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Unitary Air Conditioning

D. DASTAGIRI[1], **D.BHARATH KUMAR REDDY**[2], **M. SIVA KUMAR**[3], **SM. GIRISH KUMAR**[4]
Dept of Mechanical Engineering, Dr. KVSRIT, Kurnool, Andhra Pradesh, India.

Abstract: Unitary packaged rooftop HVAC units provide heating and cooling for more than 40% of commercial building space. While unit efficiency has advanced dramatically over the past 30 years, analysis of high-efficiency unit market share shows that progress is slowing. Incremental increases in EER and SEER are shrinking, while the investment in physical materials needed to achieve coil efficiency improvements are becoming more expensive. In addition to base efficiency, a variety of items and dynamic effects like field installation, outside air economizers, control configuration, fan energy during ventilation, and cycle effects impact efficiency. Studies have shown problems in these areas and their negative and positive impacts are not reflected in EER, HSPF and SEER testing. An advanced rooftop unit has been prototyped that includes energy-saving technologies beyond steady-state efficiency. Efficient technologies include variable speed fans, demand controlled ventilation, premium economizers, evaporative assist for condenser cooling, ventilation lockout during warm up, and a quality assurance installation. Proper application of these measures can save 30% to 48% of HVAC energy use, depending on region.

Keywords: IDOAS, Air Conditioning, HVAC.

I. INTRODUCTION

Throughout the United States, more than 40% of commercial building space is served by unitary packaged rooftop HVAC units, representing about one quad of annual energy use (TIAX 2003). Most of these units are small packaged rooftop units with single-stage direct expansion cooling. Two-thirds of units are in the 3- to 5-ton cooling range, with only 15% of units larger than 10-tons (Jacobs et al. 2003). If we are to achieve significant energy savings in new and retrofit commercial HVAC, we will have to move beyond steady-state efficiency improvements and capture other methods of savings such as evaporative pre-cooling and comprehensive ventilation control enhancements. Packaged units have been found to have significant operational problems, with a cross section of studies showing a high percentage of problems (Cowan 2004). This indicates a need for better installation and commissioning as well as development of more robust equipment. There is also an opportunity to save significant energy by improving controls and in-field performance. Ideally, an efficiency organization would set in-field efficiency targets that captured equipment and installation attributes that would support the HVAC industry in delivering true infield performance. Establishing a laboratory rating procedure that recognizes the efficiency potential of non-steady-state technologies would be a rational first step and is the focus of this paper. This paper reviews the history of steady-state efficiency improvements, reviews problems found with rooftop units in the field, and demonstrates that a large potential savings exists beyond steady-state efficiency improvement. The authors conclude by echoing a call from other quarters to develop a total efficiency lab testing method that will capture efficiency improvements from a broad range of measures (Jacobs et al. 2003; Kavanaugh 2002).

A. Dedicated Outdoor Air Systems

One approach to addressing the conditioning and dehumidification issues associated with outdoor ventilation air is use of dedicated outdoor air systems (DOAS) [References 1, 2]. In a system using DOAS, shown in Fig.1 below, the outdoor air is conditioned separately from air which is recirculate from the building space. A separate cooling unit draws in the required outdoor air flow and cools and dehumidifies it. Supply air for these units is generally at the space temperature and at a humidity level slightly lower than the space humidity. The remaining space load is served with 100% recirculating air-conditioning units or fan-coil units. This system approach has the following benefits.

- The outdoor-air-only units can more accurately deliver ASHRAE 62 required ventilation air flow.
- There are significant seasonal energy savings from capacity modulation and VAV for the recirculating units.
- The concentrated humidity loads in the outdoor air can be handled directly, more effectively, and more efficiently. By incorporating reheat into the outdoor air unit, this unit can deliver the correct amount of sensible and latent cooling required to condition the outdoor air.

