the user able to select the algorithm appropriate to the application. This would enable the experienced user to achieve the best performance from the model, by varying computation speed and solution accuracy.

Versions/listing date of models cited & acknowledgement

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Computerized Decision-aids for Warehouses and Light Industrial Buildings

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KEY WORDS

Building Data Base, Energy Analysis, Light Industrial Buildings, Shipping Doors, Software, Warehouses.

ABSTRACT

Over the past four years the Building Engineering Group has conducted a program of R and D directed at energy conservation in warehouses and light industrial buildings (WLIBs). This structured program of research has largely been funded under the Buildings Energy Technology Transfer (BETT) Program administered by the Government of Canada. During the course of this work, the following computer-based packages were developed:

BEGEN - an energy-analysis procedure

dbBEG - a data base management system for storing information on surveyed buildings and a data base of WLIBs

BEGFIT - an energy-analysis procedure for the statistical interpretation of fuel records

BEGDOR - an energy-analysis procedure for industrial or shipping doors

BEGSCI - a thermal and vapour-pressure analysis procedure for enclosure elements

All the programs have been developed for use on a personal computer. They are separate but complementary software items, and three (BEGEN, BEGDOR and BEGSCI) are suitable for widespread use. We have also developed procedures for subgrade thermal analysis and passive solar analysis that run on a mainframe computer. Together with two readily available programs, these five programs provide an integrated set of aids for both design and analysis. It will be demonstrated that the needs of people doing research, the needs of the design profession, and the needs of contractors and equipment vendors can be met with a structured set of computerized decision-aids.

Les Décisions Automatisés pour les Entrepôts et les Bâtiments Industriels Légers

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MOTS-CLÉS

l'analyse de l'énergie, la base de données pour bûtiments, les bâtiments industriels légers, les entrepôts, les logiciels, les ports d'expédition

ABSTRAIT

Durant les quatre dernières années, le "Building Engineering Group" a conduit un programme de Recherche et de Développement au sujet de l'économie d'énergie dans les entrepôts et les bâtiments industriels légers. Ce programme structural de recherche a été subventionné en grande partie du "Programme de transfert de la technologie dans les bâtiments" (BETT), du gouvernement canadien fédéral.

Au cours de ce travail, ces paquets d'ordinateur-base ont été développé:

BEGEN - une procédure de l'analyse de l'énergie
dbBEG - une base de données des bâtiments inspectés
BEGFIT - une procédure de l'analyse de l'énergie expliquée par la statistique des régistres de comburant
BEGDOR - une procédure de l'analyse de l'énergie pour les portes industrielles ou les portes d'embarquement
BEGSCI - une procédure de l'analyse de la poussée thermale et vaporeuse pour les éléments enceints.

Tous les programmes ci-haut mentionnés ont été développé pour l'usage sur un ordinateur personnel. Ils sont distincts en eux-mêmes, mais complimentaires entre chacun d'eux, quatre desquels sont appropriés à acquérir et pour l'usage étendu. En outre de ces programmes, nous avons développé des procédures de l'analyse de sous-niveau thermatique et des procédures de l'analyse système-solaire passif pour un ordinateur principal et nous avons intégré nos besoins d'analyse avec des logiciels commercialement disponibles. Il sera démontré que les besoins de la Recherche et du Développement, les besoins du modèle professionnel et ceux de l'entrepreneur et du vendeur d'équipement peuvent être réalisé par la formation et l'amalgamation des ces décisions automisées.

INTRODUCTION

In late 1981 the Buildings Energy Technology Transfer (BETT) Program was initiated by the Department of Energy, Mines and Resources (EMR), Canada. The Building Engineering Group (BEG) was selected to act as lead agency for research, development and demonstration (R, D & D) in the warehousing and light industrial building (WLIB) category or sub-categories of building. The principal objectives were to:

- identify the potential for energy conservation in both new and existing WLIBs;
- determine R, D and D requirements and their priority;
- perform and/or expedite the necessary R, D and D;
- effectively transfer the necessary technology; and
- provide technological support to EMR in the development of policy and programs.

A common feature of many buildings in the warehouse and light industrial category is that they are relatively simple--in both structural and operational terms. There is usually only one storey; there are a minimum of windows; roofs are usually flat; there is no subgrade space; and both process and people loads are often thermally insignificant. Furthermore, WLIBs are weather sensitive, and service systems and operating schedules are usually relatively simple. Usually only a small portion of the building is used as office space and, in Canada, this is the only portion of the building that is likely to be air conditioned in summer.

The total floor area of buildings of this type is second only to that of residential buildings in Canada. There are well over one billion square feet of WLIBs in Canada. Although energy consumption per unit of floor area may be relatively low, there is considerable potential for conserving energy in buildings of this type [1].

