floor (ASHARE, 2001).

Load estimating in air-conditioning system design has been carried out manually in many quarters in developing country such as Nigeria. A lot of time and energy are wasted when estimating the cooling loads in complex and intricate buildings of modern time. Automation through computer application sounds reasonable to replace tedious and time consuming manual methods. To achieve this computer automation, software is developed using "qbasic" programming language tool. Qbasic is used in this work because of its simplicity and easily understandable by professionals. Besides, it is a versatile tool that has ability to handle large and complex problem of this kind.

Many research works exist in area of load estimating in air-conditioning but less attention is being paid to the computer automation of the process. The only area found of computer involvement is in ducts design (Turtle and Bailey, 1985; CAC, 1985; CGC, 1999). Duct design is done after cooling loads have been estimated. This study develops computer software named Computer Aided Load Estimating in Air-Conditioning (CALAC-2004). The developed computer software in "qbasic" has ability to estimate cooling load in complex and simple building which assists in selecting appropriate equipment, design air distribution system and other piping systems.

2. Materials and Methods

Load components in air-conditioning system for a selected building are identified. Accurate load estimates are important pre-requisite of a good air-conditioning system design. Ultimate system performance also depends on the proper system selection based on reasonable load estimate. The air-conditioning load estimate is based on heat coming into space from outdoors on a design day when the dry and wet bulb are peaking simultaneously and also a heat generated within the occupied space. However, experience and experiments have shown that all of the loads rarely peak at the same time. To be realistic, various diversity factors must be applied to some of the load components.

A cooling load calculation determines the total sensible cooling load due to heat gain through structural components (walls, floors and ceiling for example), windows (infiltration and ventilation), and occupancy (size of people). The latent portion of the cooling load is evaluated separately as a single zone. The entire structure is considered in term of equipment selection and system design on a room –by-room bases. Based on this arrangement, amount of conditioned air required by each room is estimated based on ASHRAE (2001). Indoor design condition of 24^0C db (dry bulb) with maximum relative humidity of 50%RH is currently accepted as satisfactory indoor design criteria.

Areas of the building perimeter with exterior glass and wall exposures have an air-conditioning load that includes solar gain through glass and wall. This may include the roof gain. External loads include sun rays entering window, strike the wall and roof; and outdoor air (for ventilation). ASHRAE (2001) provides appropriate storage factors to be used with peak solar heat gain as well as equivalent temperature differences for sunlit and shaded walls and roofs. The outdoor air imposes a cooling and dehumidifying load on the apparatus because the heat and/or moisture content must be removed. Some air-conditioning system provides a system that permit outdoor air by-passing the cooling surface. The by-passed outdoor air becomes a load within the conditioned space directly. This has made load imposed by ventilation air to be estimated in two parts.

The internal load, or heat generated within the space, depends on the characteristics of the application. Proper diversity and usage factor is applied to internal loads. Similar to solar heat gain, which is partially stored and reduced the load imposed on the air-conditioning equipment. Internal heat gain includes, people (through metabolism), lights, appliances and electric calculators. The amount of heat generated from people depends on surrounding temperature and on the activity level of the person. Some of the heat generated from light is radiant and partially stored. Therefore, application of storage and diversity in usage factors is considered in estimating the load from light. Application of usage and diversity factor is also considered for electrical appliances and machines as both are not used simultaneously in most cases.

The sensible cooling load due to heat from the walls, floors and ceiling of each room is estimated using appropriate cooling load temperature deference (CTLD) and U-factors for summer condition. For ceiling under natural vented attics or beneath vented flat roofs, the combined U-factor for the roof, vented space and ceiling is used. The mass of the walls is a variable and is important in estimating energy used. Daily rang (outdoor temperature swing on a design) day significantly affects the equivalent temperature difference. ASHRAE lists daily temperature ranges and classified it as high, medium and low.

Direct application of procedures for estimating load due to heat gain for flat glass results in unrealistic high cooling loads for non-residential and residential installations. Therefore, window glass load factors (GLF) are modified for non-residential cooling load estimation including solar heat load. In this application, the area of window is multiplied by the appropriate GLF. The effect of permanent outside shaving devices is considered separately in determining the cooling load. Shaded glass is considered the same as north-facing glass. The shade line factor (SLF), the ratio of the distance a shadow false beneath the edge of an overhang to the width of the overhang. The overhang is assumed to be at the top of the windows and the shade line equals the SLF times the overhang width. The shaded and sunlit glass areas are computed separately. Roof overhangs do not effectively protect north-east and northwest- facing windows in most cases, therefore, they are considered shaded. If the anticipated infiltration is less than 0.5ACH (air discharge), when positive means of introducing outdoor air are available, controls either manual or automatic is necessary and an energy recovery device is necessary. Sensible heat gain per sedentary occupant is assumed to be 67W. The number of occupants is not overestimated to prevent gross over-sizing. Heat loss or gain to the ducts or pipes are included in the estimated load in case of air distribution system outside the conditioned space, that is, in attics, crawl spaces or other unconditioned space.