In many cases, additional suppression of conditioned outdoor air humidity levels allows the outdoor unit to completely handle the space latent load, thus allowing recirculating-air units to control simply for space dry bulb temperature. Efficient means for provision of dehumidification can be built into the outdoor air unit (runaround coils, heat pipe precool and reheat, hot liquid reheat, total energy recovery, etc.), and the recirculating-air units can condition the space with elevated chilled water temperature or evaporator temperature, since they do not need to provide dehumidification.

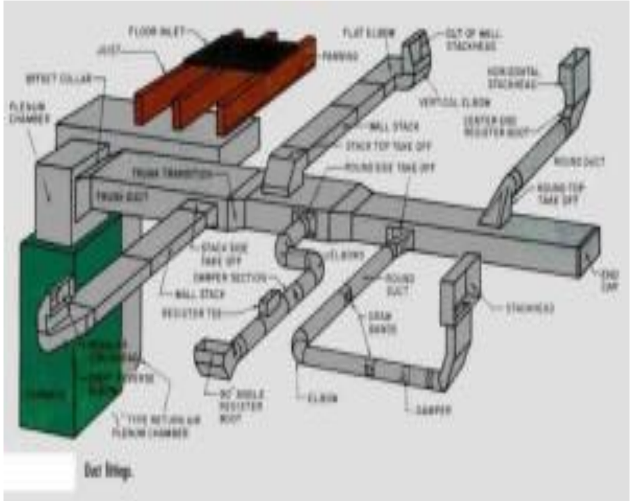

Fig.1. Dedicated Outdoor Air Systems.

B. Integrated Dedicated Outdoor Air System

The integrated dedicated outdoor air system (IDOAS) approach is based on the same approach used by systems using a DOAS unit to separately condition outdoor air. In the IDOAS concept, the separate units serving the outdoor air and the recalculated air are combined into a single package, as shown in Fig.2 below. Separate evaporators serve the two separate air streams: outdoor air to provide required ventilation and return air from the conditioned space. Separate blowers serve these air streams as well.

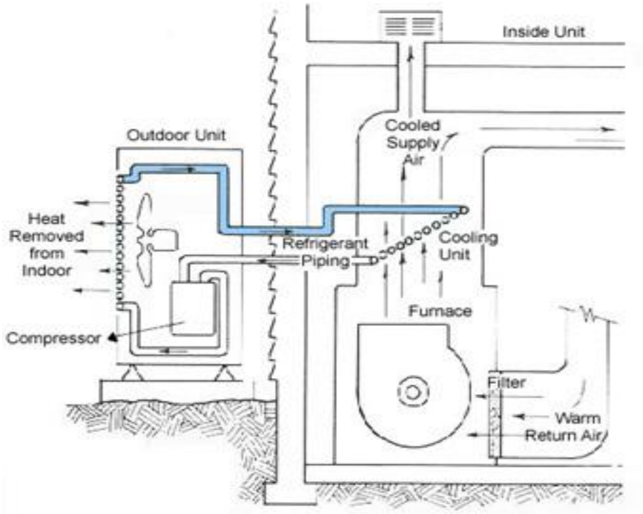

Fig.2. Integrated Dedicated Outdoor Air System.

II. HISTORY OF AIR CONDITIONING

Leonardo da Vinci had built a ventilating fan by the end of 1500 A.D. The first text on heating and ventilation was written by Robertson Buchanan, a Civil Engineer in 1815. Fans, boilers and radiators are invented by the end of 1900 A.D. Refrigeration technology was soon on the rise. In 1853, Professor Alexander Twinning of New Heaven produced 725kg. Of ice a day using a double acting vacuum and compressor pump, employing the 1834 invention of the vapor compression cycle by Jacob Perkins. He used sulphuric either as the refrigerant. A.R. Wolff who designed air-conditioning systems for as many as hundred building during his life-time. But it is W.H. Carrier (1876-1950) who is known as the 'Father of Air-conditioning'. While working with Buffalo Forge Co., he developed formulae for optimizing the application of forced-draft fans, developed ratings of pipe boiled heaters and set up a research laboratory. He engineered and installed the first year sound air-conditioning system, providing for the four major functions of heating, costing humidifying and dehumidifying. He made use of air washers for controlling the dew point of air by heating or chilling recalculated water. In 1911, carrier presented his remarkable paper 'Relational Psychometric Formulae in an ASME meeting. The paper related the dry bulb, wet bulb and dew point temperature of air with its sensible, latent and total heats, and presented theory of adiabatic saturation. These formulae, together with the accompanying psychometric chart, laid the subject of air conditioning on a complete thermodynamic basis. Carriers also employed the centrifugal compressor for refrigeration in 1922.

