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SIMPLIFIED ENERGY ANALYSIS USING THE MODIFIED BIN METHOD

Prepared for the
American Society of Heating, Refrigerating, and Air-Conditioning Engineers

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If users of this report discover errors or have suggestions, we ask that they be brought to the attention of TC 4.7 Energy Calculation Committee of ASHRAE.

David E. Knebel
Principal Investigator

Table Of Contents

	Page
Acknowledgements	ii
Table of Contents	iii
List of Figures	viii
List of Tables	xii
References	xiv

Chapter I - Introduction

A)	The need for energy analysis	1-1
B)	Energy analysis methods and tools	1-2
	1) Manual methods	1-2
	2) Comprehensiive computer programs	1-5
C)	The need for a comprehensive yet simplified method	1-5
D)	Factors affecting building energy usage	1-6
	1) Building data	1-6
	2) Climatic data	1-7
	3) Indoor load data	1-7
	4) HVAC system and equipment data	1-7
E)	General energy estimating procedures	1-7
	Step 1. Load calculations	1-9
	Step 2. Secondary system simulation	1-10
	Step 3. Primary system simulation	1-11
F)	Overview of the modified bin method	1-11
G)	Limitations on the simplified energy analysis method	1-16

Page

Chapter II - Review of Design Load Calculation

A) Design outdoor and indoor weather conditions 2-1

B) Design heating load 2-2

1) Transmission losses 2-2
2) Infiltration or ventilation losses 2-2
3) Other losses 2-3

C) Design cooling load 2-3

1) Solar heat gain through fenestrations 2-4
2) Transmission gains 2-6
3) Interior light gains 2-7
4) Other interior appliance gains 2-9
5) Gains from people 2-9
6) Infiltration or ventilation gains 2-10

Chapter III - Diversified Load Calculation

A) Zone selection 3-2

B) Solar load through glass 3-3

1) Summer 3-4
2) Winter 3-5
3) Generating the solar load profile 3-6
4) Effect of external shading 3-7

C) Transmission load 3-11

1) Glass 3-11
2) Opaque surfaces 3-11

D) Interior loads 3-14

E) Infiltration and ventilation 3-16

Page

F) Total diversified building loads 3-17

G) Example problem 3-19

H) Balance point temperatures 3-33

Chapter IV - Air System Component Analysis

Introduction 4-1

A) Heating coils 4-2

1) Fixed set point 4-3
2) Outside air reset 4-5
3) Zone controlled reset 4-5
4) Wild coil 4-8

B) Cooling coils 4-9

C) Fans 4-15

D) Mixing boxes 4-19

1) Outside air mixing and control 4-22
2) Mixing boxes for zone dampers in dual duct systems 4-24

E) Direct expansion condensing units 4-24

Chapter V - Air System Simulation

Introduction 5-1

A) System descriptions 5-1

1) Terminal reheat system 5-1
2) Multizone/dual duct system 5-2
3) Variable air volume system 5-2
4) Three deck multizone system 5-2
5) Dual fan/dual duct system 5-3

		Page
B)	Simulation methodology	5-4
C)	Sample problem data	5-16
D)	Reheat system computational procedure	5-16
E)	Dual duct multizone computational procedure	5-12
F)	Variable air volume computational procedure	5-18
G)	Three deck multizone computational procedure	5-24
H)	Dual fan/dual duct computational procedure	5-30
I)	Checking results	5-40
J)	System simulations under part load heating	5-42
K)	Checking results	5-50
L)	Modification to RAW to account for infiltration latent loads	5-51

Chapter VI - Plant Component Simulation

	Introduction	6-1
A)	Use of performance correction curves	6-1
B)	Boilers	6-4
C)	Pumps	6-7
D)	Cooling towers	6-8
E)	Compression chillers	6-10
F)	Modeling false loading and cycling of chillers	6-14
G)	Double bundle chillers	6-16

Page

Chapter VII - Bin Weather Data

Appendix A - Description Of Example Building

1) Building type and location A-1
2) Building data A-1
3) Operating data A-3
4) Outdoor design conditions A-5
5) HVAC system and plant data A-5

