The Development of Nomograph Analyses into Mathematical Functions

ABSTRACT

This study was initiated to develop a quick, accurate evaluation of the energy usage of large commercial buildings. The available computer programs designed to facilitate such energy studies require more time, accuracy, and data than is necessary for a long-term energy conservation study. The thoroughness required of a comprehensive energy analysis, however, could not be sacrificed for the sake of an expedient solution.

A compromise solution was found in the series of nomographs produced in an exhaustive study by the Federal Programs Office of the U.S. Department of Energy. The report is entitled "Architects and Engineers Guide to Energy Conservation in Existing Buildings."

Applicable nomographs from this report were converted into mathematical functions. These, in turn were assimilated into a popular spreadsheet computer program to enable the user to access the functions via standard building parameters and usage/demand criteria. The result is an effective, user-friendly format easily understood and used by professionals in the field of energy conservation.

The end result of the nomograph equations produce data which match very closely the actual, metered energy usage data available. There is a strong confidence by users of this study that the immediate figures this arrangemnt provides are invaluable in any effort whose goal is to devise an analysis of a complex structure having diverse and varied energy sources and demands.

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ENERGY CONSERVATION ANALYSIS

William H. Clark II, P.E. Presented in May 1994 at the Building Systems Symposium, Dallas Texas

ABSTRACT

There are many building simulation programs on the market that calculate the annual energy use for a facility. These programs are difficult to use in energy conservation projects. The designer must run a complete simulation for each intended design or systems modification. This can be time consuming and expensive.

This report describes a program that performs an energy analysis in a way that is much more convenient for the energy analyst. Several common conservation projects are featured in the program: tinting glass, single-to-double pane conversion, adding roof insulation, savings from landscape features, external wall shading and reduction in outside air. Each of these are evaluated in a separate building load subroutine.

The program computes and displays the annual load profile for each of these components of the envelope. It can then calculate the exact savings possible, for example, by modifying south-facing window, or by planting fast-growing shade trees to the west of the building. This is to permit the user to focus limited funds on specific projects.

The analysis takes into account geographic location, ambient temperature and latitude. It also permits the user to modify these parameters to conform to unique local conditions. The software will rotate a building as well, to discern the effect on loads of a change in building orientation.

Another feature is the ability to separate the building load by specific elements. Each screen used to input glass, roof, wall or floor data also gives a reading on the load attributed to that particular element alone, (e.g. each individual wall, window or roof section) converted into annual energy use. This is useful to the designer as it gives a relative perspective on the building load, of changes in insulation, glass area or wall color.

The program is complete with help screens, pull-down menus, input help and range constraints on data entry. It also has a full range of data editing review and print-out features.

INTRODUCTION

The Energy Policy Act of 1992 will soon require all federal-guaranteed home loans be linked to energy efficiency ratings. The U.S. Department of Energy (DOE) has organized a committee to establish criteria and to evaluate energy analysis tools for this purpose, the Home Energy Ratings System (HERS) Council. Another national organization, the Building Environment and Thermal Envelope Council (BETEC) of the National Institute of Building Sciences, has fielded many requests for a simple energy analysis tool that can be used by contractors, architects and other non-engineering professionals. This paper outlines the features of a computer program designed to fulfill both these needs.

The software was originally designed for the energy evaluation of homes. The basis of the studies are nomographs and the "Manual J" method, which are more than adequate for residential analyses, but not for commercial facilities. The software uses the mathematical equivalent to nomographs developed by DOE studies. It has proven to be an accurate simulation tool that closely approximates the load profiles output from full-scale simulation programs.

The intended users are individuals who do not have the background to use or understand the available load analysis computer programs. The structure of the software is simple, flexible, easy to use and understand.

The application of the program for selected energy conservation projects is a feature that evolved from a special structure that isolates each major component of the building envelope and computes the load attributed to each in the same subsection of the routine. Given the weather data and the internal environmental characteristics, the simulation method is able to study a wall or window's energy cost, regardless of the type of building it is in. With the ability to specify the efficiency and type of HVAC systems, the program becomes applicable to any type of facility.

The software has many applications. It is an accurate tool for the simulation of, and equipment sizing for,

residential buildings and small businesses. It can be used to determine block loads for commercial buildings, and it will function as an energy auditor's instrument in conservation projects for any building type. This paper will concentrate on the energy conservation features of the program as they apply to commercial or industrial facilities.

ENERGY CONSERVATION OPPORTUNITIES

A common approach to analyzing a building's energy use characteristics is to determine a block load, which ascertains the building envelope without regard for individual zone or air handler loads. That is, all the lights, people and equipment in a building are input to the simulation program, along with total glass, wall and roof areas. This data is used to determine the annual energy use, which is matched with actual bills to check the accuracy of the input data.

The program also investigates the savings that can be expected from various projects, such as chiller modifications, air handler controls and so forth. A full simulation is needed to evaluate such projects because they involve the central HVAC equipment. Other projects are less global in affect, and so can be studied without first running a full simulation. In fact, it is an advantage to some projects to not have to run repeated full analyses because the energy use difference from the baseline case will be quite small compared to the whole.

The residential-quality load program, then, is sufficient to study the impact of smaller projects. As long as the interior and exterior conditions are fully characterized, the accuracy of calculations by this method are as good as a more complex program.

Some of the low-cost conservation opportunities that can be evaluated by the software are as follows:

I. Existing and new building

1. Extra insulation on south and west walls only, to reduce cooling load.
2. Double paned windows at northern exposures, to reduce heating load.
3. Changing from electric to gas heating.
4. Modification of roof color to see its affect upon annual loads.
5. Changing indoor temperature setting to save on yearly energy costs.