Air conditioning application engineering is as much an art as it is a science. Science has evaluated all the factors required to determine a heating or cooling load through years of experimentation, tests, and analysis. It is the application of these factors in determining the building or space load that much care and judgment must be exercised. It is the purpose of the manual to provide data and procedures for the load calculations for the summer and winter air conditioning in small commercial and public assembly applications. The intent is primarily for the summer, winter, and year-round conditioning systems employing unitary equipment (package or split system, including heat pumps) of all types installed in commercial buildings. This manual does not apply to large buildings employing central systems using built up or central station equipment for air conditioning purposes. For applications where life, safety, or specific processes depend on maintaining specified indoor design conditions, a consulting engineer component in the particular application should be employed. For heating load calculations, it is sufficient to calculate the heat transmission through the various elements of the building without regard to orientation. In order to perform an accurate estimate of heating and cooling loads and accurate survey of the load components of the space to be conditioned must be made. When all the factors entering into a cooling load calculation are considered and the judgment involved in these considerations is recognized, it can readily be seen that air conditioning application engineering is an art as well as a science. Constant study, diligent application, good judgment, and analysis are required to become an expert.

III. HUMAN COMFORT

The main purpose of most air conditioning systems is to provide an acceptable thermal environment for human beings. For the design and operation of such systems and for the thermal design of buildings, it is essential to quantify and specify these requirements for acceptable thermal environments. We can define thermal comfort as: “The state of mind which expresses satisfaction with the thermal environment”. This condition arises when a person feels thermally neutral and does not know whether he/she would prefer a higher or lower prefer a higher or lower ambient temperature. Thermal comfort does not necessarily mean the production of a relaxed environment – it is concerned with establishing an environment which is best suited to the special needs of the people occupying theatre. The consideration of thermal comfort levels must therefore take into account:

- The environment
- Clothing, including protective clothing worn
- Individual sensitivity to the environment
- Climatic needs in relation to the particular activity engaged in.
- In practical engineering terms, the question of thermal comfort can be reduced to an energy balance equation relating personal factors, such as:
- Activity level
- Thermal insulation of clothing.

And environmental parameters, such as:

- Air temperature
- Mean radiant temperature
- Air velocity
- Relative humidity

The interpretation of thermal comfort should not only take into account the quantitative environmental data but also the special characteristics of the people exposed to that particular environment such as sex, age, health etc. In this chapter, we will consider the quantitative and some of the qualitative aspects of thermal comfort.

A. Effective Temperature

Effective temperature is the dry bulb temperature of a uniform enclosure with a relative humidity 50% and an air velocity less than 0.2 ms-1, in which the occupants have the same heat exchange by radiation, convection and evaporation as in the actual environment. The effective temperature combines the effect of dry bulb temperature and relative humidity with air movement to produce sensations of warmth or cold equal to those in the actual environment.

B. Comfort Standards

Studies of the conditions that effect human comfort have led to the development of recommended in-door air conditions for comfort, published in ASHRAE standard 55-1992, Thermal Environmental conditions for human occupancy. Some of the results of these studies are shown in figure. The shaded regions in figure are called the comfort zones. They show the regions of air temperature and relative humidity where at least 80% of the occupants will find the environment comfortable. Note that there are separate zones for winter and summer, with a slight overlap.

