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# Cooling Load Estimation in Air Conditioning System

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## Abstract

The project titled" COOLING LOAD ESTIMATION IN AIR CONDITIONING SYSTEM" is an effort to apply our knowledge of mechanical and thermal engineering in analysis of air conditioning and to estimate the cooling load for a given space. This project report also documents the analysis of the components of air conditioner.

Cooling load estimation depends upon significant building parameters like orientation, window glass shade type, number of glass panes used, wall insulation, roof type and floor type can be easily investigated. Effects of all these parameters have been investigated for a typical building block to arrive at an intelligent decision.

Many laboratory tests and research investigations have shown that the fundamental requirement for human comfort is physiological, and can be summed up by saying that optimum conditions for comfort are those existing when the body can maintain complete thermal equilibrium, with only minor adjustments in heat regulating mechanism of the body. When compared to the earlier times today's air conditioners are compact, efficient, effective, attractive, eco-friendly .Air condition is not only useful in providing human comfort but also used in many fields like food preservation, cold storage, transport air conditioning, medical sciences and varied industrial applications.

Most notably, and evaluation of the air conditioning for optimization of its efficiency came through the fruitful combination of mechanical engineering, thermal engineering, physiological sciences, and most important is the human comfort.

## 1. Introduction

Applying mechanical and thermal engineering concepts, an air conditioner was designed for the human comfort and other necessary objection. This project report delineates norms and the procedure for the estimation of the heat load on the air conditioner.

Being socially conscious technocrat I choose to invest my time, effort, and engineering knowledge into clearly understanding the mechanism underlying within the air conditioner which became a necessity in today's world .We chose to concentrate more on cooling load calculations because through this we can understand the heat gain sources so that we can have check on them the next time we switch on an A.C.

### 1.1 REFRIGERATION

The term "**refrigeration"** may be defined as the process of removing heat from a substance under controlled conditions. It also includes the process of reducing and maintaining the temperature of a body below the general temperature of its surroundings. The device that serves this purpose is called "**refrigerator".** Refrigerator has become a part of day –to-day life of man. It has become a necessity in this world of technology. In other words the term refrigeration means continued extraction of heat from a body whose temperature is below the surrounding temperature.

The refrigerant is a heat carrying medium which during their cycle in the refrigeration system absorbs heat from a low temperature system and discards it to high temperature body. There are many types of refrigerants that are widely being used. Some of them are Freon-22, R-134a, R-11, R-12, R-100, etc.

AIR CONDITIONING:

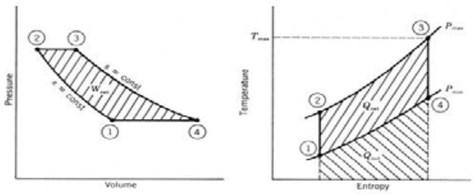
Merely lowering or raising the temperature provides comfort in general to the machines or its components and living beings in particular. In case of machine components along with temperature, humidity also has to be controlled and for the comfort of human beings along with these two important parameters, air motion and cleanliness also play a vital role. Air conditioning works on the same principle as that of Refrigerating system. Air conditioning is that branch of engineering science that deals with the conditioning of air i.e. supplying and maintaining desirable internal atmospheric conditions for human comfort, irrespective of external conditions. It also deals with the conditioning of air for industrial processes, food processing, storage of foods and other materials.

Figure1.1 AC Model

AIR REFRIGERATION CYCLES:

Air refrigerator working on Bell-Coleman cycle (Reverse Brayton cycle):

Figure:2 T-S and P-V diagrams



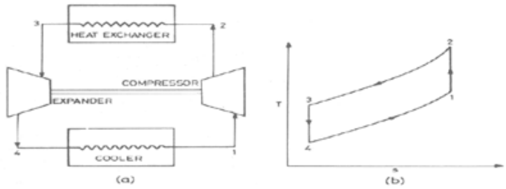




Fig :3 Bell coleman cycle

This is an important cycle frequently employed in gas cycle refrigeration systems. This may be thought of as a modification of reversed Carnot cycle, as the two isothermal processes of Carnot cycle are replaced by two isobaric heat transfer processes. This is also called as Joule or Bell-Coleman cycle.

Process 1-2: Reversible, adiabatic compression in a compressor .Gas at low pressure is compressed isentropically from state 1 to state 2.

Process 2-3: Reversible, isobaric heat rejection in a heat exchanger. Hot and high pressure gas flows through a heat exchanger and rejects heat sensibly and isobarically to a heat sink. The enthalpy and temperature of the gas drop during the process due to heat exchanger, no work transfer takes place and the entropy of the gas decreases.