In addition to the work conducted under the BETT program, BEG has also carried out several projects that have some relevance for energy-related building performance in WLIBs as well as other categories of buildings. Throughout all this work we sought to develop an integrated and complementary set of energy-analysis software packages. These computer programs were to be independent of each other, but all were to be applicable to warehouses and light industrial buildings. Initially, the objective was to identify computational needs and, where necessary, to develop suitable "standalone" software. If satisfactory energy-analysis programs already existed, then these would be used or modified to meet the particular requirements associated with warehouses and light industrial buildings. Over the past four years some five programs have been developed; together with two non-BEG programs (ENERPASS and TARP), a relatively comprehensive set of computational tools has been put together. These programs may be applied to either new or existing buildings. Fig. 1 identifies each program and its relationship to particular tasks and particular deliverables or products.

The intent of this brief paper is to discuss the five BEG-developed energy analysis programs: BEGEN, BEGFIT, dbBEG, BEGDOR and BEGSCI.

BEGEN [2][3]

BEGEN is a modified and extended version of the HOTCAN computer program. HOTCAN, produced by the National Research Council of Canada's Division of Building Research, is a user-friendly program designed to calculate the annual space-heating requirements of residential buildings. The BEGEN energy-analysis program extends HOTCAN to include warehouses and light industrial buildings. BEGEN is intended for use in modelling the monthly and yearly heating loads in single-zone buildings in which most of the energy is consumed for the purpose of space heating--as opposed to the operation of process equipment or cooling. The only theoretically significant extension of the HOTCAN procedure is the modelling of subgrade heat loss. The calculation of subgrade heat loss is based on recent research by Mitalas [4] of the National Research Council and by Wielhouwer and Burnett [5] of the Building Engineering Group. The methods used can accommodate several subgrade constructions, including slab on grade and insulated footings.

The BEGEN program is menu-driven and designed to be run on an IBM PC with at least 128K of memory. One disk drive and a monochrome display are sufficient. A printer is useful but not essential. The program is written in BASIC using the IBM DOS.

Input data forms have been developed. Printed output is quite extensive and detailed summaries of all the contributions to the space-heating energy balance are provided.

BEGEN has proved to be very useful, especially in the conduct of energy audits. A few contractors have attempted to use BEGEN as both an analytical and a marketing aid.

BEGFIT [6]

BEGFIT is a relatively sophisticated energy-analysis program. The program's principal object is to identify and, as accurately as possible, to quantify the various contributions to the space-heating energy balance for a specific building. The following criteria governed the development of this analysis procedure:

- analysis was to be driven by "knowns," i.e., billing data and climatic records;
- the relative accuracy of information (and the associated algorithms) was to be taken into account, i.e., consideration was to be given to both statistical and stochastic sensitivity; and
- the number of assumptions and approximations was to be kept to a minimum.

Accordingly, the program attempts statistically to match the calculated energy used to the actual energy consumed over a lengthy billing period (at least three years). Data are time-averaged to the billing period, and the program is driven by fuel billing records. An interactive series of regression analyses is carried out. In addition to modelling the usual contributions to heat gain and loss, an attempt has been made to model the influence of the movement and storage of goods.

The program can be run on an IBM PC or a mainframe. BEGFIT is not user friendly, nor is it easy to use. It is considered to be an in-house research tool rather than a practical aid for design and analysis.

dbBEG [7]

Because most commercially available data base packages are not well suited to storing building-related data, the software package, dbBEG, was developed. The initial objective was to provide a vehicle to store, in a compact and highly structured manner, all the physical data obtained from a performance audit of a WLIB. The amount of data collected for one building is extensive: information is recorded concerning ownership and operation, the enclosure, service systems and fuel billing records for at least three years. There is room for 200 buildings.

Since 1981 some 40 WLIBs have been surveyed. To date 22 of these buildings have been stored on dbBEG. This constitutes a very useful data base for two specific sub-categories of building. Energy-related data from this data base have been reported elsewhere.

Retrieval of data is relatively simple. A record size of 80 characters was chosen for the sake of convenience (the IBM PC screen is 80 characters wide). The data for each section were then fitted to this record size, the data being divided into two records per element where required. Each building file has 222 records, for a total of 17,792 bytes. A sufficient amount of unassigned memory is also provided to allow new data to be added as and when necessary. Data are manipulated by transferring relevant records to other commercially available software such as spreadsheets, statistical analysis and graphical packages.

BEGDOR [8]

BEGDOR was developed to aid in assessing the effects of industrial or shipping doors on the consumption of space-heating energy primarily in warehouses and light industrial buildings. Relatively simple algorithms are employed to calculate heat loss from transmission and infiltration due to both wind and stack effect. The program attempts to incorporate all the major influences on energy consumption, including climatic considerations and operating schedules for internal temperature and door operation. Door location (wind speed and direction), door condition (the presence of weather stripping, astragals or dock seals) and the presence of a truck are all taken into consideration.

The program may be used either as a tool for analysing existing shipping door installations or as a tool for use when designing new or retrofit installations. Parametric analysis is facilitated by the menu-driven nature of the program which readily permits the adjustment of one or more variables.

Written in the C programming language, BEGDOR requires an IBM PC or IBM PC-compatible equipment using MS DOS versions 2.0 or higher.

An input data sheet is provided. The output provides summaries of the heat loss over each month in the heating season, as well as an overall summary.

Input and output data can be printed out. Plotted output includes a velocity and directional windrose for the climatic zone in which the building is located.

