Cooling Load Calculations

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Abstract. Calculation of thermal loads of buildings adapted for cooling in summer and heating in winter is important for the accuracy of the design and the appropriate choice of equipment for the adaptation of air and air handling units in order to meet the requirements of operation, thermal comfort and good distribution of air in the adapted place. This paper presents some consideration of cooling load calculation techniques. The numerical calculations are performed for a certain building in Basra, which is located on a longitude of 47.78 ° and N 32 latitude with two floors.

1. Introduction
Nowadays, in terms of continuity of indoor environment comfort conditions and decreased initial investment, maintenance and operating costs, as well as selection of an appropriate cooling system are important in buildings [1–9]. In the selection of cooling system, capacity needs to be determined according to building cooling load. That cooling load is not calculated in the reliability way cause selection of cooling system that is not suitable to building, increases cooling system cost and aggravation of indoor environment comfort conditions. Therefore, the reliability calculation method should be used for calculation of building cooling loads. There are several methods that calculate building cooling loads. In this study, TEDT/TA, HB, TFM, CLTD/SCL/CLF and RTS methods that are commonly used are compared according to their using data, coefficients and calculation procedure. The elementary school that is located in Istanbul is selected to be an example for comparison of numerical differences among these methods.

2. Theory of the paper
Every home needs a specific amount of cooling to be comfortable, and achieving this level of comfort is totally dependent on having the right-sized whole home air conditioning unit. There are a number of factors that are part of calculating the cooling load for your home, including:

- Daytime heat gain - how much thermal heat your home gains throughout the day.
- The orientation of your home - the direction in which your home faces plays a large role in daytime heat gain.
- Levels of insulation from top to bottom - insulation plays an important role in stopping heat transfer, so it’s critical to know how much and what type(s) of insulation you have.
• Floor plan - an open floor plan will conduct cool air very differently from one that has many closed rooms and walls.
• Number and types of windows and doors - insulated windows and doors have a large impact on retaining the cool air in home.
• Number of stories - warm air rises, so it’s important to factor in the number of stories of home.
• Number of occupants - people generate heat, which will affect the cooling in home.
• Square footage - size relates to the amount of space your cooling needs to adequately cover.

3. Special considerations
For standard calculations, the engine will examine each space from the months of April to November and from 6am to 6pm (Oct-May in the southern hemisphere). After the loads of all the spaces have been determined, the maximum month/hour (depending on the calculation type) is used to determine the psychometrics, airflow, and coil loads. The following (borrowed liberally from the ASHRAE 2005 Handbook of Fundamentals) is a discussion of the calculation process and principles employed.

Cooling load is the rate at which a cooling system or process must remove heat from a conditioned zone to maintain it at a constant dry bulb temperature and humidity. The cooling load can be further decomposed into sensible and latent cooling loads. Sensible heat inside the space causes its air temperature to rise while latent heat is associated with the rise of the moisture content in the space. The building design, internal equipment, occupants, and outdoor weather conditions may affect the cooling load in a building using different heat transfer mechanisms [10]. The SI units are W/s.

4. Analytical procedure
The cooling load is calculated to select HVAC equipment that has the appropriate cooling capacity to remove heat from the zone. A zone is typically defined as an area with similar heat gain, similar temperature and humidity control requirements, or an enclosed space within a building with the purpose to monitor and control the zone’s temperature and humidity with a single sensor e.g. thermostat [11]. There are utmost 4 ways for energy (heat) transfer in a zone, these include:
- Solar transference (due to temperature difference);
- Air change load (infiltration or exfiltration);
- Machine load (heat dissipation via equipments);
- From living organisms.

Cooling load calculation methodologies take into account heat transfer by conduction, convection, and radiation. Methodologies include heat balance, radiant time series [12] cooling load temperature difference, transfer function [13] and soil-air temperature. Methods calculate the cooling load in either steady state or dynamic conditions and some can be more involved than others. These methodologies and others can be found in ASRAE handbooks, ISO Standard 11855, European Standard (EN) 15243, and EN 15255 [14]. ASHRAE recommends the heat balance method and radiant time series methods.

Differentiation from heat gains. The cooling load of a building should not be confused with its heat gain. Heat gain refer to the rate at which heat is transferred into or generated inside a building. Just like cooling loads, heat gain can be separated into sensible and latent heat gains that can occur through conduction, convection, and radiation. Thermophysical properties of walls, floors, ceilings, and windows, lighting power density (LPD), plug load density, occupant density, and equipment efficiency play an important role in determining the magnitude of heat gains in a building. ASHRAE handbook of fundamentals refers to the following six modes of entry for heat gains [15]:
• Solar radiation through transparent surfaces.
• Heat conduction through exterior walls and roofs.
• Heat conduction through ceilings, floors, and interior partitions.
• Heat generated in the space by occupants, lights, and appliances.
• Energy transfer through direct-with-space ventilation and infiltration of outdoor air.
• Miscellaneous heats gains.
Furthermore, heat extraction rate is the rate at which heat is actually being removed from the space by the cooling equipment [16]. Heat gains, heat extraction rate, and cooling loads values are often not equal due to thermal inertia effects. Heat is stored in the mass of the building and furnishings delaying the time at which it can become a heat gain and be extracted by the cooling equipment to maintain the desired indoor conditions. Another reason is inability of the cooling system to keep dry bulb temperature and humidity constant.

