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SERI-DOE-2 SOLAR SIMULATION STUDY

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ABSTRACT

This paper discusses the Solar Energy Research Institute's (SERI) analysis of the solar energy simulator section of DOE-2, a public domain computer program that allows users to explore the energy-use patterns of proposed and existing buildings and their heating, ventilating, and air conditioning (HVAC) systems. This computer program contains a solar energy simulation portion called Component-Based Simulator (CBS) incorporated into the HVAC Plant (large equipment) section. SERI is investigating the adequacy and sensitivity of DOE-2's solar portion when various active solar energy systems and combinations of solar components are interfaced with standard space conditioning systems or used in a stand-alone mode. The components have been assembled into typical configurations and parametric test runs have been performed examining the problems associated with the program and the characteristics of the output for eventual comparison with other energy analysis computer programs.

INTRODUCTION

To provide analysis methods that would help designers reduce energy consumption and to furnish an evaluation tool for the Building Energy Performance Standard (BEPS), the Department of Energy (DOE) has been developing a computer code to model the energy consumption and air conditioning systems designs of proposed structures. Development work on the computer program called DOE-2 has been funded by DOE at Lawrence Berkeley Laboratory (LBL) and Los Alamos Scientific Laboratory (LASL) [1]. Included within DOE-2, CBS deals with the possible solar energy subsystems of such structures. This paper will discuss SERI's investigation of CBS as a part of DOE-2 and as a stand-alone computer program. The report will describe the large DOE-2 program and CBS components and outline the SERI plan, as well as give examples of preliminary results. Finally, the paper will discuss the use of other computer codes for comparison to CBS output.

GENERAL DESCRIPTION

DOE-2 is a large computer program primarily designed to aid the architect and mechanical engineer when evaluating the future performance of air conditioning systems in new buildings. The version of the code being used at SERI is DOE-2.0A that will be current until DOE-2.1 is published and released in March, 1980 [2]. LBL and LASL are performing formal research into the operations and continued development of DOE-2 [3]. SERI is investigating the computer program in support of BEPS as part of its inquiry into all solar analysis methods with a copy of the code on the CDC 6600 computer located at the Water & Power Resources Service Computer Center near Denver, Colo. SERI is scrutinizing the solar energy aspects of DOE-2 and CBS because the program is being emphasized as a design tool and evaluation method. SERI is also investigating many other solar energy computer codes to include the national solar energy code center.

DOE-2 is a very powerful computer code, capable of analyzing many different HVAC systems over a full year. The simulations of DOE-2 are mostly directed at the HVAC loads, systems, plant, and economics as illustrated by the major portions of the program shown in Fig. 1. As one can see in this simplified diagram, DOE-2 consists of five major programs, the first being the Building Design Language (BDL) Processor with its material and weather libraries containing ASHRAE Test Reference year (TRY) data [1]. Since DOE-2 was designed to allow simplified entry of the many variables needed to describe a building and its operation, BDL is necessary to analyze the user input instructions and to control subsequent simulation portions of the program called Loads, Systems, Plant, and Economics (LSPE). After the BDL processor has prepared the input for the program, data is sent to all the other elements that are used sequentially through the process of computer overlays.

Within the LSPE construction of DOE-2, Plant, which contains CBS, is the focus of the SERI investigation into the program's active solar energy system simulation capabilities. Other research at SERI will study the passive solar aspects of Loads and Systems. Within Plant, CBS is attached to the energy supply simulation allowing solar energy to be used as if it were another conventional energy source. As the HVAC data is passed to Plant from Systems through the Modified Hourly Data as shown in Fig. 1, one can program Plant to decide how to meet the energy demand most efficiently, which may include the use of available solar energy if CBS systems are programmed into the Plant options.

