COMPUTER SIMULATION OF ENERGY CONSERVING BUILDINGS

By Thomas T. Shishman

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Energy-conscious design is the only economical way to successfully integrate energy conservation and construction. Retrofitting and energy management projects merely compensate for the deficiencies of old designs that reflect the bargain energy used to be. Now that energy is expensive, the basic principles of conservation must be built **into** design. The consideration of energy-saving alternatives throughout the design process is the key to the successful design of energy-conscious buildings for the 1980's.

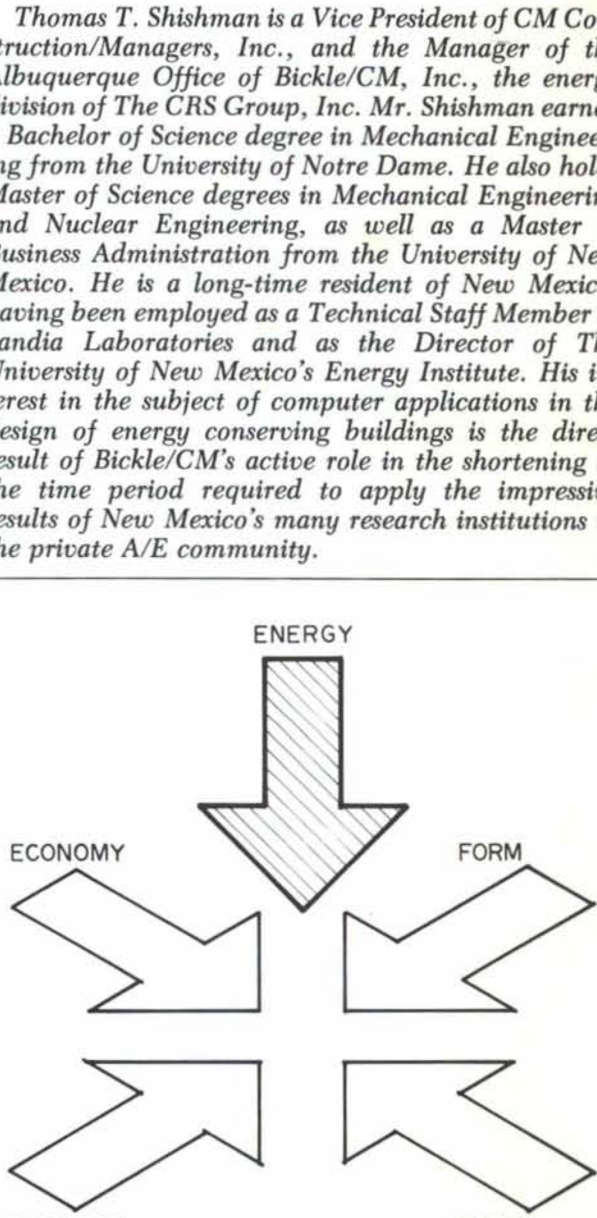
Architects and engineers are expert at balancing the fundamental design determinants of function, form, economy, and time. It is our experience that today's design team is faced with a new challenge—introducing and incorporating a fifth design constraint, ENERGY, into the traditional design process. There is true need for specific types of computerized design tools.

The decade of the 1970's witnessed the development and application of a variety of energy analysis computer programs. A large number of computerized analysis methods for solar heating and cooling applications were also introduced during the late 1970's.

The problem is that most of the computer models available were developed by a particular organization to solve a specific problem(s). Also, a significant number of the codes are proprietary, some are inadequately documented for general usage, some are very difficult to obtain, and essentially all are difficult to input, are costly to run, and are highly subject to user interpretation of output results. However, several are extremely useful design tools at both the programming (analysis) and design (synthesis) phases of a project.

Ideally, energy considerations should be addressed with the Owner, even before the A/E Team is selected. If energy is introduced as a design determinant only at the end of the programming phase, the potential benefit of energy-conscious design concepts will have diminished significantly.

During conceptual design, the design team can effectively utilize a series of very simple, synthesis-oriented computer programs. The objective of these programs is not to analyze energy consumption, but to identify the major design variables which influence



ENERGY DISRUPTS TRADITIONAL DESIGN

energy consumption. It is helpful to assess the sensitivity of the final design to these variables, and to evaluate the interaction of various key parameters. During early schematic design, progressively more complex computer models are desirable; large energy analysis and simulation programs are normally utilized during the latter stages of schematic design and design development.

The following computer programs evaluate the effectiveness of energy conservation alternatives. They are coordinated with energy conscious design methodology, and range from simple statistical reference data sources to comprehensive simulations.

In explaining each program, it's helpful to discuss:

- Problem that led to the program's development
- Solution offered by program,
- Input required, and
- Output format.

Major Computer Program: EBUDG

Problem: Architect/Engineer design teams frequently spend tremendous amounts of time and effort looking at areas of conservation and alternative energy sources that are not appropriate to a particular project.