**Cooling loads in air systems.** In air systems, convective heat gains are assumed to become a cooling load instantly. Radiative heat gains are absorbed by walls, floors, ceilings, and furnishings causing an increase in their temperature which will then transfer heat to the space air by convection. Conductive heat gains are converted to convective and radiative heat gains. If the space air temperature and humidity are kept constant then heat extraction rate and space cooling load are equal. The resulting cooling load through different air system types in the same built environment can be different [15].

**Cooling loads in radiant systems.** In radiant systems, not all convective heat gains become a cooling load instantly because radiant system are not able to remove heat from the zone through convection causing air temperature to rise and increase the surface temperatures of non-active surfaces. Non-active surfaces then release heat through convection or radiate heat to an active cooling surface. Radiative heat gains are absorbed by active and non-active cooling surfaces [17]. If absorbed by active surfaces then heat gains become an instant cooling load otherwise a temperature increase will occur in the non-active surface that will eventually cause heat transfer to the space by convection and radiation [14].

Design of cooling loads are based on the assumption of steady periodic conditions (i.e., the design day's weather, occupancy, and heat gain conditions are identical to those for preceding days such that the loads repeat on an identical 24 h cyclical basis). Thus, the heat gain for a particular component at a particular hour is the same as 24 h prior, which is the same as 48 h prior, etc. [16].

After collecting all of the cooling load components for each space, the heating load is calculated. Psychrometric calculations use thermodynamic properties to analyze conditions and processes involving moist air. By calculating these various saturations we can determine the necessary airflows, entering and leaving air temperatures, and equipment loads of the zone.

Once the individual space loads, psychrometrics, and equipment loads are all calculated, the engine determines the final block loads of the zones, levels, and building [14].

Insuring that you install the right size furnace, air conditioner, heat pump or complete HVAC system is critical to providing consistent indoor comfort for you and your family. It's also important for saving energy, which can be wasted by either a too-large or too-small system. Since energy savings translate to monetary savings, in today's economy you simply can't afford to ignore system sizing when selecting your new HVAC equipment.

What happens when HVAC system is too large or too small: a number of issues can occur when your heating or cooling system is the wrong size for your home. Correctly Sized System is a system that is correctly matched to your home's heating or cooling requirements offers the following advantages:

- It operates at optimal efficiency, saving you money on energy costs.
- It keeps your indoor temperature and overall comfort level more consistent.
- It provides proper humidity control, increasing comfort and lowering the likelihood of mold or mildew problems.
- It operates without excessive noise, which could otherwise indicate an improperly sized system or another issue that needs addressing.
- It operates according to its intended specifications, rather than overburdening the system and shortening its life cycle.

**System Capacity Ratings: BTUs**

The initials BTU stand for British Thermal Unit. This rating is a measure of the system's heating or cooling output per minute. HVAC products are labeled with a BTU rating to give consumers a better
idea of the approximate area a given piece of HVAC equipment might be expected to heat or cool under ideal conditions. This rating, however, is not intended to replace the advice of an HVAC professional, who understands all the variables involved and can assess these variables in relation to your specific situation and your particular heating and cooling requirements. While BTUs per minute can get you in the ballpark on system sizing, this measurement can't give you the specifics that will let you know exactly how all the zones in your home figure into the overall system-sizing equation. Therefore, BTU ratings should only be used to roughly estimate the system size you'll be likely to need and should always be double-checked by performing official heating and cooling load calculations.

5. Experimental work

Building specification

For numerical calculations we will consider a building in Basra, which is located on a longitude of 47.78 ° and N 32 latitude with two floors and 68 rooms. External design temperature is 43 °C. Interior design temperature is 25.5 ºC. The daily range of external temperature change is 15 ° C. Relative humidity to be available in room is 50% RH. Every square meter of the floor needs 25 W of light. The building is single-glass type (single glazed). Components of cooling load are presented in Fig.1.

![Figure 1. Cooling load components.](image)

![Figure 2. Construction scheme of the building](image)

Figure 2 presents a construction scheme of the building, namely:

a - Brick face wall of building, thickness is 100 mm;
b - Cement, thickness is 20 mm
c - Brick of construction, thickness is 200 mm;
d - Cement, thickness is 20 mm;
b - Light layer of whiteness, thickness is 2 mm.

Further we numerically calculate cooling load for Room 2, first floor, which we take as an example. Here we consider 1 window, 1 door and area (5.68 *4.5*3) m. The number of fans is 1 and the number of lamps is 4 (fluorescent lamps). The room is facing the north and we added a hairdryer, a coffee machine and one laptop. 1 person is in the room.