Investigation of CBS through Plant, while tied to the main program, can be very time consuming and expensive; however, once a sample structure has been modelled and run through DOE-2, the Systems output can be stored in a separate file for direct use by Plant. Therefore, one can accomplish later runs that involve changes only in CBS by

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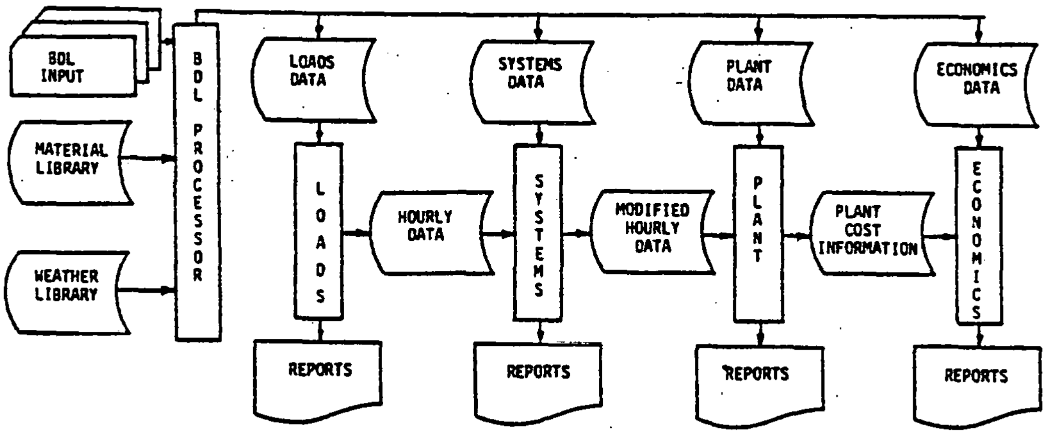


Figure 1
DOE-2 Program Outline

running Plant alone and by using previously saved Systems data files as input. Also, one can examine the reports from Loads and Systems for the HVAC load characteristics and those can be modelled separately to produce a file containing hourly loads. Both of these file-creating techniques allow one to use CBS in a stand-alone mode without needing to execute the entire DOE-2 program, thus saving time and money. One may use the degree-day simulator component available in CBS to perform the heating load calculations and to allow a parametric study of the code without using the main DOE-2 program.

CBS DESCRIPTION

The CBS portion of DOE-2 consists of many modelled active solar energy components designed to permit easy assembly by the user into various liquid and air configurations. This code structure allows flexibility in the solar energy systems design when the subsystem is still conceptual. SERI investigation of CBS is very extensive, but only a few example components will be discussed (see Figs. 2, 3, 4, and 5). CBS contains many more components than just these few illustrations including many preconnected into subsystems [2]. Figure 2 shows a collector model component consisting of four smaller components programmatically connected into this configuration. Using the procedures in CBS [2], the programmer can either use these connections of collectors, relief valves, pumps, and heat exchanger models or can chose to further divide the system into each individual component if more detail and flexibility is desired. One should refer to the CBS documentation [2] for a complete description of the possible combinations and configurations available in the computer program.

Figure 3 shows the fully mixed, unstratified storage tank component included in the DOE-2.0A version of CBS. As modelled in the figure, the fully mixed tank receives the output energy data from the collector model and simulates the reaction of a storage tank to that energy. The storage tank component then passes output data to one of the selected HVAC subsystems. Figures 4 and 5 show two possible configurations for these subsystems—one designed primarily for a commercial building and the other for a residence. As one can see in Fig. 4, the commercial system offers the designer a number of options when selecting the heating coil connections within a HVAC system. Also shown are the connections for the auxiliary system and a fresh air make-up. The residential system in Fig. 5, which has the necessary connections for the auxiliary energy system, is less complex than a real system would be in actual use.

