THE USE OF THE COMBINE PROGRAM WITH DOE2.1C

by

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ABSTRACT

COMBINE is a file utility program developed by Jeff Hirsch of Lawrence Berkeley Laboratories for use with the DOE2.1C building energy simulation program. COMBINE merges the data arrays that are passed from the SYSTEMS simulation subprogram to the PLANTS simulation subprogram in DOE2.1C. To date, it has not received extensive publicity but it is a program that expands the applications and power of DOE2.1C and it deserves recognition as one of the most practical building energy simulation innovations of the past several years.

This paper discusses the COMBINE program from the perspective of a user of DOE2.1C. COMBINE expands the limits of DOE2.1C by increasing the number of spaces that can be contained in a single building energy simulation model, by allowing explicit modeling of campus and district heating and cooling systems on a building by building basis, and by focusing attention on the plant simulation capabilities of the DOE series of building energy simulation programs.

Demonstration of simulation techniques available when using COMBINE is provided through examples of DOE2.1C models at Kaiser Hospital in Panorama City, California; and California State University at Fresno (CSUF). The Kaiser Hospital model used COMBINE to expand an existing DOE2.1C model that already contained full data arrays. At CSUF, the COMBINE program was used to facilitate the explicit modeling of the entire college campus on a building by building basis.

COMBINE creates new opportunities for the use of building energy simulation in the solution of complex engineering and planning problems. Use of COMBINE represents, one strategy for improving the state of simulation software with a minimum of additional effort. Future developments that would improve COMBINE include the development of COMBINE for use with the LOADS subprogram and for use with microcomputer-based versions of DOE2.1.

INTRODUCTION

COMBINE is a file utility program developed by J. Jeff Hirsch at the Lawrence Berkeley Laboratory for use with the DOE2.1C building energy simulation program. COMBINE works by reading the contents of two to four DOE2.1C intermediate files into data storage arrays and then summing the arrays. The data in the combined data are then written to new intermediate files. In this manner, up to 4 intermediate LOADS or SYSTEMS files, generated by individual DOE2.1C simulations, can be combined into a single intermediate file. To date, COMBINE has been written for use with DOE2.1C SYSTEMS intermediate files. Nonetheless, COMBINE is a powerful utility that expands the building energy simulation applications of DOE2.1C.

Two examples of energy simulation applications made possible through the use of COMBINE are discussed in this paper. One simulation project was performed for the Kaiser Medical Center Hospital and Clinic in Panorama City, California. This project involved two separate computer models and demonstrates very aptly the ability of COMBINE to expand the input limits of DOE2.1C.

The other project was performed for the California State University at Fresno. This project involved an energy master planning effort for the entire campus. COMBINE allowed the engineers conducting the study to explicitly model each individual building on campus as well as 15 future buildings that are planned to be constructed over the next 20 years. All of the building energy simulation models were eventually combined to analyze a number of central plant alternatives. Such an approach to campus or district heating and cooling system analysis could not be performed using DOE2.1C without COMBINE.

USE OF COMBINE

COMBINE is a program that is tailored to the architecture of DOE2.1C. To understand the potential uses of COMBINE fully, one must be familiar with the general structure of DOE2.1C.

Structure of DOE2.1C

DOE2.1C consists of four primary subprograms - LOADS, SYSTEMS, PLANT, and ECONOMICS - linked together through intermediate files. These functions of these subprograms are indicated by their names. The LOADS subprogram computes peak and hourly heating and cooling loads for each defined space in the building energy simulation model. Following calculation of building heating and cooling loads, DOE2.1C writes the hourly loads data to an intermediate file. Additional information concerning the design day, run period, and other simulation guide data is written to another intermediate file. These files are referred to as the loads hourly data file and the design file. The simulation of the heating, ventilating, and air conditioning (HVAC) systems is accomplished using the SYSTEMS subprogram, the intermediate files from the LOADS subprogram are read and used for the HVAC systems simulation. The LOADS intermediate files are then deleted from the memory of the supporting computer system. Intermediate files are generated and deleted in a similar manner following completion of the SYSTEMS and PLANT programs.

In order to combine intermediate files, DOE2.1C must be instructed to save the files rather than deleting them at the completion of processing of any particular subprogram. DOE2.1C contains an input command called SAVE-FILES that can be inserted at various locations within the input file to allow the saving of the intermediate files generated by the LOADS, SYSTEMS, PLANT subprograms. Since the current versions of COMBINE are written to function only with intermediate files from the SYSTEMS program, it is necessary to save only the SYSTEMS intermediate files.
In all, three individual files will need to be saved to use COMBINE:

1. a SYSTEMS identification file,

2. a simulation design file,

3. the SYSTEMS hourly data file.

If the SAVE-FILES command is input properly and executed in conjunction with the operating system requirements of the supporting computer system, all of these files will be saved.