SCOPE OF THE PROJECT:

This research briefly introduces the principal components of cooling load of a building, namely, wall transmission, solar effect, internal heat gain (light, equipment, occupants) orientation of building, etc. The indoor design condition was set at 24 OC and a relative humidity of 50% applied to buildings of different constructions. The outdoor condition was extracted from long term climatic data obtain from Meteorological Department of Ghana. Chapter 1 deals with the introduction to the topic and the objective of embarking on such a project. Chapter 2 is on literature review on definition of load terms and simplified method of estimation of cooling load.

## 2. Literature Review

The basic concept behind air conditioning is known to have applied in ancient Egypt, where reeds were hung in windows and were moistened with trickling water. The evaporation of water cooled the air blowing through the window. This process also made the air more humid

Andersson et al. [1] designed heating and cooling loads for a sample residential building at different orientations, using a development version of the building energy analysis computer program BLAST. They identified that the total loads were found to be higher for north than south orientation except in extreme southern latitudes of the U.S.

Omar et al. [2] calculated the hourly cooling load due to different kinds of wall, roof and fenestration using transfer function method (TFM). The output of this method was compared with the well-known Carrier program and the results were acceptable. In the case of cooling load, when the results were compared with the ASHRAE examples, some differences were noticed due to wall and roof. They also studied the effects of changing the wall color on cooling load.

Adnan Shariah et al. [3] studied the effect of the absorptance of external surfaces of buildings on heating, cooling and total loads using the TRNSYS simulation program. Two types of construction materials, namely heavy weight concrete block and light weight concrete were used in the simulation. They also calculated the effects of the absorptance on energy loads for insulated buildings. They reported that, for uninsulated buildings, as the absorptance was changed from one to zero, the total energy load decreased by 32%, while for insulated buildings, it decreased by 26% inAmman. Whereas the decrease was about 47% for uninsulated and 32% for insulated buildings in Aqaba.

Kulkarni et al. [4] optimized cooling load for a lecture theatre in a composite climate in India. The lecture theatre had a dimension of 16m×8.4m×3.6m and was situated at Roorkee (28.58°N, 77.20°E) in the northern region of India. The monthly, annual cooling load and cooling capacity of air conditioning system was determined by a computer simulation program. They reported that the use of false celling, ceramic tiles on roof and floor, electro chromic reflective colored, 13mm air gap, clear glass gave the best possible retrofitting option.

## 3. Analysis and Evaluation

As the main objective of our project was analysis of air conditioning for optimum efficiency, I went to nizam's institute of medical sciences (nims**)** to see that how a centralized AC plant has been set up there and do analysis for our project based on their results and conclusions.

- The compressor being used is semi-hermetic compressor. The multistage has been introduced to the compressors. So each AC equipment has 4 compressors, a condenser, muffler to each and every compressor, expansion valve, chiller pipes, safety valves, pressure gauges etc.

- The condenser is water cooled, that is water acts as the secondary refrigerant. The capacity of each compressor is 86 TR i.e. 86*4=344 TR is the capacity of each AC equipment. There are 6 such AC equipments that make a centralized AC.

- The refrigerant is R134a. Semi-hermetic means the compressor is in built with the motor.

- The condenser is water cooled. It is shell and water cooled condenser with counter-flow type of heat exchanger. Here the water gets heated up and flows to the cooling tower where the water gets cooled.

Example of hospital space

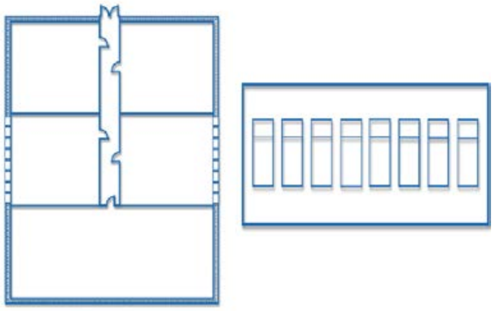


Figure4 : layout of room

## Internal heat gains:

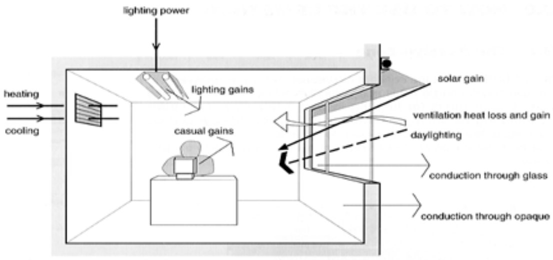



Figure 5: internal heat gains

The next component of the space cooling load is the heat that originates within the space. Typical sources of internal heat gain are people, lights, cooking processes, and other heat generating equipment, such as motors, appliances, and office equipment.
While all of these sources contribute sensible heat to the space, people, cooking processes, and some appliances (such as a coffee maker) also contribute latent heat to the space.