Solution: EBUDG provides direction to the design process by establishing a reasonable "energy budget" for the building and identifying major energy end uses. After the building type and climatic zones are outlined, EBUDG breaks down the types of energy use to show us which areas the design team should concentrate effort on to realize the most effect. For example, some buildings in Houston use 50% of their energy demand for air conditioning—so cooling techniques are a logical focus for the design team.

Input: General climate zone; area by usage type (E.G. 10,000 square feet of office space, 50,000 square feet of warehouse, etc.); number of occupants anticipated.

Output: Two bar charts. One shows the 20th percentile, mean, and 80th percentile range of an energy budget for a typical building, modeled from our input. The scale is in units of BTU's/square foot/year.

The other chart shows a breakdown of energy usage by type. It depicts what percentage of total energy consumed will go for the various end uses such as lighting, cooling and equipment operation.

Major Computer Program: WONDER-2

Problem: It is often difficult to determine the relative importance of internal loads (such as people and equipment), compared to external loads placed on the building.

Solution: Designed to be run in series with EBUDG, WONDER-2 analyzes how various components in a building contribute to overall energy consumption. WONDER-2 also introduces the concept of time into the evaluation.

By performing a simple hour-by-hour energy balance, or "mix", for the building, the program shows relative time relationships between various load components as well as average overall energy use. If, through EBUDG, we determine that cooling is a prime end use, WONDER-2 will show us what percentage of the cooling load comes from the glass, the walls, the ceilings, infiltration, etc. And we'll see how peak load air conditioning relates volume-wise and time-wise to other end uses, such as lighting. Designers can use WONDER-2 many times during conceptual design to understand the building's performance as a dynamic system.

Input: Hourly weather data, either for a typical day, typical season, or typical year, and the best possible description of the building. If the building's geometry and orientation are known, they can be used as input; if not, the program has default values for typical buildings.

Output: Rainbow plots, pie charts, or linear graphs showing the temporal relationship between internal and external loads. Because the input for WONDER-2 consists of hourly profiles, the precision of the program can be increased simply by using auxiliary programs to generate more and better hourly readouts for the different elements of the building. Key design alternatives can also be evaluated through the auxiliary programs.

Auxiliary Computer Program: COMPGLZ

Problem: Glazing questions tend to be extremely complex. They affect so many energy issues—solar gain, heating and cooling load, natural lighting. Also, there is a basic economic issue involved in the life cycle value of double-glazed glass.

Solution: The design team defines three or four windows designs and picks several different glass types; COMPGLZ determines the annual BYU's/sq. ft./yr. consumption rate associated with each glass type, for each orientation.

Input: Glass type; the material properties of the glass (thickness, index of refraction, normal vector); overhang/fin geometry; and hourly weather data, including solar radiation.

Output: A figure representing the cooling load, the net number of BTU's/sq. ft./yr., produced by each glazing option. This figure is then compared to the load of standard building wall, as a point of reference. The program predicts beam and diffuse radiation and conduction gains and losses on an hour-by-hour basis through use of an empirical model.

Auxiliary Computer Program: LUMEN II

Problem: Lighting typically turns out to be the most important energy use in commercial scale buildings, so we need to place particular emphasis on high efficiency systems that make maximum use of natural lighting.

Solution: LUMEN II analyzes artificial lighting schemes based on the predicted number of occupants and the availability of natural lighting.

Input: Description of the proposed auxiliary lighting system, the lighting fixtures, lamp type, room geometry.

Output: A "map" of the lighting levels which shows the specified area's light distribution, both from a side and an overhead view. The girds are figured in **light candles**, as if a light meter were read at one-foot intervals and lines were drawn to connect all the 30-light candle readings, etc.

Auxiliary Computer Program: EFFUFAC

Problem: There are many walls that actually use more energy when more insulation is added to them. In a cold climate, for instance, a south-facing wall acts as a solar collector; insulation only detracts from the wall's collecting efficiency and increases the heating load. Also, in buildings with very high internal loads, such as manufacturing plants, some of the process heat must be vented.

Solution: EFFUFAC takes into account the internal heat load generation and external absorbed solar radiation on an **average annual basis**, so the long term heat gains and losses are understood.

Input: Description of the building's wall construction, including the material properties (both physical and thermal); site orientation, latitude and longitude; shading information; local hourly weather data.

Output: Three sets of figures describing 1) the instantaneous heat flux on an hourly basis, 2) the integrated net heat transfer over a specified period of time, and 3) the Effective U-factor for the buildings.

Auxiliary Computer Program: ECONZER

Problem: There is frequently a need to evaluate the long term effectiveness of various economizer cycles and heat recovery schemes.

Solution: ECONZER is a simple and inexpensive program to use and describes the annual energy savings associated with, for example, the selection of an economy control on an air conditioning unit for a particular climate and a particular combination of internal loads.

Input: Hour-by-hour weather data and hour-by-hour internal load data.

Output: A figure summarizing the average yearly BTU savings which would result from a scheme's implementation.

The auxiliary programs described thus far have dealt with individual components. The efforts up to this point have been **synthesis**-oriented, that is, working toward a cohesive energy network. The next two programs are **analysis**-oriented. We evaluate the interaction between the energy saving components and determine the total effectiveness of the entire energy system. *T.T.S.*