CALPAS4 AND BEYOND --
MICROCOMPUTERS, GRAPHICS, AND BUILDING ENERGY SIMULATION

Charles S. Barnaby
Berkeley Solar Group
3140 Martin Luther King Jr. Way
Berkeley, CA 94703

ABSTRACT

Traditional batch style building simulation models are designed around the capabilities of computers dating from 10 or 15 years ago. Programs of this type, including Berkeley Solar Group's CALPAS3, have a number of limitations imposed by this traditional organization, the most significant one being that all information must be reduced to text form prior to input. Current generation microcomputers offer inexpensive graphic capabilities and can serve as dedicated workstations. They can thus serve as the basis for an entirely new program structure which accepts at least some input in non-text form. CALPAS4, the successor to CALPAS3 now under development, is one such implementation. Examples of CALPAS4 graphics are shown in the paper.

Development of this new type of program, which includes an extensive database of geometric building information, points out the need for standardized means for representing and communicating building data. Other segments of the design industry, such as CADD, use similar but incompatible databases; lack of standardization will retard the application of building energy simulation.

INTRODUCTION

Berkeley Solar Group has been developing and using energy analysis software for more than ten years. We worked first with active solar models, then with enhanced versions of NBSLD, and most recently with CALPAS and its derivatives. We also make extensive use of DOE-2. We are now in the midst of the development of a major enhancement to CALPAS. This paper describes CALPAS3 and shows how its successor, CALPAS4, will address some of its shortcomings. Many of these problems are generic to programs that share the traditional structure used in CALPAS3; however, microcomputers provide an opportunity to solve them at a fundamental level.

Sophisticated building energy simulation programs such as CALPAS4 also point out the need for standardized methods for representing and communicating building related data. This is discussed as well.

CALPAS3

CALPAS3 is a full 8760 hour building simulation model for predicting the energy performance of residential and small commercial buildings (1,2). The program was originally a minicomputer enhancement of CALPAS1 (3), but in 1983 the full model was moved to the IBM-PC; current implementations are now available for the Data General MV-series, the DEC VAX series, and most MS-DOS microcomputers.

CALPAS3 can straightforwardly model both conventional and passive buildings. A simple, free-format input language allows terse description of the building. The short basic output summarizes performance annually and by month; extensive optional daily and hourly reports are available. All output is in an 80 column format.

The program currently models building loads only. User-supplied seasonal efficiencies are used to convert loads to fuel requirements. However, an equipment simulation post processor has recently been developed (4) to allow hourly modeling of heat pumps, furnaces, and air conditioners.

A number of simplifications are made in the CALPAS3 model in order to allow it to execute quickly. These include fixed exterior film coefficients (as opposed to windspeed-dependent coefficients), combined radiant-convective interior coefficients, and the modeling of the thermal mass of lightweight materials (furnishings, gypsum board, etc.) as a single lumped capacitance. For most applications, these approximations introduce only minor inaccuracies. The benefit in run speed is significant -- a full year simulation of a single zone building can be completed in about 1 minute on a supermini and in under 10 minutes on an IBM-PC.

CALPAS3 is used primarily in four somewhat overlapping contexts. First, since CALPAS3 is certified by the California Energy Commission for compliance with that state's Title 24 residential energy code, it is used extensively for predicting energy budgets as part of building permit applications. Second, it is used by designers to optimize buildings for good energy performance. Third, researchers use the program to find general energy conserving strategies or investigate other areas of interest. Finally, CALPAS3 is used in educational situations for student experimentation with passive and conservation approaches (BSG offers a low cost version of CALPAS3 for educational use).

In terms of number of simulations performed, CALPAS3 is certainly one of the most heavily used of available models. More than 9,000 runs were done by outside users on the BSG timesharing service during 1984. No statistics are available for other systems and microcomputers on which the program is installed, but probably 20,000 runs per year is a reasonable estimate of the current level of CALPAS3 use.