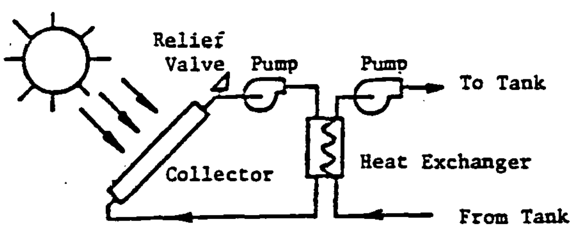


Figure 2
Collector System Model [2]

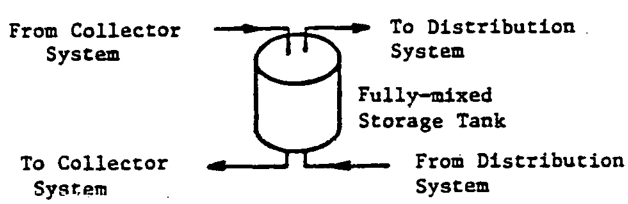


Figure 3
Storage Tank Model [2]

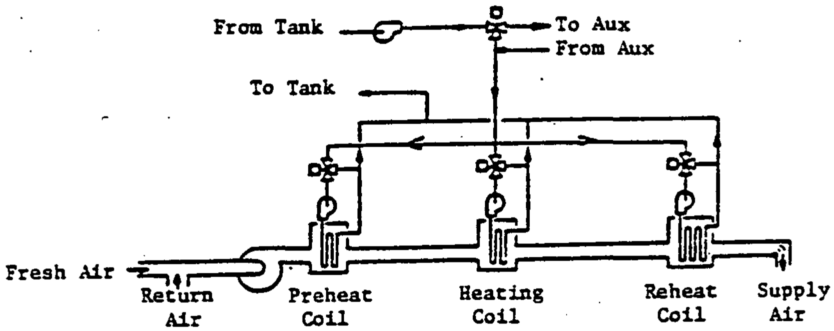


Figure 4

Commercial Distribution System Model [2]

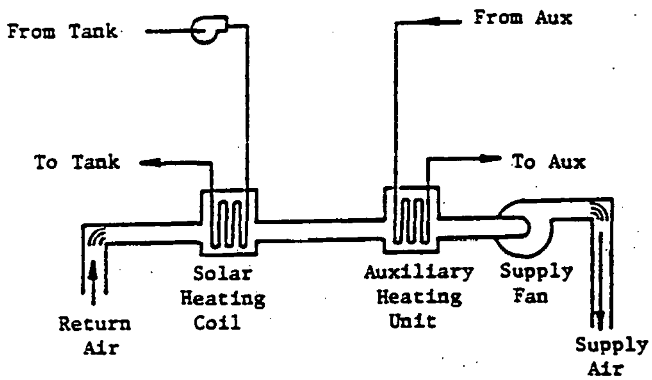


Figure 5

Residential Distribution System Model [2]

Once the solar energy system is configured by the selection and assembly of the components, the programmer chose which CBS component to use as the controller, insolation model, report format, and load simulator. As discussed previously, the load can come from a file created by a run of a DOE-2 sample, from a file of loads from any hourly simulation program, or from a degree-day load calculator. The entire program is then run for a complete year, and the results are available for study or comparison to other designs or other programs.

MODELLING APPROACH AND RESULTS

The Systems Analysis and Testing Program [4] at SERI is directing the evaluation of CBS to determine its sensitivity to various parametric changes and to compare its output to programs such as TRNSYS [5]. The researchers at SERI developed a baseline solar building model and solar energy system combination shown in Fig. 6 for the parametric studies. The basic building is patterned after Sample 3A from the DOE-2 Sample Run Book [1]. Researchers ran the complete DOE-2 program and simplified the thermal energy load output with the degree-day component into a "heating only" load. Further studies can build on this thermal energy base case. The solar energy systems were then added to the roof as shown in Fig. 6 to begin the CBS testing.

