# Design of Air Conditioning system considering Human Comfort Conditions and its impact on the commercial growth of the manufacturer

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**Abstract -** *Human comfort is governed by numerous parameters, rendering comfort to be a relative term that varies from person to person whereby the comfort of a particular person may lead to discomfort of another. While designing air conditioning systems, the comfort factor needs to be considered to be of utmost importance as the beneficiary is a human being. This paper intends to discuss the necessary comfort conditions, science behind the same and their importance in designing the air conditioning system. Two cases shall be studied namely that of a manufacturing space with an automated machine and an office working space. Towards the end, the commercial aspect of design and manufacturing considering comfort, shall also be briefly discussed. The objective of this paper shall be highlighting the importance of consideration of human comfort during the design of air conditioning systems.*

***Key Words*: Air Conditioning, Psychrometry, Comfort, Human, Efficiency, Effectiveness**

## 1. INTRODUCTION

The process of designing a thermodynamic system requires considerations to be made on the basis of theoretical as well as practical standpoints. The theoretical concepts yield the basic constraints and the practical aspects provide the basis for the conceptualization of the product. One of the most used thermodynamic systems is the air conditioning system. While designing the same, the factors that need to be considered are quality of air, temperature of air, velocity of air flow, direction of air flow in the air conditioned space and relative humidity. On a keen observation these physical quantities direct to one basic requirement which is called 'Comfort'. In the true sense, comfort is a relative term whose definition changes from person to person or case to case. While designing an air conditioning system, comfort of the occupants needs to be particularly considered as this itself dictates the effectiveness of the system. Since comfort cannot be accurately quantified, it cannot be called a physical quantity but its existence is inevitable. This work shall try to bring out the qualitative analysis of comfort conditions to be considered while designing in addition to the external operating conditions.

## 2. REFRIGERATION AND AIR CONDITIONING

Refrigeration is a process of maintaining the temperature of a closed space below that of the surrounding temperature by continuously extracting heat from it by means of external work. This leads to an effect wherein, the closed space is always cooler than the surroundings. Further progress in the field of refrigeration has lead to development of air conditioning systems. In air conditioning systems, air cooling is not the sole objective. In addition to air cooling, conditioning of air in terms of increase or decrease of its wetness or dryness and maintaining the air quality are the key areas of consideration. Thus one can say that Air conditioning is refrigeration but refrigeration is not air conditioning.

In order to extract heat from the closed space a low temperature fluid called refrigerant is circulated in the piping. Following the second law of thermodynamics, this refrigerant is continuously subjected to a cycle comprising heat addition, compression, heat rejection and expansion. This itself facilitates the objective of maintain the closed space at a temperature lower than that of the surroundings.

In practice, there are two widely employed systems of refrigeration viz. Vapour compression refrigeration and Vapour absorption refrigeration systems. The Vapour compression refrigeration systems employ physical compression of the refrigerant and serve the purpose of refrigeration. In vapour absorption refrigeration systems, instead of physical compression, thermal compression of the refrigerant takes place by means of absorption of the same in another fluid. As most of the Air Conditioning systems work on the principle Vapour compression refrigeration system, the further study shall be undertaken keeping this point in view.

Over the years, popularity of air conditioning systems has grown from use in research laboratories and food preservation to domestic air conditioning, air conditioning in auditoriums and so on. With this progress, there is a paradigm shift in the method of design of these systems. As the air conditioning systems are now been used for human occupants, there is a continuous requirement of enhancement of human comfort conditions. This shall be addressed in the subsequent sections.

## 3. COMFORT CONDITIONS

According to The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), "Thermal comfort is that state of mind which expresses satisfaction with the thermal environment [1]" . It depends largely on psychological and physiological factors which makes its quantification complex [3]. If the person is not in a closed space that has comfortable thermal conditions, there are a number of hazards like heat exhaustion where the body rapidly loses heat or heat stroke where there may be increase in the body temperature due to improper cooling. Although these are biological ailments, comfort air conditioning can provide an effective solution to a greater extent in this regard. The comfort zone can be defined as a state wherein the dry bulb temperature of the air conditioned space is between 20-25°C, wet bulb temperature is 12-18°C at a relative humidity of 30% to 70% [3]. However, the specific magnitude of these physical quantities may be different for different seasons, occupants, operating conditions and designers. Thus, depending upon individual preferences, comfort can be defined at a personal level for further design considerations.