Limits of DOE2.1C

When preparing a building energy simulation using DOE2.1C, there are several input limits with which a modeler will have to contend. On large projects, or detailed simulation effects, one of the major input limitations is the maximum of 64 space definitions (48 spaces for the microcomputer version of DOE2.1C). If a modeler is attempting to explicitly model a building, then limitations on the number of window and wall inputs, 128 separate definitions for each, can also cause problems.

One solution to the limitations of DOE2.1C is to use the multiplier input features of the program. Instead of inputting information for every discrete window, for example, select a representative window and use a multiplier input to multiply the loads associated with this window by the number of windows on any particular exterior surface. Another solution involves translating the building simulation model into an abstraction of the real building. This can be done quite simply by combining walls and windows or leaving certain surfaces out of the model. Both solutions are examples of simplifying assumptions which are often made during building energy simulation projects. Careful exercise of engineering judgement is required when such simplifying assumptions are made to insure that the building energy simulation is based upon a reasonable approximation of the actual building and building energy systems.

As will be discussed further in this paper, there are applications where the limitations of DOE2.1C will cause problems even if abstract, or simplified, models are prepared. Even when the best judgement is applied, it is often difficult to communicate the rational behind the simplifying assumptions to other interested persons. COMBINE allows complex and detailed building simulation applications to be performed using DOE2.1C without the necessity of simplifying assumptions.

CASE STUDIES

The two case studies presented in this paper are rather unusual applications of DOE2.1C. Both applications would have been difficult, if not impossible, to perform without the use of COMBINE and they provide excellent examples of the use of building energy simulation to solve challenging planning and design problems associated with complex building energy systems.

Kaiser Hospital

The building simulation model performed for the Kaiser Foundation Medical Center Hospital and Clinic offers an interesting look at the ability of COMBINE to overcome the input limits of DOE2.1C. As part of a cogeneration and energy conservation feasibility study, a DOE2.1C model was prepared for a 10-story hospital and clinic building in Panorama City, California. This model was prepared prior to the development of COMBINE, and required some simplification to include the entire building in a single 64-space model. The model was input, calibrated, and used in the analysis of several energy conservation alternatives including natural daylighting, cogeneration, thermal energy storage, heat recovery, and waste heat-driven absorption chilling. The central plant alternatives relied upon DOE2.1C to predict the interactive effects of several of the above technologies when combined into a single plant alternative.

In 1987, Kaiser purchased one single-story and one multi-story office building adjacent to the hospital. Plans were developed to convert the office buildings into medical offices and clinic space. The hospital requested that the heating, cooling ,and electrical loads of the two office buildings be evaluated in an update of the original analysis. The two office buildings were input into a single 20-space building energy simulation model using DOE2.1C. The SYSTEMS intermediate files from this model were saved using the SAVE-FILES input command. Additionally, the original hospital model was rerun and the SYSTEMS intermediate files from this model were also saved. COMBINE was employed to combine the SYSTEMS intermediate files from the original hospital model and the new office building model into a new combined model. Plant options including cogeneration, thermal storage, and absorption chilling were reexamined by preparing and submitting just the PLANT and ECONOMICS input for each DOE2.1C run required.

The combined building energy simulation model for Kaiser Hospital at Panorama City incorporated a total of 84 defined spaces. Six different system types were defined within a total of 20 discrete HVAC systems. Many attributes of the actual buildings were treated in considerable detail by the building energy simulation models including extensive exterior building shading surfaces, detailed description of window shading features, individual definition of the majority of actual windows, and detailed scheduling of space occupancy according to function.

Fresno State

The use of a building energy simulation tool, such as DOE2.1C, in the analysis of campus or district heating and cooling systems has generally required significant abstraction and simplification of the computer model. Indeed, the energy simulation of an entire campus usually requires that all buildings of significant heating, cooling, or electrical load be lumped into a single model. With a limit of 64 spaces, a campus or district heating and cooling system of any significant size becomes very difficult to model using programs such as DOE2.1C. An energy master planning study for California State University at Fresno provided another unique opportunity to apply COMBINE and DOE2.1C. At CSUF, part of the project involved performing energy conservation studies on 26 individual buildings. Building energy simulations were required to be performed on each of these buildings. In addition, a significant portion of the project was devoted to the analysis of the existing central plant and the preparation of a plan for economic plant expansion to meet future building loads over the next twenty years. COMBINE offered an attractive strategy for the maximizing the useful information gained through the building energy simulation involved in the project. Building energy simulation models were prepared for 29 existing buildings, including the 26 buildings that required individual energy studies. An additional 15 building energy simulation models were constructed to represent future buildings.

The individual models served as the base case for the individual building energy studies. Once the individual models were completed, COMBINE provided the flexibility to group buildings together in any combination desired. THe individual building models were combined into aggregate models to examine 14 separate central plant options. Five of the central plant options involved analysis of a second central plant to serve the campus. The various plant alternatives were run using DOE2.1C PLANT and ECONOMICS input files for each central plant alternative and the combined SYSTEMS intermediate files from the individual building models.