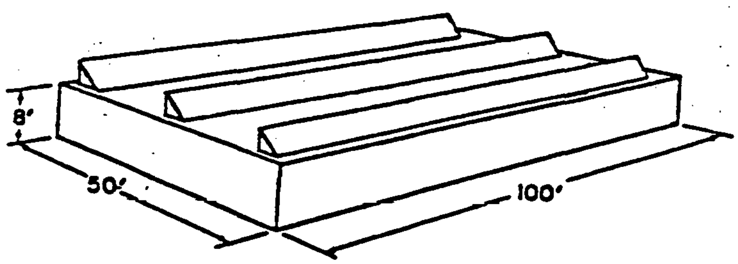


Figure 6

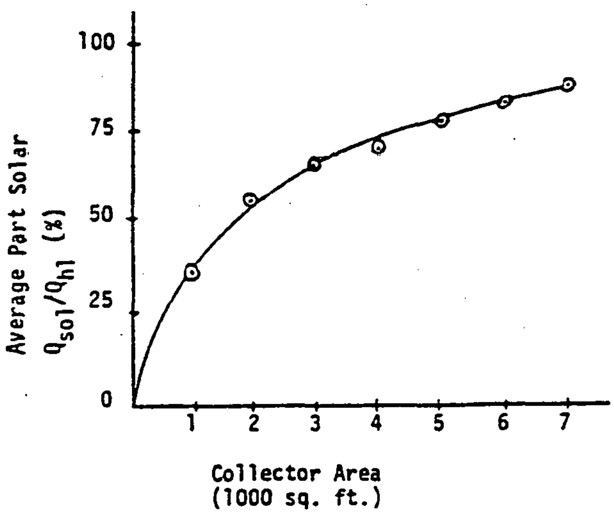
Simple Building with Collectors

The first systems tested were flat-plate collectors using liquid as a transfer medium. The city chosen was Chicago and the weather was the TRY data contained in the Weather Library. The weather data is prepared by a separate DOE-2 weather processor into a format compatible with the program. Future plans call for sensitivity studies that compare variations in site, systems design, and system types.

An example of the capabilities of CBS and one of many possible reporting formats is shown in Table 1. As one can see in this table, the program can analyze modelled solar energy systems and list the various outputs of interest to researchers. The data presented are summaries of the simulation of each hour collected into daily and then monthly reports. The trends of this system's performance can be noted and as the parameters are changed, these effects can also be observed. For this specific run, the liquid collector area was 4000 ft^2 of nonselective, single-glazed panels; the storage tank volume was 8000 gal. of water; and the ethylene-glycol water mixture flow rate was 1000 gpm. Through the variation of these and other parameters, output can be generated and then plotted as shown in Figs. 7 and 8. Figure 7 illustrates the parametric analysis of a liquid collector system using collector area as a parameter and maintaining the ratios shown for flow rate and tank volume. As one can see, the addition of collector area shows the diminishing return in increases of average solar fraction. Figure 8 shows the relationship of an optimum flow rate with the average solar fraction while holding collector area and tank volume constant. These two figures demonstrate the direction of the research at SERI on CBS.

Table 1. SOLAR SYSTEM PERFORMANCE SUMMARY

	Total Incident Energy (Million Btu)	Total Collected Energy (Million Btu)	Total Heating Load (Million Btu)	Total Solar Heating (Million Btu)	Avg. Stor. Temp. (F)	Max. Stor. Temp. (F)	Min. Stor. Temp. (F)	Avg. Collector Eff. (%)	Avg. System Eff. (%)	Avg. Part Solar (%)	Avg. Solar Bldg. Load Ratio	Total Solar Elec. Load (kWh)
Jan.	112.853	17.613	23.815	7.513	103.6	128.6	97.7	15.6	6.7	31.5	4.74	126
Feb.	126.075	23.616	19.898	10.354	106.3	126.9	98.2	18.7	8.2	52.0	6.34	150
Mar.	160.584	27.540	12.487	12.487	131.3	150.9	111.9	17.2	7.8	100.0	12.86	146
Apr.	195.927	20.820	3.146	3.146	187.4	200.3	141.6	10.6	1.6	100.0	62.28	118
May	193.832	16.281	1.085	1.086	190.9	200.9	174.0	8.4	0.6	100.0	178.61	128
June	204.565	16.548	0.031	0.031	198.0	201.9	192.1	8.1	0.0	100.0	999.00	131
July	229.639	14.692	0.000	0.000	197.3	201.5	192.2	6.4	0.0	100.0	999.00	131
Aug.	210.159	14.432	0.000	0.000	196.8	201.6	190.0	6.9	0.0	100.0	999.00	135
Sept.	196.561	11.782	0.680	0.680	194.6	200.9	186.5	6.0	0.3	100.0	289.20	105
Oct.	160.418	16.586	2.643	2.643	177.1	188.6	160.1	10.3	1.6	100.0	60.70	107
Nov.	118.594	15.092	9.530	9.487	139.0	188.6	99.6	12.7	8.0	99.6	12.44	107
Dec.	95.871	13.634	16.851	4.723	101.3	110.4	97.4	14.2	4.9	28.0	5.69	130
	2005.077	208.638	90.165	52.149	160.5	201.9	97.4	10.4	2.6	57.8	22.24	1514