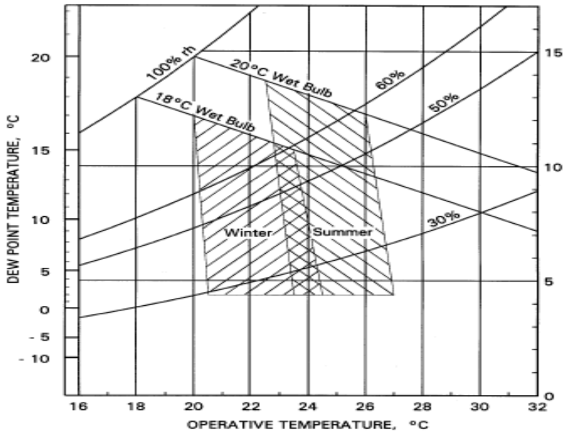

Fig. 3. Comfort zones Chart.

Fig3 shows the comfort zones of indoor air temperature and relative humidity. These zones apply to persons clothed in typical summer or winter clothing engaged in sedentary activity.

IV. CLIMATIC CONDITIONS

These summaries include values of dry-bulb, wet-bulb and dew point temperature and wind speed with direction at various frequencies of occurrence. This information is commonly used for design, sizing, distribution, installation, and marketing of heating, ventilating, air-conditioning, and dehumidification equipment; as well as for other energy-related processes in residential, agricultural, commercial, and industrial applications. Sources of other information such as degree-days and typical weather years for energy calculations are also described. The design conditions in this chapter are provided for those locations for which long-term hourly observations were available (at least 12 years of data). Consequently, many U.S. locations listed in previous versions (1993 and before) of this chapter are no longer listed because they lacked long-term data. The number of Canadian and international locations has increased significantly. Warm-season temperature and humidity conditions correspond to annual percentile values of 0.4, 1.0, and 2.0. Cold-season conditions are based on annual percentiles of 99.6 and 99.0. The use of annual percentiles to define the design conditions ensures that they represent the same probability of occurrence anywhere, regardless of the seasonal distribution of extreme temperature and humidity.

A. Climatic Design Conditions

Information on station location, period analyzed, heating design conditions, wind, mean annual extreme and standard deviation of minimum and maximum dry-bulb temperature, and mean daily temperature range is listed in Tables 1A, 2A, and 3A of ASHRAE hand book. Information on the design conditions for cooling and humidity control is provided in Tables 1B, 2B, and 3B. (ASHRAE HAND BOOK).

B. Weather and Design Condition

For climatic reasons, the application of air conditioning to office spaces in the UK in the post war period lagged behind that of the U.S. It was not the need for the calculation of cooling load, but with the need to calculate maximum temperatures in natural and mechanically ventilated buildings that the Admittance method was first developed. Unlike ASHRAE, whose methods were directed toward assuming a constant internal temperature, CIBSE primary aim was to demonstrate the role of internal mass in modifying room temperature. Another difference between the earlier U.S. calculation methods and the U. K. methods is that the dynamic model of the room fabric is integrated with a simplified zone convection and radiant heat transfer model. The room model is known as the environmental temperature model.

V. PSYCHROMETRICS

The atmospheric air that surrounds us is a mixture of dry air and water vapor, called moist air. Because this gas mixture is conditioned in environmental control systems, it is necessary to understand how it behaves. Psychometric is the name given to the study of air- water vapor mixture as shown in Fig.4. Hereafter, as conventionally done, we will use the word air to refer to the air-water vapor mixture that is the atmosphere.

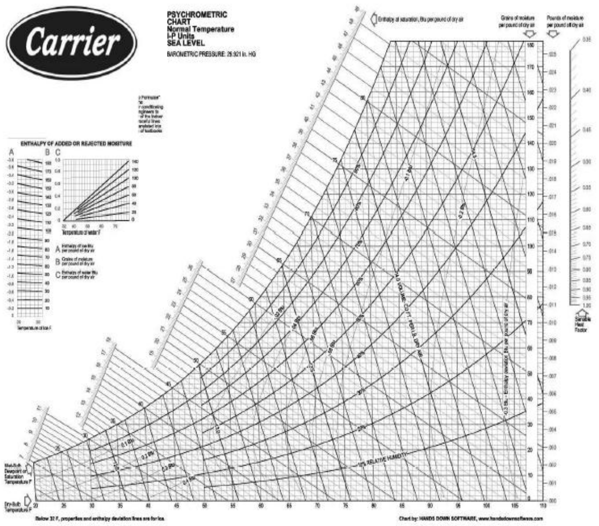

Fig.4.Psychometric Chart.