BEGSCI [9]

BEGSCI is a user-friendly program designed to calculate thermal gradients and vapour-pressure gradients across the main elements of the building enclosure: above-grade walls, windows and roofs. Thermal and vapour-related properties of the enclosure element are computed and the heat-flow rate, vapour flow rates and the rate of condensate accumulation (if any) are determined. Extreme as well as intermediate climatic conditions for both summer and winter can be considered. The program is well suited to parametric analysis since mean as well as variable values for the various properties can be input. In addition, both vented and non-vented air spaces can be considered.

The program is primarily menu-driven. It is written in C for an IBM PC using MS DOS 2.0. An input data sheet is provided to help users assemble pertinent information and enter the data. Output may be printed and plotted.

The program is relatively simple because steady-state parallel heat flow and vapour diffusion are assumed. On its own the program is extremely useful as a basic design aid and has proved a valuable tool in courses on building science.

COMMENTARY

Collectively, the seven programs listed in Fig. 1 provide a comprehensive and useful aid for arriving at decisions regarding the energy-related performance of a building and its component parts. They have been used in the development of a computerized data base of warehouses and light industrial buildings and in the conduct of numerous energy audits and several R and D studies. Individually, the three programs, BEGEN, BEGDOR and BEGSCI, have proven their value in design and research and as demonstration or educational tools. Because of their portability and ease of use, they could also be used as a sales or marketing aid; BEGDOR is particularly well suited to the dual purpose of design and sales for both new and existing (i.e., retrofit) door installations.

As of March 1986, no serious attempt had been made to market BEGEN, BEGDOR or BEGSCI. One obstacle has been ownership (BEGEN was funded by the Federal Government); another has been lack of funding; and a third has been the nature of the trade-off between the costs and the benefits of marketing products of this sort.

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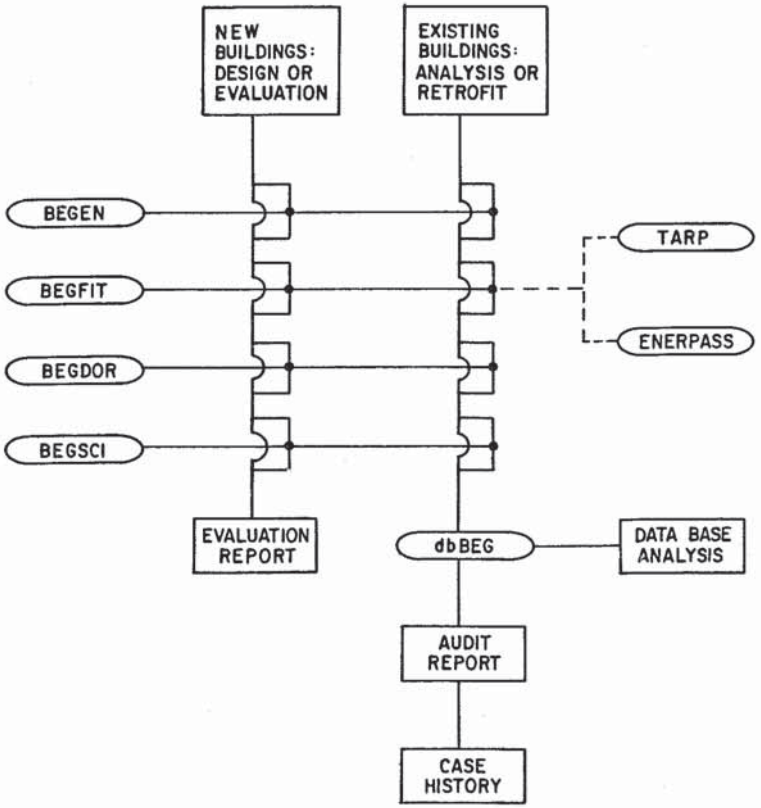

Fig. 1: ENERGY ANALYSIS PROCEDURES FOR WAREHOUSE AND LIGHT INDUSTRIAL BUILDINGS.

The Energy Performance of Buildings with Distributed Thermal Storage

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KEYWORDS

Building Energy Usage, Energy Conservation, Performance Analysis, Solar Energy, Storage Materials, and Thermal Storage.

ABSTRACT

The cost of comfort control in a building can be reduced by moderating its temperature swings with distributed thermal energy storage components. Various storage concepts involving either heat or cool storage have been evaluated and potentially cost effective designs for passive solar and energy efficient buildings have been identified. The analyses make use of finite difference methods to solve thermal network building models at short time intervals over a full year's simulation. Each thermal storage component concept is modeled parametrically so that a series of annual building simulations provides a basis for selecting an optimum storage component design. The focus is on new, solid-state, phase-change materials which, unlike previous phase-change materials, remain solid throughout the range of service temperatures. These materials are readily incorporated into concrete, gypsum board, wood products, etc. Results indicate that optimized, phase-change thermal storage components used in Trombe walls or as wall coverings in direct solar gain designs can provide greater energy savings than conventional masonry or wall-board. Low temperature phase-change components may be used to shift the demand for air conditioning power to off-peak periods, thereby reducing the cost of building cooling.