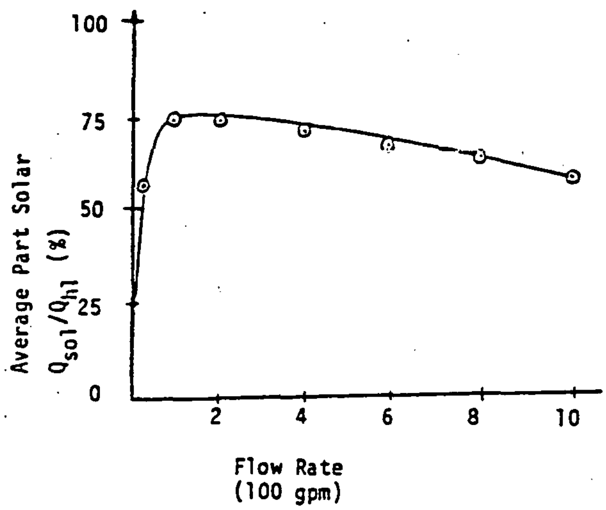


Flow rate=collector area x 0.01

Tank vol.=collector area x 2.0

Figure 7

Plotted Parametric Output (Collector Area)



Collector area=4000

Tank volume=8000

Figure 8

Plotted Parametric Output (Flow Rate)

FUTURE PLANS

Parametric analysis of CBS is being performed at SERI. Detailed comparison to TRNSYS output is a near-term objective. The plans of the Systems Analysis Branch reflect a strong desire to become thoroughly familiar with the operations of CBS both within the DOE-2 Plant and as a stand-alone modelling technique. TRNSYS appears to be the choice for the comparison of CBS to another code because of its widespread availability, its exposure in the technical community, and its generally accepted modelling accuracy. CBS is only one of many codes SERI is investigating or planning to examine closely. The researchers will compare CBS and TRNSYS outputs for agreement over a wide spectrum of solar energy systems and component combinations. Also, the researchers will vary chosen parameters to determine the changes in output of both programs and to compare any differences to develop confidence with CBS capabilities. This will be especially critical when CBS is used with DOE-2 as an evaluation tool for BEPS and to fulfill SERI's mission to become the national solar energy code center. SERI investigations of CBS support the further development of general solar energy expertise at the institution through the technical knowledge gained by the research personnel. Continued research into the operations of this and other codes supports the national planning effort for code development. All aspects of the various solar energy codes can be examined and the best of those can be highlighted for continued research. SERI is an institution that is not directly involved with developing CBS or DOE-2 and, as such, can exercise the codes and objectively report results for purposes of both research and application.

Finally, by keeping abreast of solar simulation advancements, SERI can aid LBL and LASL in determining the direction of code development by having firsthand knowledge of any shortcomings in the code and by being directly involved in future solar energy research. Such advice would be helpful by avoiding delays in program upgrading and improvements, and by having solar energy experts involved early in the conceptual phase of code development. This approach should soon benefit the modelling and analysis of proposed hybrid active/passive systems. Many other areas of investigation by LBL and LASL are possible for CBS with adequate assistance, advice, and technical knowledge from SERI.

CONCLUSION

This report has examined CBS both when used as a part of DOE-2 and when used in a stand-alone mode. A few components of CBS have been discussed as well as some typical output from a parametric study of a liquid collector system. The report also covered some of SERI's future plans for investigating the capabilities of CBS and the effects of that research on the development of the code.

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