A COMPUTER PROGRAM FOR ASSESSING THE HOURLY AND PEAK REFRIGERATION LOADS OF AN AIRCONDITIONING CONSTANT VOLUME FLOW PLANT

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DECLARATION

I declare that this project report is my own, unaided work. It is being submitted in partial fulfilment for the Degree of Master of Science in Engineering in the University of the Witwatersrand, Johannesburg.

It has not been submitted before for any degree or examination in any other University.

A J DA SILVA

12 th day of October 1987

SYNOPSIS

A program capable of determining the steady state refrigeration and heating loads of an airconditioning plant is presented. The program makes use of building load data from a heat program developed previously by the author. The peak design psychrometric analysis is suitable for any plant whilst the partial load analysis is suitable for a constant volume flowrate plant with a preheat and reheat control cycle. The program's function is to assist designers with system and equipment selections.

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1. INTRODUCTION

An air conditioning system is a system or arrangement of equipment used to achieve and maintain desired conditions of temperature, relative humidity and cleanliness of the air in a given space.

A program capable of predicting the steady state psychometric requirements of a constant volume flow air conditioning plant is presented. The program is of use to designers who design and specify air conditioning systems.

The specification and selection of an air conditioning system requires the analysis of many systems variables, the most important of which is the determination of a cooling load from which the plant's selection and operating parameters is determined.

The cooling load is comprised of two major components: a building sensible latent load component and a fresh air load component. The sum of the building and fresh air loads represents the plants refrigeration capacity. The estimation of these components are the most vital part in the design of an air conditioning system. Unless an accurate assessment is made, the system will not function correctly even if all other aspects of the design and application are correct. From the load estimate, the plant refrigeration capacity and air quantities are determined. Oversizing of these values can lead to a high degree of intermittent operation, which is inefficient and leads to high demands in power with a resulting increase in plant capital and running costs. The larger air volumes which will need to be circulated, combined with the intermittent plant operation, will make correct dehumidification of the space difficult. Undersizing of plant capacities will mean that the plant will not cope with the building loads, resulting in complaints from the occupants.

An accurate analysis of the load requirements, taking into account all the factors involved, will ensure the lowest plant capital and running costs. Such an analysis will indicate:

(i) the true cooling or heating requirements;

(ii) the possibilities for greatest load reduction at lowest cost;

(iii) the most economical equipment selection;

(iv) the most efficient air conditioning system;

and often results in considerable savings and therefore competitiveness against less accurate assessments which could be made by others.

A program capable of accurately estimating the first component of the load calculation, namely the buildings sensible and latent loads has been developed previously by the author and is used to generate the required data base for the simulation program.

Building loads are calculated by considering the :

(i) areas;

(ii) direction in which each wall faces;

(iii) shading of windows;

(iv) type and colour of the surface exposed to the sun;

(v) position of sun: varying with latitude, with the season and with the time of the day;

(vi) thermal lay of structures;

(vii) people, machines and light loads.

The building loads (see reference 4 and appendix 1 for more details) do not include the load resulting from outdoor air. Outdoor air constitutes the second major load component and must be introduced for ventilation of conditioned spaces. The amount required depends primarily on the number of occupants and on the materials and apparatus within the space that may give off odours.

The load resulting from outdoor air is cyclic for constant indoor design temperatures and is also proportional to the outdoor dry-bulb temperature at constant outdoor relative humidities. To obtain the peak plant refrigeration load due to building and outdoor air loads, it is necessary to sum the hourly values of both these loads and then select the maximum value. This is a time consuming and laborious computation which has to be repeated for the plant operating hours of each design month. The repetitious nature of the calculation and the probable need of a building designer or energy manager to perform several such calculations during the normal course of events, points strongly to the use of a digital computer as the ideal mechanism for such an analysis.

The potential advantages of using a computer-aided system are based on :

(i) the ease of use since the designer only requires a knowledge of the system under calculation;

(ii) an inherent increase in the speed of computation coupled with a reduced likelihood of errors;

(iii) the ability to optimize plant capacities, or benefits of modifications of coil bypass factors;

(iv) the convenience of storing design and calculation data within the program for retrieval when required;

(v) obtaining other data necessary for the design and selection of accessory equipment such as pumps, controls, heaters, fans and ducts.