## 4. DESIGN OF AIR CONDITIONING SYSTEMS CONSIDERING COMFORT CONDITIONS

The main factors that affect human comfort are effective temperature, heat transfer from human body, Loss of moisture from human body, moisture content of air, air quality and air motion [3]. The effective temperature refers to the temperature of the system due to combined effect of dry bulb temperature, wet bulb temperature and the velocity of air. The effective temperature is the design input for the system wherein the desired Coefficient of Performance needs to be achieved by providing the required input. The second factor is the heat transfer from human body. This factor varies from person to person and mainly depends upon the individual metabolism rate. A person with a high metabolism rate will transfer more heat to the surrounding due to faster conversion of food to glucose and liberation of equivalent energy for life and sustenance. There should be proper rate of heat rejection to the surrounding failing which, there are chances of health issues due to accumulation of heat. Further, as time progresses, there is loss of moisture from the human skin in small quantities. Over a considerable period of time, this can lead to discomfort if the rate of loss of moisture is high. Moisture content of air decides the psychological comfort of the occupant to a greater extent. High moisture content increases the relative humidity and increases perspiration. This factor can be addressed by dehumidification to the desired extent. The air quality is another important factor that governs the comfort of a person. Generally the air in a closed space must be replaced by fresh air periodically in decided proportion to facilitate comfort. This principle is used mainly in long distance railways' air conditioned coaches of the higher classes. Air motion refers to the direction, velocity and turbulence of motion of air in the air conditioned space. Desirable conditions for comfort would be a mild breeze of air with slight turbulence in oblique direction to cover maximum area. These are certain design consideration factors that govern comfort air conditioning. The further sections shall consider two cases wherein design considerations have been mentioned for an air conditioned automated manufacturing space and for an air conditioned office area with computer systems.

## 5. DESIGN CONSIDERATIONS FOR COMFORT CONDITIONS IN AUTOMATED MANUFACTURING SPACE

An automated manufacturing space is one in which, there are certain number of automatic machines, required tooling, inspection equipment and an operator. Considering a closed space with one CNC Turning Centre with a main spindle capacity of say 15 kW, 300 mm diameter chuck and 6 station turret basic specifications, a closed space of 5 m X 5 m X 5 m, total dead load of other metallic and non-metallic items of around 50 kg other than the dead load of the machine and an operator of normal built, the following study can be undertaken.

Since it is an automated machine, it's use can be economical only when run at full load for the specified durations as the case may be. While designing an air conditioned space for this scenario, the factors that need attention is the heat generated by the machine during operation, heat emitted by the operators body, specific heat of the dead load other than the machine dead load, Conductivity of the metallic components and effective convective heat transfer coefficient for the closed space.

The heat generated by the machine is continuous due to continuous input of electric current. This is a major contributor to the heat that needs to be extracted from the system. The dead load has a tendency to absorb heat on account of the presence of a thermal gradient. The specific heat of the materials plays an important role to determine the critical materials that can cause entrapment of heat. As the operator is a human being, the body liberates heat at an average rate of 25 W to 30 W. These values can aid inputs to the cooling requirements. Assuming the value of Coefficient of performance of the system as specified, the net input work to the air conditioner compressor can be calculated. This addresses only the cooling requirements. To address the comfort, the quality of air needs to be studied for its relative humidity, quality and variations in the convective heat transfer coefficient over a period of time and its relation with the air quality. On accurate consideration of all these factors, an air conditioned space can be designed that may provide the desired comfort. The last variable that needs to be considered in this regards is the changing requirement of the operators with change in seasons, health, psychology and so on. These factors are not accurately measurable and require the aid of correlations.

## 6. DESIGN CONSIDERATIONS FOR COMFORT CONDITIONS IN OFFICE WORKING SPACE

An office working space mainly comprises computer systems, furniture and occupants. The computer systems consume electrical energy and generate heat which is liberated to the working space by the convection fans attached to the mother boards of the systems. This heat, if considered locally, can be insignificant but the collective effect does cause increase in thermal load on the air conditioner. During working hours, another thermal load is that of the mobile phones and their chargers which contribute a minor share of the overall load. In the previous consideration of design of air conditioning systems for an automated manufacturing space, only one operator was considered but in this case, the collective heat generated and liberated by a number of occupants needs to be considered. In this case, approximations may not yield accurate results and it is required to experimentally determine the thermal load due to presence of the occupants. Additionally, during the early hours of the morning, certain employees carry lunch boxes with food at a temperature higher than that of office ambient temperature which can add to the thermal load. The furniture acts as the dead load that tends to absorb heat and disturb the thermal equilibrium thereby. Thus while designing, all these factors need to be considered in accurate proportions to facilitate and arrive at the desired comfort.

## 7. COMMERCIAL ASPECT OF DESIGN OF AIR CONDITIONING SYSTEM CONSIDERING COMFORT CONDITIONS

The commercial aspect of designing the air conditioning system with comfort has a special market implication. The product can gain sufficient dominance over competitive products. This can be evidently seen as there are new features added to air conditioners of various brands as observed on various media. Commercially speaking, addition of every new feature calls for additional investment and this increases the overall cost of the product. This has led to further development of the product to add cost competitiveness and reduce the unnecessary costs. Thus if a market is created for customized products, there can be substantial business growth. In this context, the comfort provided by the product to the user acts as a positive catalyst in growth of business as the delighted customer tends to propagate and publish the effectiveness of the product. This clearly indicates that the need of the air conditioning market in the present trend is an air conditioner that is cost effective and that which can provide the desired comfort to the user.

## 8. CONCLUSION

Thus it can be concluded that, comfort air conditioning can be effectively implemented by designing the air conditioning systems considering various factors like effective temperature, rate of heat transfer of occupants, rate of loss of moisture, air quality and certain psychological factors like humidity or moisture content in the air and recirculation of air. The design depends upon variable factors that cannot be fixed and require flexibility to accommodate the choice and preferences of the occupants. The commercial aspect also highlights importance of considering human comfort while designing with the intention of business growth. Thus the comfort factor can indeed contribute towards comfort of the occupant and lead to commercial growth of the manufacturer too.

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