Appendix B - Design Load Estimates

Appendix C - System Sizing

A) Terminal reheat system C-4
B) Dual duct and three deck multizone systems C-8
C) Variable air volume system C-14
D) Dual fan/dual duct system C-18

Appendix D - Plant Sizing and Performance

A) Chiller performance D-3
B) Cooling tower performance D-4
C) Boiler performance D-4
D) Pump performance D-4

Appendix E Sample Calculations - Reheat System E-1

Appendix F Sample Calculations - Dual Duct Multizone System F-1

Appendix G Sample Calculations - Variable Air Volume System G-1

Appendix H Sample Calculations - Three Deck Multizone System H-1

Appendix I Sample Calculations - Dual Fan/Dual Duct System I-1

Appendix J Summary Of Results - Appendices E - I J-1

Appendix K Simulation Of Modified Control Strategies K-1

Chapter I
Introduction

A. The Need for Energy Analysis

Energy analysis plays an important role in developing an optimum HVAC and architectural design for new buildings and in determining cost effective modifications to existing buildings. In new buildings, it is important that the energy analysis process be implemented for individual design decisions early in the design process. Maximum benefit will be obtained if proper optimization techniques are applied at each step of the evolution from concept to working drawings. In existing buildings a comprehensive energy analysis is the basis for making rational decisions on cost effective building alterations and system modifications. A large number of separate analyses are necessary to adequately analyze the economic benefits of various energy conserving modifications.

As the need for making accurate energy utilization decisions has become more and more important, many standards and codes have been adopted which require energy analysis procedures to demonstrate compliance. An example of this type of standard is ASHRAE 90. Standard 90 is basically of a prescriptive nature, and requires the use of energy analysis to show compliance if all the prescriptive requirements are not met.

The ASHRAE TC 4.7 has been largely responsible for the development of comprehensive hourly simulation algorithms to determine accurate heating and cooling requirements and simulate performance of heating and cooling systems/equipment [6,16]. Numerous building energy calculation procedures have emerged since the late 1960's encompassing methods from simple degree day procedures to comprehensive and computerized procedures which simulate building heat transfer and system/equipment performance on a minute by minute basis. Although these programs are considered very comprehensive and accurate, they are not readily accessible to practicing engineers because of their complexity, cost, and difficulties in usage. A simplified procedure, which is transparent to users and whose calculation procedures are familiar to practicing engineers is needed; at least for the pre-planning analysis where most engineering hours are spent.

The purpose of this text is to present a brief background of existing energy analysis procedures and to provide the mathematical foundation for understanding and implementing a simplified energy analysis procedure. The methodology has been in development and evaluation by ASHRAE committee TC4.7 since 1975. Results of preliminary evaluations have shown that the methodology provides good correlation with hourly simulation procedures[14].

B. Energy Analysis Methods and Tools

There are a variety of energy analysis procedures presently available. Each of the procedures has its strengths and weaknesses. In selecting the procedure to be used for a specific project, it is important that the limitations of the procedure be recognized. The available procedures are divided into two categories - those that can be implemented manually and those that require the use of computers. Between these two categories are procedures that can be implemented manually, but have fairly extensive computational requirements and may be more convenient to implement on computers. A brief discussion of the more commonly available procedures is given below.

1. Manual Methods

a. Degree Day Procedure

The traditional degree day procedure [1] for estimating heating energy requirements is based on the assumption that, on a long term average, solar and internal gains will offset heat loss when the mean daily outdoor temperature is 65 F, and that energy consumption will be proportional to the difference between the mean daily temperature and 65 F. As an example, on a day when the mean temperature is 20 F degrees below 65 F, twice as much fuel is consumed as on days when the mean temperature is 10 F degrees below 65 F.

The applicability of this procedure is limited to residential buildings, where the envelope transmission and infiltration are the dominating factors contributing to the building load. In commercial

buildings with highly varying internal loads, sophisticated control systems, complex air systems or plant arrangements, the degree day method is totally inadequate.