EVALUATION OF CALPAS3

CALPAS3 is widely used and has established that there is strong interest in hourly simulation. It also makes it clear that microcomputers available currently are suitable for running full-year models. This brings the capabilities of hourly simulation to a new (and growing) group of users. Thus from several points of view, CALPAS3 must be regarded as a successful program. As with any piece of software, however, it has some shortcomings. It is interesting to examine these.

First, CALPAS3 has a number of restrictions that are annoying and limiting to the user. For example, only a limited number of thermal masses can be modeled. The user is forced to lump masses together in situations where this limit is exceeded. In other areas, CALPAS3 has no such maximums; for instance, there are no limits on the numbers of walls or windows which can be input.

Second, some of the component models included in CALPAS3 are outdated, insufficient, or inaccurate. Included here are fixed exterior film coefficients, which introduce significant errors on high U-value surfaces such as single-glazed windows; overly simple ground coupling modeling; lack of a latent load model; and inaccurate overall heat transfer in some cases due to combined radiant-convective interior coefficients. Some of these shortcomings are common to most other models. Ground heat loss, for instance, is not handled well by any program in general use. Other component models could be easily enhanced with techniques developed in the last few years. However, applying these improvements to CALPAS3 without reducing its speed presents significant programming problems.

The third area of weakness in CALPAS3 is by far the most challenging. CALPAS3 is a "traditional" simulation tool. An input file is prepared with a text editor. This file is read by the program; if no errors are discovered, the simulation proceeds and output is produced. If errors are found, program output consists of input echo and diagnostic messages only (no simulation output) and the user must cycle back to the text editor to make corrections. CALPAS3 shares this traditional structure with DOE-2, BLAST, TRNSYS, and many other models. The structure dates from batch processing days when punched cards were prepared externally and read into the computer sequentially. (In fact, some users still refer to their input file as a "deck".)

The traditional structure has a number of consequences:

- No immediate error checking, prompting, or user feedback can be performed, since the program is not talking directly to the user. All communication is carried on via text input and output.
- All input information must be reduced to text form prior to input; traditional programs have no way of capturing input in other forms, such as graphic.
- Although not inherent in the traditional structure, most batch-style programs perform one or at most several analyses during a given run. Problems addressed with simulation are often divided into a series of cases that are being compared. The programs do little or nothing to manage input and output to facilitate analysis and result presentation in multicase situations.

Due to these limitations, traditional programs are extremely difficult to use on all but the smallest projects. In larger studies, input files become long and cumbersome. They must be carefully hand checked to avoid errors. Many programs provide verification reports summarizing input data, but these still must be checked. Output reports must be managed also. Either hand labor or custom programming is required to collate and assemble results from multiple runs into a coherent report.

The overall result is that traditional programs are rarely used accurately. A recently published study (5) showed that expert program users, even with some prompting, prepared DOE-2 input that produced substantial spread in predicted energy performance of several types of buildings. This variance occurred even though the users knew they were being compared and were presumably highly motivated by professional ego to avoid errors.

Clearly, then, if simulation is to continue to contribute to the construction of energy conscious buildings, a substantial step must be taken to reduce the effort and error rate inherent in traditional program structures.

MICROCOMPUTERS

Ironically, the availability of computers with less power forms the basis for a solution to this problem. One of the motivations behind the batch structure was that since computers were such powerful and expensive pieces of equipment, it was not acceptable for them to pause while a mere user scratched his or her head to consider the next piece of input. The batch structure obviously prevents the computer from having to wait during "thinking time", but it also prevents the computer from being helpful with any task except the crude computational aspects of analysis. Microcomputers reverse this situation.

The key facts about using currently available IBM-PC style personal computers for building simulation are:

- With good programming, they have adequate numerical computing power, memory space, and disk storage to perform hourly simulation.

- They offer graphic display capabilities at a low price.

- They are dedicated workstations, available to the user at all phases of a project.

The numerical capability of microcomputers has in the past been a limit to their applicability to computationally intensive tasks like building simulation. Currently, however, the combination of the 8087 coprocessor and good software design provides adequate power for this type of work. Further, first generation IBM-PC style machines are already being replace by faster systems based on more advanced microprocessors. The conclusion, then, is that the computing power limit is no longer a primary concern.