Time constraints dictated that simplifying assumptions be applied to each of the individual building models, particularly in deciding how to thermally zone each building for the purposes of simulation. Nonetheless, the largest combined model represented 44 buildings and a total of 178 spaces. Plant alternatives analyzed included steam boilers, steam-driven absorption chillers, direct-fired absorption chillers, electrically-driven centrifugal chillers, thermal energy storage, cogeneration, heat recovery chillers, ground water heat pumps, and free cooling options using the existing cooling tower.

BENEFITS OF COMBINE

The case studies presented above highlight several benefits of COMBINE when applied with DOE2.1C in engineering analysis applications. In the case of the Kaiser Hospital simulation, COMBINE allowed the expansion of a detailed computer model that had exhausted the capacity of the simulation program on which it had been prepared and run. The successful application of COMBINE in the Kaiser Hospital simulation project demonstrates one modeling approach for anyone faced with detailed simulation applications of DOE2.1C. Assuming no time constraints, a careful modeler can use COMBINE to gain essentially unlimited detail in DOE2.1C building energy simulation. Sophisticated building energy systems that would previously have stretched the limits of the program can be broken up into any number of smaller models and combined at the SYSTEMS level. This allows the modeler to input with great detail, if desired, all of the exterior surfaces, building shading surfaces, windows, interior surfaces, and enclosed spaces.

The master planning effort at CSUF provides an excellent example of the opportunity now available, through the use of COMBINE, to explicitly model large campus and district heating and cooling systems using DOE2.1C. A college campus, for example, can now be modeled building by building and space by space. It is possible for large system operators and planners to develop DOE2.1C simulation libraries of all of the buildings connected to their systems. Using COMBINE, they can then simulate the performance of the campus central heating and cooling plant. Should there be a change in a building, the building model can be changed, recombined, and the resulting effect of central plant performance analyzed.

An explicit modeling approach is more easily understood and accepted by plant and building engineers and operators than an abstract approach. COMBINE makes it possible use this approach on large multi-building energy systems thus extending the application of DOE2.1C to plants that were previously impossible or infeasible to simulate using the program.

Other Benefits

COMBINE works synergistically with DOE2.1C to emphasize some of the analytical power available in the PLANT program contained in DOE2.1C. Available plant equipment options include steam boilers, hot water boilers, electric boilers, low pressure absorption chillers, high pressure absorption chillers, reciprocating chillers, centrifugal chillers, double-bundle chillers, cooling towers, air-cooled condensers, thermal energy storage, heat recovery, diesel engine generators, gas turbines, and steam turbines. Such a choice of equipment readily lends itself to the analysis of innovative central plant alternatives. The ECONOMICS program in DOE2.1C is especially capable, when combined with a plant including cogeneration, of supplying straightforward, valuable analysis of the economics of cogeneration. With its ability to break through the input limits of the LOADS and SYSTEMS programs in DOE2.1C, COMBINE provides engineers and planners with a powerful tool to perform sophisticated plant analysis and simulation.

Another benefit of COMBINE is the increased efficiency of information storage on any supporting computer system. Systems intermediate files require the same amount of memory space whether the file represents just the Men's Gymnasium at CSUF or the entire campus.

FUTURE OF COMBINE

The building energy simulation projects at Kaiser Hospital and CSUF would seem to indicate the immediate benefits of using COMBINE with any mainframe or minicomputer version of DOE2.1C that is to be applied to the following types of projects.

1. Simulation applications requiring extensive detail in building input.

2. Large buildings in which the number of significant thermal zones in greater than 64.

3. Campus buildings and their associated central heating and cooling plants.

4. District heating and cooling systems.

These are areas where the use of DOE2.1C was generally not feasible prior to the existence of COMBINE.

Potential Improvements

Several opportunities exist for improvements to the COMBINE program. The further development of COMBINE for use with LOADS intermediate files is one such opportunity. The program was originally intended to be capable of combining LOADS intermediate files as well as SYSTEMS intermediate files. While the combining of LOADS intermediate files is significantly more complicated than SYSTEMS intermediate files, such a capability would allow greater flexibility in the analysis of HVAC systems, particularly self-contained systems such as water loop heat pumps.

Development of a microcomputer version of COMBINE represents another opportunity for improvement. DOE2.1C is fast becoming one of the most widely used and accepted building energy simulation tools in the engineering and building design community. This growth is due in large part to the development and marketing of microcomputer versions of the DOE2.1C. To date, a microcomputer version of COMBINE has yet to be developed. Such a development would extend the benefits of COMBINE to many DOE2.1C users who would otherwise not be able to take advantage of COMBINE. Because the input limits are even more severe on the microcomputer versions of DOE2.1C, the development of a microcomputer version of the program should fill an immediate need.

Finally, the logic of COMBINE should be examined for applicability to other building energy simulation programs. The concept of COMBINE represents a simple and pragmatic development in building energy simulation software. It is a relatively short utility program and could be applicable, in concept to any simulation program similar in general architecture to DOE2.1C. Development of similar programs for use with several other hourly building energy simulation programs may represent an inexpensive and very cost-effective contribution to the users of all building energy simulation programs.