Federal University of Technology, Akure (FUTA) newly built library is facing north at latitude 7.25^0N. Roof construction of library building is made of conventional roof-attic-ceiling combination, vented to remove moisture with 150mm of fibrous insulation U= $0.62W/m^2K$. The floor construction is 100mm concrete slab on grade. The windows are made of clear-double glass, 3mm thick, in and out, with closed medium colour venetian blinds. The window glass has a 600mm overhang at the top. Doors are made of solid core flush with all-glass storm doors (U= $1.87W/m^2K$). Temperature of 34^0C dry bulb (db) with a humidity ratio of 0.0136kg vapour/kg dry air and 28^0C wet bulb. Indoor design condition is made of temperature of 24^0C db and 50%RH. The occupants are assumed based on the available space. The electrical consultants gave the values of appliances and light in Watts according to the library design plan. Air-conditioning system designed in the plan is either window or split type based. The formulae used in estimating the sensible, latent and total cooling loads for non-residential building with their respective conditions are summarised in Table 1. The meaning of indicated symbols/abbreviations are: q, sensible cooling load (W); Q, volumetric airflow rate (1/s); Dt, design temperature difference between outside and inside air (K); ACH, air change per hour (1/h); A, area of applicable surface (m^2);U, U-factors for appropriate construction (W/m^2K); CTLD, cooling load temperature difference (K); and GLF, glass load factor (W/m^2).

Table 1: Summary of Procedures for Non-Residential Cooling Load Estimation

Load source	Equation for load q estimation
Glass and window areas	GLF.A
Doors	U_d.A.CTLD
Above-grade exterior wall	U_w.A.CTLD
Partitions unconditioned space	U_p.A.Dt
Ceilings and roofs	U_r.A.CTLD
Exposed floors	U_r.A.CTLD
Infiltration	1.2QDt
Internal loads-people,appliances,light	Plan 67W per person
Total load	Total cooling load = load factor LF x Sum of individual sensible cooling load components

Source: ASHRAE, 2001

The estimates are made easy through the use of computer software named Computer Aided Load Estimating for Air-conditioning (CALAC-2004) developed in “qbasic:”. The flowchart developed for the CALAC-2004 is shown in Figure 1. The mode of operation of the flowchart/software is summarised using the following algorithm:

10 Input parameters
20 If glass and window load goto 100 else30
30 If doors load goto 100 else 40
40 If exterior wall load goto 100 else 50
50 If partitioned unconditioned space load goto100 else 60
60 If ceiling and roof loadgoto 100 else 70
70 If exposed floor load goto 100 else 80
80 If infiltration load goto 100 else 90
90 If internal load goto 100 else 20
100 If modification in parameters exist goto 10 else goto 110
110 Calculate the following load statistics, then goto 120:

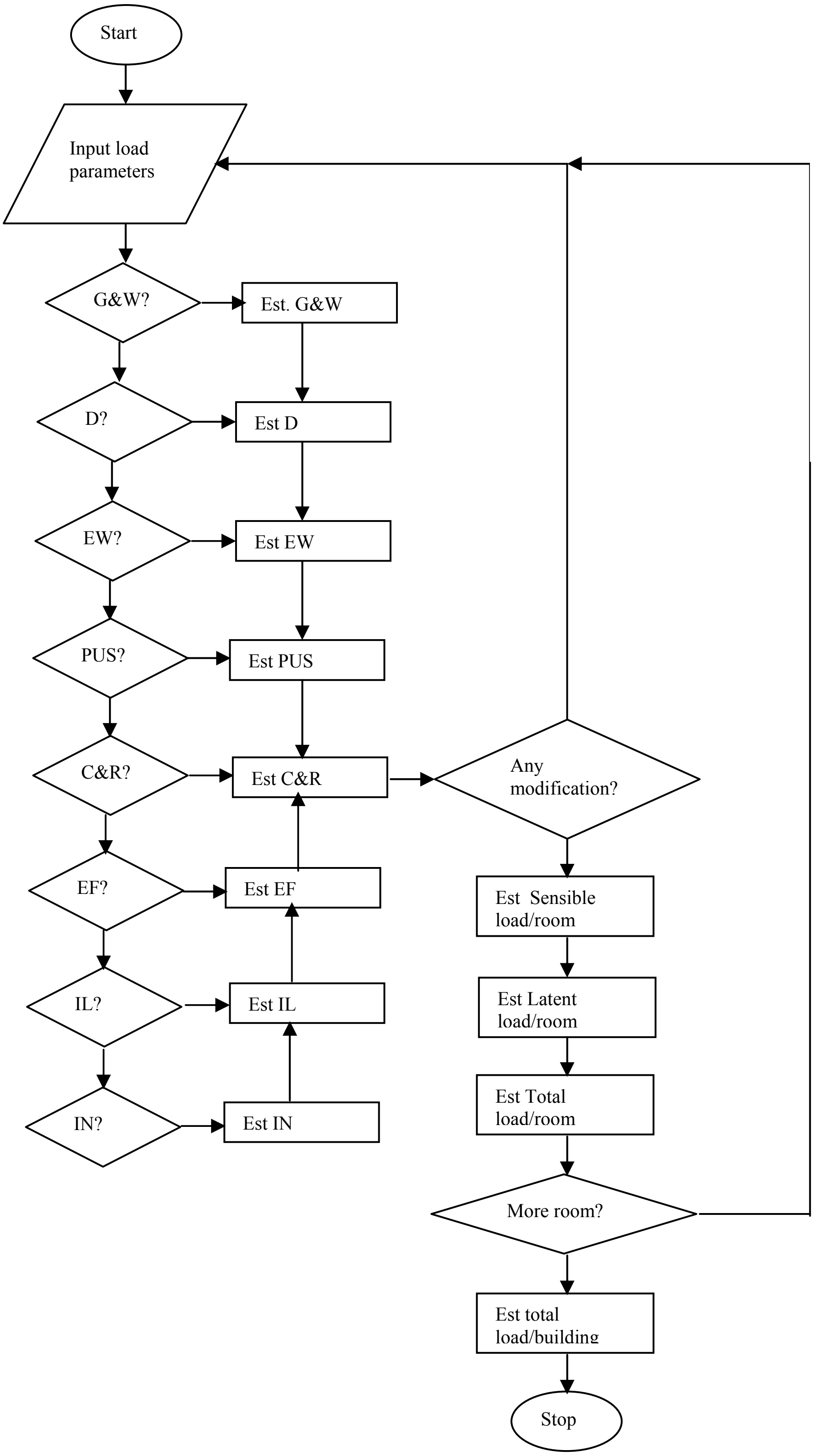
Glass and windows
q_g = (GLF)A
Doors
$q_d = U_d A(CTLD)$
Exterior walls
$q_w = U_w A(CTLD)$
Partition unconditioned
$q_p = U_p A(Dt)$
Ceiling and roof
$q_r = U_r A(CTLD)$
Exposed floor
$q_r = U_r A(CTLD)$
Infiltration
$q_i = 1.2\ Q(Dt)$
Internal
q_l= 67W per person

120 Calculate the cooling load per room CL= LF(load factor).$\sum q$ (or SL)
130 If room(s) left goto 10 else 140
140 Calculate the total cooling load
$TCL = \sum CL$
150 Calculate the total latent load
$TLL = TCL - TSL$

The U-values, that is, Coefficient of transmission U_r for roof, U_w for wall U_p for partitions and U_v for doors were obtained/evaluated as 0.62W/m^2 K, 1.61W/m^2K, 1.47W/m^2K and 1.87W/m^2K respectively from ASHRAE (2001). Latent load factor of 1.15 is used. Areas of the respective system are obtained from the measurement of lengths, breadth or height as explained before. Table 2 gives, the sensible, latent and the total loads obtained for each room of the new FUTA library complex as indicated appropriately. The summary of the result for the three floors are given in Table 3. The result in Table 3 is helpful in the choice of required sizes or equipment based on the load capacity as stated in Carrier General Catalogue (CAC, 1985; Trane, 1999)

3. Results and Discussion

The results obtained for new FUTA library using CALAC-2004 showed that loads estimated - sensible, latent, and total load varied from one room to the other. The highest load estimates of 63.59kW, 89.13kW and 93.27kW were obtained for open-access collection/reading rooms in the ground, middle and last floors respectively. This suggests that alternative method of cooling using central air-conditioning system will be economical in three reading rooms of the three floors because cooling loads estimated in these zones are beyond what a split or window type of air-conditioning, currently in use, can carry. The window and split types of air-conditioning system can carry load of 2.72 kW, 2.35kW and 2.42kW and 2.45kW, which are smallest loads estimated for secretary office (last floor), secretary office (middle floor) and secretary office/waiting room (ground floor) respectively.