II. New construction only

1. Floor type
2. Roof type

These are all projects that require only modest expenditures, but with the potential for significant energy savings. They are seldom done now because the cost of running a full simulation for each design alteration is prohibitive. As a result, architectural enhancements are rarely done on this scale.

PROGRAM SETUP

Figure 1 is a snapshot of the first screen of the program.

Building Loads Simulation Program

I. General Project Information

1. Job Number [1]
2. Client Name [2]
3. Latitude of City [3]degree
4. Building Area [4] sq.ft.
5. Operating hrs/week [5]hrs
6. Designer's Name [6]

II. Job Defaults Settings

1. Source of Heating [7]
2. Electricity Rate [8]$/kwh
3. Gas Rate [9] $mcf

III. Equipment Specifications:

SEER of Air Conditioning Unit [10] <F1>
Heating Equipment Efficiency [11] <F2>

Figure 1 Project and Default Data Screen

The values that can be changed for project analyses are (1) operating hours, to discern the affect of curtailing the weekly schedule of HVAC systems; (2) source of heating, to study the savings possible with gas heating; (3) equipment efficiency, if more modern units are to be considered for a retrofit project.

The next screen asks for weather data that can either be input directly or selected from a database of values already in the program.

Building Loads Simulation Program

I. Meteorological Data
City Name [1]
Langleys [2]
Heating Degree Day [3] days
DEGREE HOURS:
>78 F DB [4] F
>66 F WB [5] F
<54 WB, 68 DB [6] F

II. Data For Peak Loads Calculation
A. Cooling
Outdoor Design Temp [7] F
Daily Temp Range [8] F
Design Wet Bulb [9]
B. Heating
Outdoor Winter Temp [10] F
Inside Design Temp [11] F

Figure 2 Weather and Design Temperatures Data Screen

This is a critical part of the program that affects all the calculations. It is important that the valves input are as accurate as possible, so there is unlimited flexibility available for the designer to customize the climatic conditions. For example, a coastal area may be given a higher wet bulb than the ASHRAE standards stipulate or the winter temperature might be input higher for a building in the midst of a large city. Such freedoms are, if available in other load analysis packages, difficult for the non-technical program user to input accurately.

This screen also has an input for heating and cooling season inside temperatures. Changing these valves will produce different annual energy costs, so that the user can ascertain the result of modifying thermostat settings.

BUILDING ELEMENTS

The next four screens will show the data for glass, wall, floor and roof loads. In each case the user can input element types, then denote where in the structure each type is situated. This itemization is done in the lower part of each table.

Building Loads Simulation Program

TYPE U VALUE W VALUE CONST LENGTH WIDTH

1 0.35 0.45 G2 12.0 4.0
2 0.45 0.65 G1 3.0 5.0

TYPE EXP QTY OVER DIST SHADE-OUT SHADE-IN

2 N 4 - - .1 .2
2 S 2 - - .9 .1
1 W 1 - - .1 .8

F2/F2 FOR LOADS: COOLING[ ]HEATING [ ]
TOTAL COST: [$] = [$] + [$]

Figure 3

Notice the energy use and annual costs for heating and cooling that are filled in at the bottom of the form. These are calculated and displayed by striking a function key on the computer. Another feature shows the part of the total load attributed to each building part. This will highlight that part of the building - e.g. south-facing windows - that will benefit the most from a conservation project.

The wall data form is set up here to allow the user to change the color for different walls to study the affect on energy use. External or landscape shading can also be evaluated.

Building Loads Simulation Program

TYPE	U VALUE	COLOR	CONSTRUCTION
1	0.06	L	W2
2	0.06	M	W2
3	0.06	D	W2

TYPE	AREA	EXPOSURE	SHADE ESTR
3	100	N	.5
1	250	S	.4
1	700	W	.2

F3/F3 FOR WALL LOADS: COOLING [ ] HEATING [ ]
TOTAL COST: [$] = [$] + [$]

Figure 4

Again, the program has the feature of providing information on the amount of the total load due to each wall portion. The floor and roof forms follow a

similar format and permit alterations in color, construction and u-valve.

After each mini-simulation is performed the data can be printed out to provide a hard copy of the information, cost and savings. This snapshot can also be taken of the screens depicted in Figures 1 and 2 for the building and weather data.

Building Loads Simulation Program

I. COOLING LOAD CALCULATION DATA help:

1.	Number of people	[1]
2.	Equipment (sensible)	[2]
3.	Equipment (latent)	[3]
4.	Duct heat gain	[4]

II. HEATING LOAD CALCULATION

1.	Duct heat loss	[5]

Figure 5 Miscellaneous Peak Loads Calculation Data

The last screen, Figure 5, gives the user an opportunity to be more specific about the latent and sensible loads in the building. This is a convenient way to study the subtle affects of reducing latent loads in a building, often a source of high energy expenses.

SOFTWARE CHARACTERISTICS

The application has all the latest software enhancements, including color screens, pull-down menus, mouse-compatability, error messages and abundant help screens accessible from every calculation point. Depending on the user's hardware configuration, the program can be provided with disk-caching and a virtual memory manager. Almost any common printer driver can be provided as well. Full documentation is available.

CONCLUSION

The advent of new, more stringent energy conservation standards will soon require many professionals in the building and construction trades to be versed in energy use characteristics. This program offers a simple, flexible tool to learn the affects of various building parameters on the HVAC load. It is also a powerful analysis tool for engineers and architects that will help them design by the latest codes and standards.

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