The 65 F base which was established on the basis of studies made by the American Gas Association and the National District Heating Association, has been modified due to several factors. Residential envelope insulation levels and internal loads have increased significantly, infiltration rates have decreased through tighter construction practices, and occupants have lowered indoor temperature settings in efforts to reduce energy consumption. Consequently, use of the 65 F base results in a significant over-estimation of the heating energy requirements. To increase the accuracy of the degree day procedure, ASHRAE has introduced a correction factor [1]. Even then, the fixed base degree day method can, at best, be considered to provide only a rough estimate of residential heating requirements.

Recent research at NBS [2] shows that the use of a variable- base/two- base degree day method for residential buildings yields results that compare well with those obtained by using the DOE-2 computer program. However, the improved procedure is still not applicable for commercial buildings, and has limited capabilities for analyzing time dependent energy consumption factors which are not included in design load calculations.

b. Equivalent Full Load Hours

The equivalent full load hour procedure considers only the cooling loads of buildings. It consists of using an estimate, based on local experience of the ratio of annual cooling energy requirements to rated capacity of the cooling equipment. Equivalent full load hour data for various locations in the U.S. is available [1,3,4].

This procedure ignores all operational aspects effects of the particular systems serving the building

which heavily influence energy usage in commercial buildings. Although this procedure may provide results that are statistically meaningful, it provides only crude estimates of the energy usage for individual buildings.

c. Basic Bin Method

The basic bin method [1] consists of performing an instantaneous energy calculation at many different outdoor dry bulb temperature conditions, and multiplying the results by the number of hours of occurence of each condition. This procedure can account for the part load performance of HVAC equipment and has been specifically used for analysis of heat pump systems. Additionally, by performing separate calculations for different time periods,variations of indoor loads with time and operating schedules of HVAC systems can be considered.

The envelope loads at the mid-point of each of the temperature bins can be obtained by linear interpolation between the design heating and cooling envelope loads. Refinements to the procedure include separate consideration of indoor loads and the use of coincident wet bulb temperatures to calculate the latent loads at each temperature bin.

The principal drawback of this procedure is the interpolation between end points corresponding to the summer and winter design envelope loads. The summer loads are based on the design hour and do not account for the variation in the transmission and solar loads which, on the average, are much lower than the design hour values. These loads could be further reduced by cloud cover and other effects. Conversely the winter design envelope loads ignore solar effects which could significantly reduce the total losses through the envelope.

Because of these limitations, the standard bin method has limited applicability in estimating building energy usage, particularly for commercial buildings. The procedure developed in this manual is a

refinement of the standard bin method and addresses the questions of time dependent and solar loads.

2. Comprehensive Computer Programs

Numerous comprehensive building energy analysis computer programs that perform hourly calculations have been developed. These programs model the hourly envelope heat transfer process as well as the detailed HVAC system and equipment simulations to estimate the building energy usage.

These programs can be very useful and provide reliable results, however they face several barriers to widespread usage. They require a mainframe computer with large memory and high speed. The cost of leasing these programs can be high. Additionally, special training in the use of particular programs due to their complexity, and access to a computer terminal are required. Therefore, the average consulting engineering firm may not have the resources or the volume of projects to justify their use.

In addition, because of the complexity of the algorithms, average practicing engineers find it difficult to asses the accuracy or credibility of the results obtained. The services of specially trained energy consultants are often needed to make use of these programs. Very few of these hourly simulation programs are currently available on microcomputers.

C. The Need For A Comprehensive Yet Simplified Method

With the increased use of building energy analysis, a need exists for a more middle-of-the-road approach . Manual methods and procedures are not sufficiently comprehensive to account for the various factors affecting the energy usage of buildings. On the other hand, the comprehensive computerized procedures are complex, time consuming, and may not be necessary for every analysis. Thus, there is a definite need for a procedure that is simple enough for a manual application and which accounts for the significant parameters affecting the energy usage of buildings. The procedure discussed in this manual has been developed to fill this need.