G&W, glass and window load
D, door load
EW, exterior wall load
PUS, Partition unconditioned space load
C&R, ceiling and roof load
EF, exposed floor
IL, internal load
IN, infiltration
Est., estimate

Figure.1 Flowchart for the load estimating software

Generally, it will be more meaningful and economical to have a library design with the plan of installing a central a-c system that will take care of all the cooling loads at once. Efforts in this direction would greatly save space and economic in maintenance. The only disadvantage of this arrangement is the total discomfort it may cause in the case of failure of the central a-c system.

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Internal loads-people,appliances,light	Plan 67W per person
Total load	Total cooling load = load factor LF x Sum of individual sensible cooling load components

Source: ASHRAE, 2001

Table 2a: Total Cooling Load for Ground Floor

Conditioned space	Sensible load (kW)	Latent load (kW)	Total load (kW)
Secretary's office	2.13	0.32	2.45
Dept. Univ. Lib. Tech.	5.35	0.82	6.15
Reference room	20.25	3.04	23.29
Reference library	3.84	0.58	4.42
Non-controlled reading/catalogue	22.58	3.39	25.97
Subject librarian	6.05	0.90	6.95
Optic workstation	17.18	2.60	20.48
Circulation library	4.23	0.63	4.86
Bindery	4.02	0.61	4.63
Bindery office	3.77	0.57	4.34
Processing lab.	2.83	0.42	3.25
Wet room	2.13	0.32	2.45
Photo studio	4.07	0.62	4.69
Staff room	4.30	0.65	4.95
Kitchen	6.39	0.96	7.35
Acquisition section	3.56	0.54	4.10
Acquisition librarian	3.29	0.49	3.78
Automation librarian	3.29	0.49	3.78
Automation unit	7.17	1.08	8.25
Open access collection/ reading room	55.29	8.30	63.59
Newspaper/CNN reading room	8.88	1.33	10.21
Cataloguing section	4.91	0.74	5.65

Table 2b: Total Cooling Load for Middle Floor (First floor)

Conditioned space	Sensible load (kW)	Latent load (kW)	Total load (kW)
Work room (1)	2.28	0.34	2.62
Serial librarian	2.28	0.34	2.62
Secretary's office	2.03	0.32	2.35
Dept. Univ. Lib. readers	3.84	0.58	4.42
Audio room	6.34	0.95	7.29
Reference room	20.25	3.04	23.29
Work room (2)	4.21	0.63	4.84
Artist studio	5.37	0.80	6.17
Open access collection/ reading room (1)	77.51	11.62	89.13
Subject librarian	6.30	0.95	7.25
Open access collection/ reading room (2)	71.43	10.71	82.14
Postgraduate research room	52.15	7.82	59.97

Table 2c: Total Cooling Load for Last Floor (Second floor)

Conditioned space	Sensible load (kW)	Latent load (kW)	Total load (kW)
Work room (1)	2.28	0.34	2.62
Serial librarian	2.28	0.34	2.62
Secretary's office	2.03	0.32	2.35
Dept. Univ. Lib. readers	3.84	0.58	4.42
Audio room	6.34	0.95	7.29
Reference room	20.25	3.04	23.29
Work room (2)	4.21	0.63	4.84
Artist studio	5.37	0.80	6.17
Open access collection/ reading room (1)	77.51	11.62	89.13
Subject librarian	6.30	0.95	7.25
Open access collection/ reading room (2)	71.43	10.71	82.14
Postgraduate research room	52.15	7.82	59.97

Table 3: Summary of the Cooling Load Results

Floor	Load (kW)	Total sensible load (kW)	Total latent load (heat) (kW)
Ground floor	230.82	200.71	30.11
Middle floor	281.60	244.47	36.73
Last floor	293.84	255.51	38.33
Total	806.26	709.09	105.17

4. Conclusion

The study has developed a system framework that estimate 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).

When data collected from the FUTA new library was analyzed and used as input into the CALAC-2004, one concludes from the results obtained that alternative method of using central air-conditioning system is necessary for effective cooling of loads generated in the library complex. The use of central a-c unit will reduce space and at the same time promote effectiveness in cooling ability. Demerit of it in the area of non-selectivity in cooling action and at the time of failure since the system is centrally controlled.

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