(vi) give the designer a "feel" for the partial load characteristics of the plant, thereby assisting in the specification of plant controls to obtain satisfactory performance during partial load conditions.

As a first step in implementing the above advantages, program POET (Plant Optimization of Energy Transfer) has been developed to assess the operating parameters of a constant volume airconditioning plant for a particular control system. A total of eight air handling plants are allowed to serve a maximum of twelve building thermal zones.

The optimization of plant refrigeration loads can only be achieved by accurately determining the individual load components and by the selection of appropriate control systems. Since the plant will operate under partial-load conditions for most of the time it will be necessary to analyse these conditions. The most common methods of controlling space conditions at partial-load conditions are the following:

(i) reheat the supply air;

(ii) control the refrigeration capacity;

(iii) on-off control of the refrigeration machine;

(iv) on-off control of the air handling machine;

(v) control the supply air volume flowrate;

(vi) bypass the supply air around the heat transfer equipment.

The type of control for a specific application depends on the nature of the loads, the conditions to be maintained within the space, and the available plant facilities.

Program POET makes use of the control system (i) described above to determine the required design parameters for control at partial-load conditions. The supply air reheat system is commonly used where temperature and humidity parameters need to be accurately controlled within narrow limits as in process or microfilm storage rooms. Assumptions used in program POET to determine partial-load control conditions are as follows:

(i) the control system operates optimally to meet the required off-coil states;

(ii) a steam humidifier is provided and operates isothermally;

(iii) a pre-heater and re-heater are provided and operate optimally;

(iv) volume supply flowrate remains constant;

(v) outdoor air temperature varies at constant outdoor relative humidify;

(vi) outdoor ventilation volume flowrate remains constant;

(vii) coil bypass factor is a straight line function and remains constant;

(viii) refrigeration plant operates at 100% or 0% capacity.

Reheat control maintains the dry-bulb temperature within the space by replacing any decrease in the sensible loads by an artificial load. As the latent loads decrease the space relative humidity decreases and rehumidifying is required.

The analysis at partial-load conditions will also determine the capacities of the humidifier and heater banks.

The majority of airconditioning plants perform under conditions of partial load for the greater part of their life and therefore the analysis of the equipment under these conditions is important in the design and will provide an energy consumption envelope from which energy maximum demand and running costs may be calculated. This will assist designers with their life cycle cost analysis when comparing alternative systems.

Program POET thus constitutes an important step after the building load calculation in providing designers with information with respect to more accurate maximum refrigeration capacity and partial-load states and energy consumption. This is done for one type of plant and control system. It is therefore proposed that the program's scope of analysis be increased in future work to allow for other plant systems and control sequences; namely:

(i) variable mass flowrate plant with or without humidity control;

(ii) constant mass flowrate with zone reheat with or without humidity control.

(iii) step refrigeration control with minimum refrigeration capacity control limits.

(iv) all the above with outdoor economy control.

The program is structured to facilitate the addition of subroutines which will be necessary to incorporate the above additions.

This report is structured to initially familiarize laymen with the airconditioning process and the program's data requirements. The Appendices provide more detailed information on the program's structure for those who wish to make use of the subroutines for other work.

2. AIRCONDITIONING SYSTEM DESCRIPTION

The operation of a constant volume air conditioning system for comfort conditioning is generally as follows:

(i) Air from the conditioned space is drawn into the equipment and mixed with a proportion of fresh air as required. Mixing of fresh air and return air is carried out for reasons of economy, since the return air will generally be closer to the required supply air conditions than fresh air, and so demand less treatment. The mixing is effected by dampers in the fresh and return air streams, which are either fixed (giving a predetermined mixture) or automatically controlled (giving a mixed air temperature to suit the space conditions).

(ii) The mixed air passes through filters which remove particles of dirt and dust.

(iii) The air then passes through a cooling coil which cools the air and extracts moisture from it. Cold fluid (refrigerant or water) passes through the pipes and where dehumidification is also required, this cooling is taken to a temperature below the dewpoint of the air so that condensation takes place. The moisture is then drained off.