It is worth noting, however, that the quality of development software used for constructing application programs can have a substantial impact on their ultimate performance. The following table shows execution times for a code fragment typical of building simulation. The fragment was coded in FORTRAN or C, as appropriate, and compiled using all available optimization features. All tests were run on an IBM-PC equipped an 8087 coprocessor.

Compiler	Run time (sec)
Lattice C 2.14	210
Microsoft FORTRAN 3.20	42
Mark Williams C	39
Lahey F77L FORTRAN 1.06	38
Computer Innovations C86 2.20M	37
IBM Professional FORTRAN 1.00	29
Microsoft C 3.00	29

From this, it is clear that compiler selection can have at least a 30 % effect on execution time (discounting Lattice C). The conclusion stands, however, that with some care in selection of development tools and in application design, current personal computers have sufficient numerical capability to perform building simulation.

The graphics display features of IBM-PC style microcomputers is their most revolutionary capability. A PC with basic graphics capability costs only a few hundred dollars more than an otherwise equivalent text only system. Affordable, interactive graphics opens the possibility of constructing building simulation software that communicates in non-text formats.

Finally, the microcomputer is dedicated to a single user and can be used for thermal analysis in an interactive fashion much like a word processing system is used for writing. This allows a much broader view of what a simulation program should do. Numerous associated tasks such as report preparation, results storage and manipulation, reference data storage, to mention a few, could be automated and included in the package. Further, facile connection and integration with other programs performing other building-related tasks (structural analysis, cost estimates, etc.) can be envisioned.

CALPAS4

CALPAS4 is an effort to strengthen some of the weak areas in CALPAS3 and to take steps away from the traditional batch structure. Numerous model enhancements are being made, including a multizone combined building loads and HVAC simulation.

The most ambitious addition is extensive use of the IBM-PC graphic capabilities for direct input of geometric data without intermediate text translation. The user inputs a basic building plan with the cursor control keys and other keyboard input. (We are also looking into the use of mouse input; current implementations use keyboard only.) After basic input, windows can be added (or removed) and corners and walls can be moved. Figure 1 shows a simple plan. The building elevations can be viewed and edited as well, as shown in Figure 2, to allow entry of non-rectangular walls. Since the program maintains a full three dimensional model of the building, 3-D projections from any viewpoint can easily be generated (Figure 3). Finally, the display capabilities can be used to show shading patterns at specific times as seen in Figure 4.

All the information displayed in these examples was captured without a single number being typed. Yet the program can easily calculate all wall areas, glass areas, conditioned floor areas, room volumes, and other data which is required for thermal analysis. In traditional programs this information must be laboriously prepared by the user. In addition, the graphic display of the building geometry allows quick checking of input correctness.

Although our development has focused to date on building geometry, the success of the graphic approach is such that it is easy to imagine numerous other applications for it. For instance, an HVAC system could be schematically input by manipulating symbols for coils, fans, dampers, and other components. Building schedules could be captured with user-adjustable bar graphs.

CALPAS4 will also contain initial versions of schemes for managing multiple alternative cases of a given building design and for merging and comparing the results from simulations of several cases.

In summary, CALPAS4 is a step toward taking advantage of the capabilities of microcomputers to overcome the limitations of the traditional batch program structure which has been in use for the last ten or fifteen years.