## Table for analysis:

Table 1: U-Factor for windows

| | Aluminum without Thermal break | Aluminum with thermal break | Wood/vinyl |
|---|---|---|---|
| Single glazing 1/8 in. (3.2mm) glass | 1.13 (6.42) | 1.07 (6.07) | 0.98 (5.55) |
| Double glazing | | | |
| 1/4 in. (6.4mm) air space | 0.69 (3.94) | 0.63 (3.56) | 0.56 (3.17) |
| 1/2 in. (12.8mm) air space | 0.64 (3.61) | 0.57 (3.22) | 0.50 (2.84) |
| 1/4 in. (6.4mm) argon space | 0.66 (3.75) | 0.59 (3.37) | 0.52 (2.98) |
| 1/2 in. (12.8mm) argon space | 0.67 (3.47) | 0.54 (3.08) | 0.48 (2.70) |
| Triple glazing | | | |
| 1/4 in. (6.4mm) air spaces | 0.55 (3.10) | 0.48 (2.73) | 0.41 (2.33) |
| 1/2 in. (12.8mm) air spaces | 0.49 (2.76) | 0.42 (2.39) | 0.35 (2.01) |
| 1/4 in (6.4mm) argon spaces | 0.51 (2.90) | 0.45 (2.54) | 0.38 (2.15) |
| 1/2 in. (12.8mm) argon spaces | 0.47 (2.66) | 0.40 (2.30) | 0.34 (1.91) |

## Calculations:

**Conduction through Windows:**
Conduction heat gain through the west-facing windows:
- U-factor = 0.63 Btu/hr•ft2•°F [3.56 W/m2•°K]
- Total area of glass = 8 windows x (4 ft x 5 ft) = 160 ft2 [8 x (1.2 m x 1.5 m) = 14.4 m2]
- CLTD hour=17 = 13°F [7°C]

$$[Q_{windows} = 0.63 \times 160 \times 13 = 1{,}310 \text{ Btu/hr}$$

$$Q_{windows} = 3.56 \times 14.4 \times 7 = 359 \text{ W}]$$

**Internal Heat Gains:**
Internal heat gain from people:
- Number of people = 18
- Sensible heat gain/person = 250 Btu/hr [75 W]
- Latent heat gain/person = 200 Btu/hr [55 W]
- CLF = 1.0 (because the space temperature set point is increased at night)

QS = 18 people x 250 Btu/hr per person x 1.0 = 4,500 Btu/hr

$$Q_{sensible} = 18 \times 250 \times 1.0 = 4{,}500 \text{ Btu/hr}$$

$$Q_{latent} = 18 \times 200 = 3{,}600 \text{ Btu/hr}$$

$$[Q_{sensible} = 18 \times 75 \times 1.0 = 1{,}350 \text{ W}]$$

$$[Q_{latent} = 18 \times 55 = 990 \text{ W}]$$

## 4. Results and Discussion

**Summary of Space Cooling Loads**

| **Space load components** | **sensible load** Btu/hr [W] | **latent load** Btu/hr [W] |
|---|---|---|
| Conduction through roof | 12,312 [3,563] | |
| Conduction through exterior wall | 502 [144] | |
| Conduction through windows | 1,310 [359] | |
| Solar radiation through windows | 22,733 [6,447] | |
| People | 4,500 [1,350] | 3,600 [990] |
| Lights | 22,097 [6,480] | |
| Equipment | 8,184 [2,404] | 1,540 [450] |
| Infiltration | 2,988 [876] | 3,969 [1,159] |
| Total space cooling load | 74,626 [21,623] | 9,109 [2,599] |
| Ventilation | 6,640 [2,047] | 8,820 [2,709] |
| Total coil cooling load | 81,266 [23,670] | 17,929 [5,308] |

From the above analysis and calculations made, it is observed that the maximum amount of heat gain is happened through windows of solar radiation 22,733Btu/hr [6,447 W]and the minimum heat gain is happened through the heat conduction through exterior walls 502 Btu/hr [144 W ]. By consedering all the factors of heat gain for a given space the TOTAL COOLING LOAD = 99,195 Btu/hr (8.3 refrigeration tons).

## 5. Conclusion

Finally, the cooling coil in the air-conditioning system that serves this space must be capable of handling the sensible and latent loads for the space, plus any additional loads that affect the coil only. In our example, outdoor air for ventilation is the only additional load affecting the cooling coil. Based on the calculations performed in Period Two, the total load on the cooling coil is 99,195 Btu/hr (8.3 refrigeration tons) [28,978 W].

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