A heater battery or hot water coil is used for heating.

(iv) Finally the air passes through the circulating fan and is returned to the conditioned space.

In addition it may be necessary to have a system of ducting and diffusers to convey the air to the conditioned space, and to ensure that distribution within the space takes place in the correct manner. Figure 2.1 depicts a simple system operating on these lines.

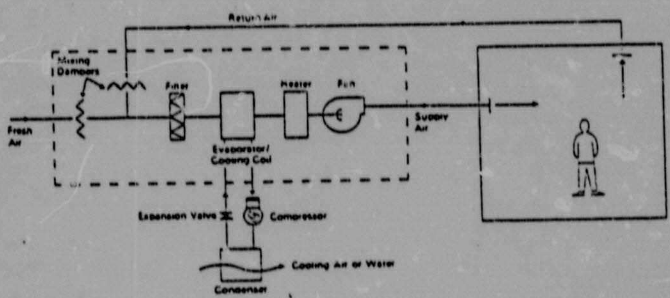

Figure 2.1 Simple single zone air conditioning system.

All air conditioning processes can be represented on a psychrometric chart by combinations of four processes and mixing. The four basic processes - sensible heating, sensible cooling, moisture addition and moisture subtraction - are represented as shown in Figure 2.2 taking A as the starting condition of the air.

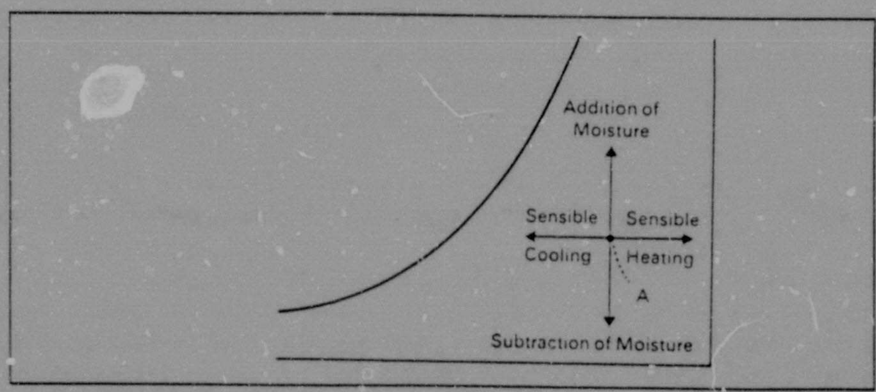

Figure 2.2 The four basic air conditioning processes.

The cooling cycle for the system shown in Figure 2.1 can be represented as shown in Figure 2.3.

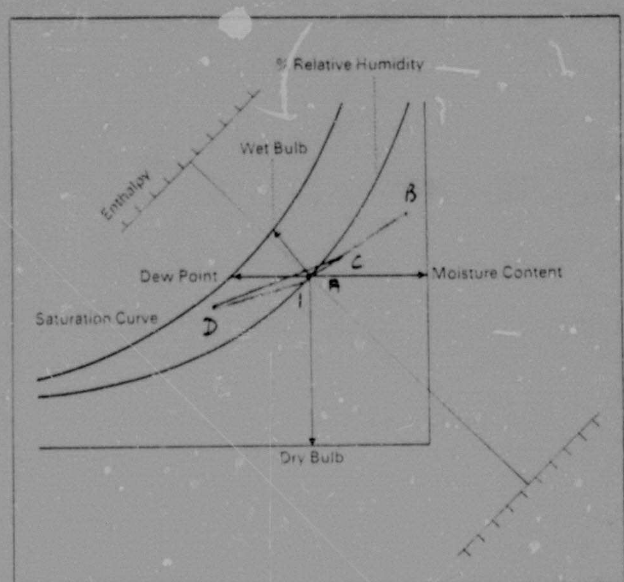

Figure 2.3 Psychrometric presentation of Figures 2.1 cooling cycle.

Outdoor air represented on the psychrometric chart at point B is mixed with return air at state A resulting in a mixture at state C. The mixture is then passed through the apparatus where it is cooled and dehumidified (point D) before entering the room. The air supplied to the room absorbs the sensible and latent heat gains to the room (represented by line DA).