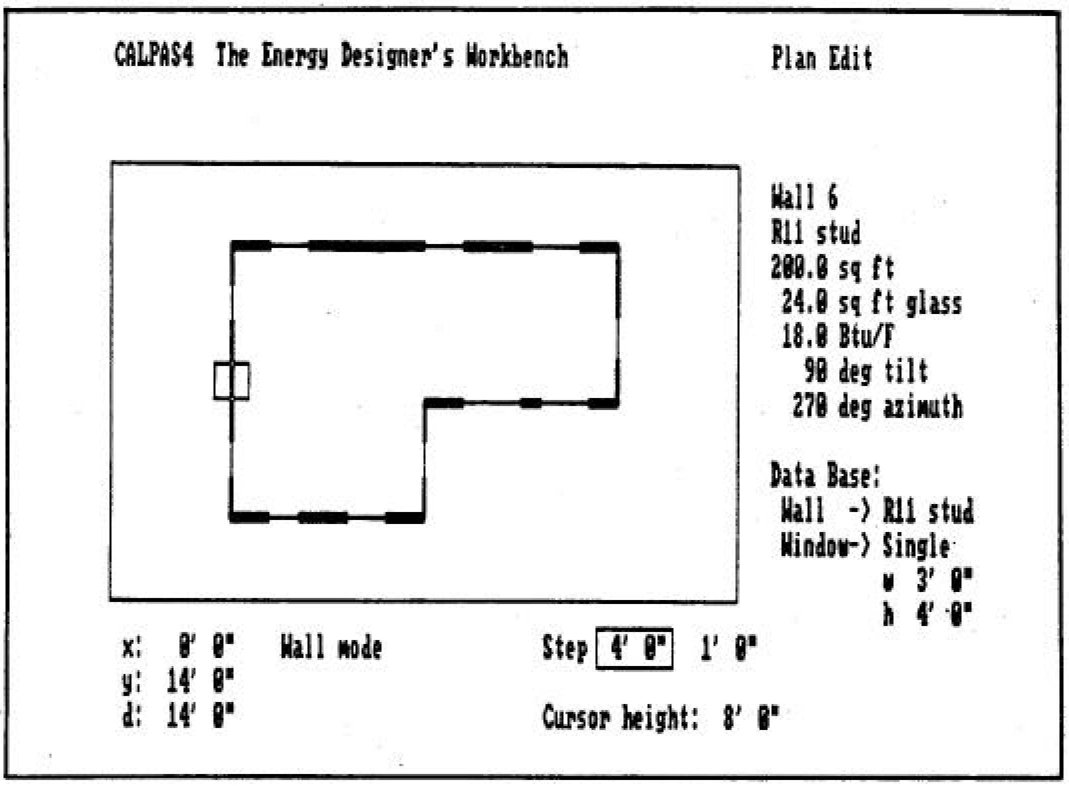

Figure 1

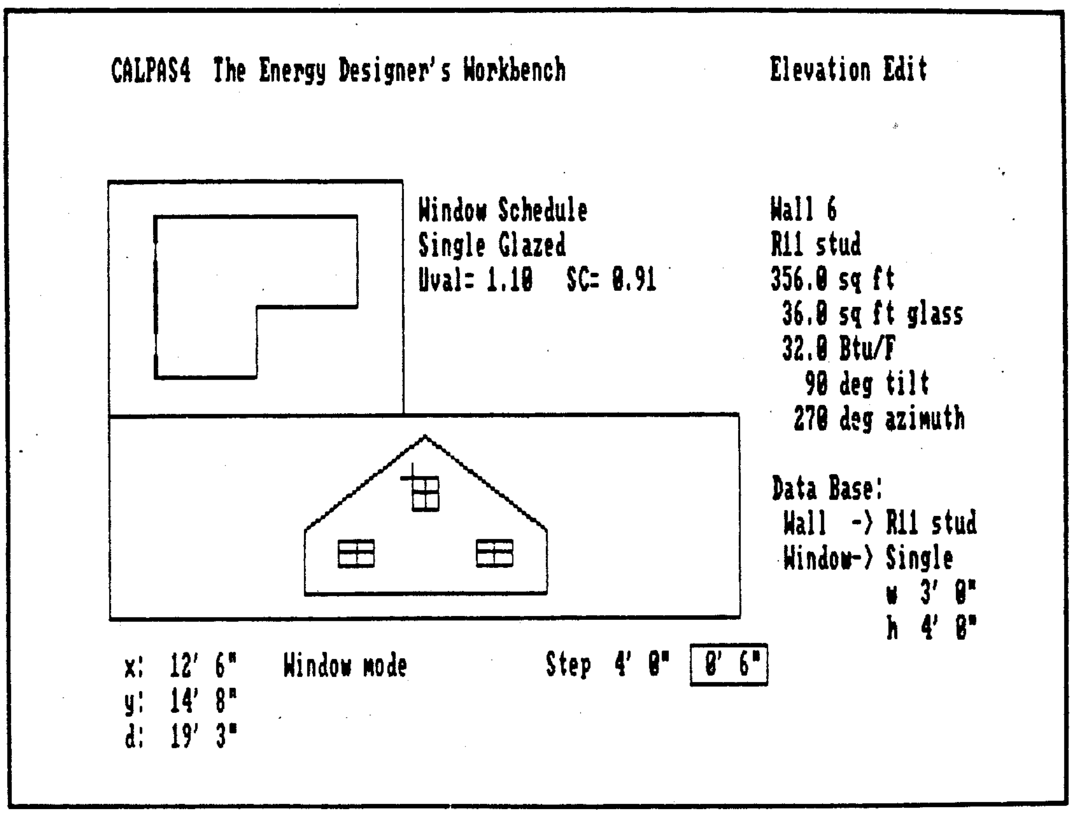

Figure 2

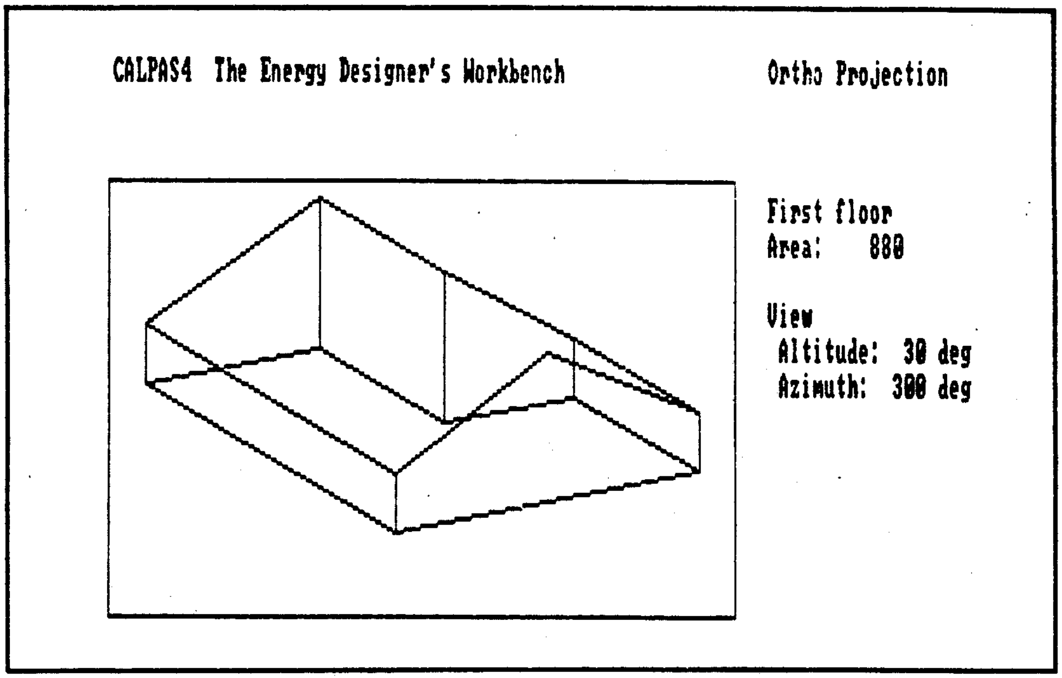

Figure 3

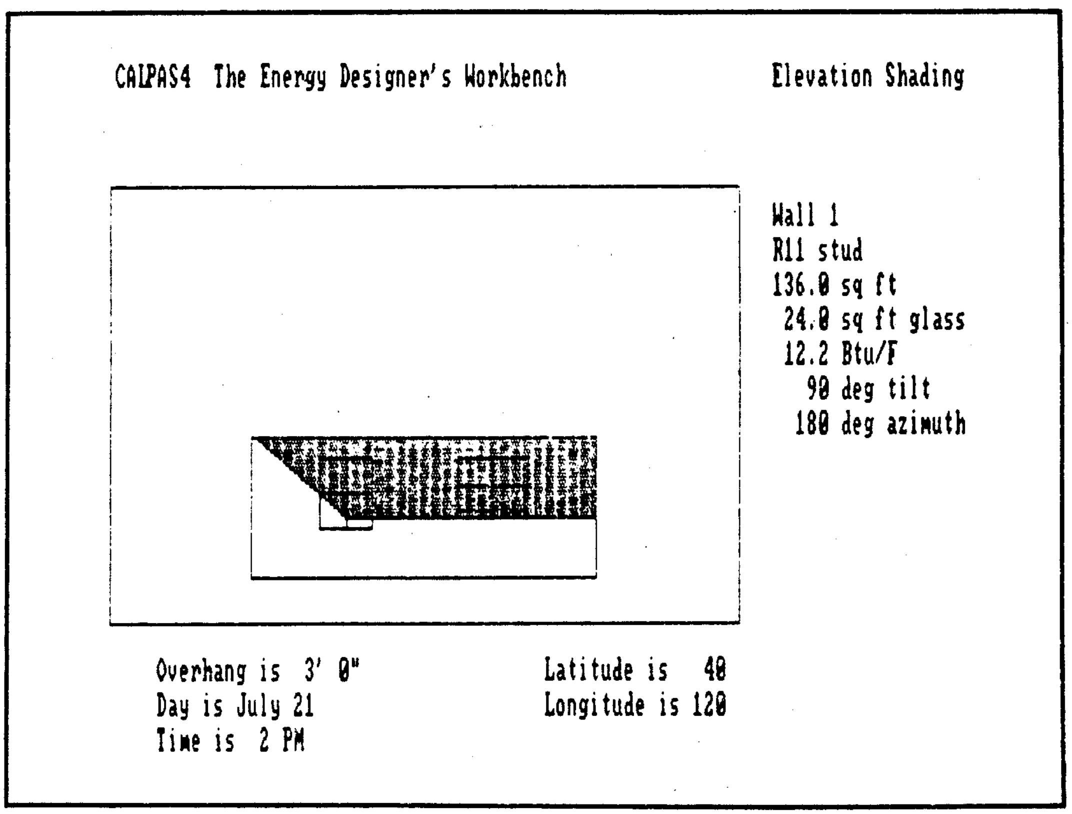

Figure 4

BEYOND

As energy simulation programs such as CALPAS4 are enhanced to include detailed building data bases and facile graphic user interfaces, the issues compatability and integration of programs become overwhelming. Without standard formats for presenting and communicating building related information, the energy calculation field will remain specialized, divided, and small. A thorough discussion of many of these issues is found in (6).

Current developments in the use of CADD (computer aided design and drafting) in the building industry are illustrative. Only limited compatability exists among the numerous available systems. The result is that only large multi-disciplinary firms which control all project phases can productively use the systems. Small offices generally use a mixed bag of outside consultants. If all firms installed CADD systems today, there would instantly be a tremendous compatability bottleneck which would result in a large amount of theoretically needless duplicate entry of building data. Offices which do not initiate drawings, such as consulting mechanical engineers, are therefore particularly reluctant to install a CADD system; they would have to redraw basic information (such as floor plans) which they now receive as reproducible drawings from their clients.

Obviously a standardized data interchange format will have to be developed before CADD systems will be widely used. CADD vendors recognize this and are actively jockeying to be well positioned as standards come into play. Secondary segments of the design industry, such as energy simulation, will have to make their presence [illegible] soon or they will be ignored in any standards development effort.

Over the next ten or twenty years, the design industry is going to come to rely on computerized tools. Whether energy simulation is central or peripheral to that transition depends on our ability to look beyond the CALPAS4's and think in terms of integrating all aspects of the design process.

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