B. Dry Bulb & Wet Bulb Temperatures

Dry bulb temperature of the air is the temperature measured by an ordinary thermometer. When measuring the dry bulb temperature of air, the bulb should be shaded to reduce the effects of radiation. The wet bulb temperature of the air is the temperature registered by a thermometer whose bulb is covered by a wetted wick and exposed to a current of rapid moving air having a velocity of around 1500 fpm. A sling psychometric has dry and wet bulb thermometers. After saturating the wick with clean water, the instrument is whirled rapidly for approximately one minute, after which the readings can be taken from wet and dry bulb thermometers. Whereas as a dry bulb thermometer, being unaffected by humidity, measures only the actual temperatures of air, a wet bulb thermometer because of its wetted wick, is greatly influenced by the moisture content of the air, thus a wet bulb temperature is in effect a measure of the relationship between the dry bulb temperature and the moisture content of the air,lower is the wet bulb temperature.

VI. BUILDING SURVEY

A. Overview

This chapter is a first step in identifying the aims and objectives in this project by reviewing the latest research in design and analysis of HVAC systems. The previous researches show the findings of thermal comfort of the occupants based on the indoor and outdoor temperatures. The research findings show that there is a need to predict the comfort levels of the occupants in real time due to the complex heat flow patterns. This will be done by representing the actual site conditions and based on the real weather data to study the effect of environmental factors affecting the comfort levels checks will be made on the current environmental strategy to show it is feasible to maintain the comfort levels as specified in the ASHRAE standards.

B. Site Survey

An accurate survey of load components of the space to be air conditioned is a basic requirement for a realistic estimation of cooling and heating loads. The result and accuracy of this survey is the very foundation of the estimation, and its importance cannot be over-emphasized. Mechanical and architectural drawings, complete fields sketches and in some cases photographs, of important aspects are integral parts of a good survey. The following physical aspects must be considered.

VII. DUCT DESIGNING

The function of duct system is to transmit air from the air handling apparatus to the space to be conditioned. To fulfill this function in a practical manner, the system must be designed within the prescribed limits of available space, friction loss, velocity, sound level, heat and leakage losses and gains as shown in Fig.5.

Fig. 5. Duct designing.

A. Selection of Duct Size

Designing of ducts can be carried out on the software given by ASHRAE called as McQuay Duct sizer, by entering the required cfm calculated while performing heating/cooling calculations as shown below Fig.6.

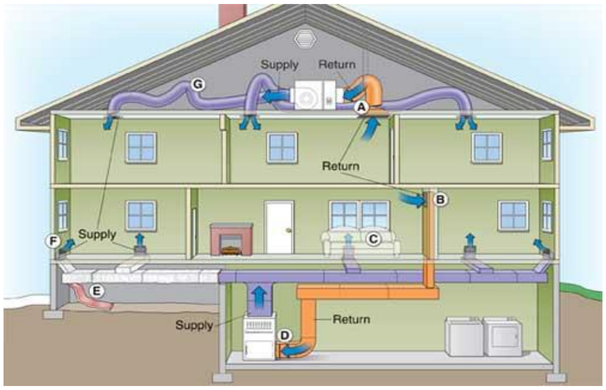

Fig.6. Roof top or Package Air conditioners.

VIII. CONCLUSION

In this project we have calculated total Ton of refrigeration required for a small room and as per the results obtained, fabricated a working air conditioner which has indoor unit and outdoor unit in a single chamber which is called a package unit. For one ton of AC the air flow required is 400 cfm, which is distributed using a ducting system using Bernoulli’s continuity theorem.

IX. REFERENCES

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Related Web Links:

- http://en.wikipedia.org/wiki/Hvac
- http://www.ashrae.org/.