The set of formulas is used in our calculations:

Total thermal resistance (R) is a sum of components: $R_{total} = \frac{1}{F_0} + R_{i} + R_{d} + R_{c} + R_{b} + \frac{1}{F_o} [W/m^2\cdot{^\circ}C]$

where: $F_0$ is heat transfer factor for outdoor air;
$F_i$ is internal air temperature transmission factor taken from tables of ASHRAE;
$(R_i+R_d+R_c+R_b+...)$ are layers of surface.

$U_{total} = \frac{1}{R_{total}} [W/m2{^\circ}C]$  

CLTD is cooling load temperature difference, $CLTD_c$ is corrected cooling load temperature difference.

$$CLTD_c = \{(CLTD+LM)\cdot K+(25.5-TR)+(TM-29.4)\} \cdot F$$

LM is correction factor for latitude and longitude and backward value by wall direction. LM=0.5 in July month and for latitude 32 north [10].
K is correction coefficient for ceiling color =1 for the light roof;
F is coefficient of ventilation between the surface and the secondary roof = 1 (if no ventilation);
TR is internal design air temperature = 25.5 °C;
T0 is external design air temperature rate = 43 ºC; TM=T0-(Daily range/2)=35.5 ºC.
Heat gain, usually heat gain per unit time Q is calculated in the following way (through walls, doors, roofs, and windows): Q=U*A*CLTDc
A states for Area. For example, ceiling area= 25.56 m²; U is the total temperature transmission coefficient of the examined surface. For example, for roof Uroof=0.489 W/m²K.
We will calculate all this parameters (cooling loads, etc) numerically for internal walls (which in our considered case is south wall), for windows in the north direction, doors and other surfaces. The next calculation is devoted to heating load which resulting from the air of ventilation to be provided (ventilation).
The resulting loads are the result of the installation of the place to be adapted to new air and the ventilation air must be fitted at sufficient rates to the space adapted to sustain adequate levels of sanitary conditions for occupants and to keep smells within acceptable limits. Physical heat associated with ventilation air is the following: Qsensible = 1.22× Vvent× (Tout− Tin)
Vvent is total ventilation air, which is the amount of air each person needs to ventilate.
The number of air changing times for an hour depends on the quality of the building and on the number of exposed surfaces. For example, number of air changing per hour for space of room not exhibited to the outer surrounding is 0.5; for one-side exhibition space for external conditions it is equal to 1; for entrances to buildings it is equal to 2. And since one class is exposed to the outer ocean by one side, the number of times the air switches per hour is equal to 1. Vvolume=76.68m³, Vinf = N*Vvolume/3600=0.0213, Qsensible =0.558kw=558.7 W.
Latent heat associated with leakage air is calcutated using the expression:

Qlatent = 2940× Vinf× (Wout− Win)

We get values ΔW from the air-conditioned scheme.
Also we take into account the resulting thermal load from the other devices, i.e hairdryer (795 W), Coffee machine (1000 W) and computer (990 W). So the total device power is Powertotal=2785 W.
By combining all previous results, we obtain the following Table, which presents numerical values for heat gains for various cooling load components of the considered building.

| Time     | 1200   | 1400   | 1600   |
|----------|--------|--------|--------|
| Wall out | QN     | 420.81 | 420.81 | 439.027 |
| Wall in  | Qs     | 329.337| 329.337| 329.337 |
| Class    | QN     | 547.909| 568.269| 553.959 |
| Q door   | 103.2  |        | 103.2  |        |
| Qlight   | 1074.087| 1074.087| 1074.087| 1074.087|
| Qfan     | 95     |        | 95     |        |
| Personage| QL     | 110    | 110    | 110    |
| Qs       | 130    |        | 130    |        |
| Roof     | Qh     | 376.21S| 438.709| 501.203|
| Air      | QL     | 938    | 938    | 938    |
| penetration | Qs | 558.7  | 558.7  | 558.7  |
| Other device | QT | 2785   | 2785   | 2785   |
| QTOTAL (WATT) | 7468.254 | 7551.112 | 7617.513 |
| QTOTAL (TR)   | 2.133  | 2.157  | 2.176  |

6. Conclusions
While the heating and cooling load calculations used for correctly sizing your HVAC equipment aren't difficult, they are fairly involved and take time and patience to complete. While the average
person would likely find the calculations more complex than they’d be interested in tackling, if you do
decide to handle them on your own, you’ll need to make specific calculations for each zone, figuring
the area and insulation level of the space and estimating air infiltration.

While sizing your HVAC equipment is a process that’s based on scientific principles, it is,
nevertheless, an inexact science. So many different factors combine to create the specific heating and
cooling environment of every home, HVAC system requirements will vary widely. Cooling and
heating load calculations are a key variable in the sizing equation - one that’s been carefully designed
to determine the best system for your needs. In this work we tried to summarize all these arguments
and present a numerical calculation of heat parameters on an example of a building in Basra.

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