SUNCODE-PC: A MICROCOMPUTER VERSION OF SERI/RES

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ABSTRACT: SUNCODE-PC is a multi-zone hourly simulation model available for MS-DOS machines with 8087 or 8287 chips. It is functionally equivalent to the well-tested mainframe model SERI/RES, but has been updated and enhanced. SUNCODE-PC is intended to model almost all residential buildings and most small commercial buildings; it is particularly suitable for analysis of passive solar buildings. It allows rapid, interactive data entry and has flexible input and output requirements and capabilities. A thermal network approach is used for simulation.

INTRODUCTION

SUNCODE-PC is a general purpose thermal analysis program for residential buildings. It is the microcomputer version of SERI/RES, a mainframe program written for the Solar Energy Research Institute. SERI/RES has been extensively tested by SERI and others using measured building data, and has also been compared with such mainframe programs as DOE 2 and BLAST. It has proven itself in the United States and over 14 foreign countries for over three years. SUNCODE-PC is functionally equivalent to SERI/RES; in addition, a large number of bugs have been corrected, making SUNCODE an updated and enhanced version of SERI/RES.

SUNCODE-PC is an hourly simulation multi-zone model. It uses TMY (Typical Meteorological Year) or any other hourly weather data, and employs a thermal network approach to model buildings. It is meant to have enough generality to accurately model almost all residential buildings and most small commercial buildings, and it is particularly suitable for the analysis of various types of passive solar buildings. Special provisions are made for the analysis of attached sunspaces, thermostatically controlled fans, rockbin thermal storage, phase change materials, and vented Trombe walls. SUNCODE-PC is primarily a thermal loads model. It does not simulate equipment efficiencies.

The program allows the user great flexibility in choosing the level of detail to be used both in modelling a building and in the output. This allows it to be used in a quick and cursory way to evaluate general options and, at a later stage, to perform detailed analysis of the final design.

OVERVIEW OF SUNCODE-PC

SUNCODE-PC is written in Microsoft FORTRAN. It should run on any MS-DOS machine that has 256K of memory, an 8087 or 80287 chip, and an ANSI.SYS device driver.

The program actually consists of two modules, the EDITS module and the LOADS module. The EDITS module allows quick, interactive creation and editing of building descriptions. It provides extensive error checking, and converts the building description into the mathematical form used in the actual simulation. The LOADS module performs the simulation, using hourly TMY weather data, and generates the output. Each of these modules are discussed further below.

An accompanying utility program is capable of displaying output files on the screen (allowing the user to move easily from one section of output to another), producing simple graphics, and producing ASCII files for "importing" into other programs (particularly spreadsheets) for more extensive graphics and analysis.

CREATING AND EDITING BUILDING DESCRIPTIONS -- THE EDITS MODULE

The EDITS module is used to create, display and edit building descriptions. The screen editor allows rapid interactive entry and editing of the many parameters required for a particular simulation. The user is prompted with headers that give the format and approriate units for each of the parameters entered (building descriptions may be entered in either English or metric units). Default values are available for most parameters. If certain input sections are to be used frequently without alteration, library files may be created and read into the building description. The interactive screen editing capability makes data entry fast -- an experienced user can input a complex building description in an hour.

SUNCODE allows a great deal of flexibility in the level of detail specified for both input and output. While some building description parameters are required, many are optional and may be omitted if a simple model is desired. In addition, some input variables such as heating and cooling setpoints, internal gains, infiltration rates and glazing U-value may be scheduled, i.e. assigned different values for different hours during the day or different seasons in the year. This is useful because it enables the user to more accurately simulate occupant behaviors such as nighttime thermostat setbacks, the opening of windows for ventilation, or the use of night insulation.

The type of output desired is also specified in the building description; again a great detail of flexibility exists. Results can be displayed monthly, daily or hourly. The period of simulation may cover a full year or several days. Output may be obtained for the building as a whole, or for each individual wall, fan and window. Such detailed results as hourly solar radiation and heat flux on a single wall surface may be obtained.

Finally, the EDITS module performs two levels of error checking to aid in data entry. As building parameters are entered, they are checked to ensure they are in the proper format (e.g. not too long, correct character type, etc.). If an error is encountered, the incorrect data line is displayed, and the user is immediately given the opportunity to correct the entry. Once the building description is completed, the EDITS module converts it to the mathematical form used in the simulation. At this time, it is checked for undefined or incorrect parameters; these errors are reported to the user.

BUILDING ENERGY SIMULATION -- THE LOADS MODULE

The LOADS module calculates temperatures and heat flows at various locations in the building as they change over time. Heating and cooling equipment operation and occupant behavior are also simulated. The program uses TMY or other hourly weather data with the following information: direct normal radiation, total horizontal radiation, ambient temperature, dew point temperature, and wind speed.

The building is represented in mathematical form as a thermal network with nonlinear, temperature dependent controls. The network equations are then solved repeatedly, at time intervals of one hour or less, for the period of simulation, usually one year. The mathematical solution technique uses a combination of forward finite differences, Jacobian iteration and constrained optimization.

In a thermal network, a building is conceptualized as one or more zones. SUNCODE allows each zone to have independent solar inputs and independent heating, cooling and ventilation equipment and controls. Each zone may also contain a rockbin. Zones may be connected by walls or pure thermal conductances. In addition thermostatically controlled fans may connect zones.

The points at which temperatures are calculated are called nodes. Some nodes have heat capacity; others do not. Each zone is represented by a single temperature node. All heat transfer paths are connected to the central zone node. Each wall is divided into a number of slices (usually 1 to 5), each of which is assumed to have a uniform temperature. The nodes are connected by thermal conductances or resistances.

For purposes of illustration, a typical thermal network model of a building is shown in Figure 1. This represents a two zone building. Zone 1 is a sunspace with concrete floor. It is separated from Zone 2, the living area, by a concrete wall. A thermostatically controlled fan delivers heat to the living area. The sunspace has no provision for heating, venting or cooling. The living space has all three. The sunspace is assumed to have night insulation operated on a schedule. Since the storage wall will dominate the thermal mass effects, thermal mass in the rest of the living space is ignored and a pure resistance is used to calculate heat flow to the exterior. The zone air temperatures activate the controlled sources which represent the heating, venting, and cooling

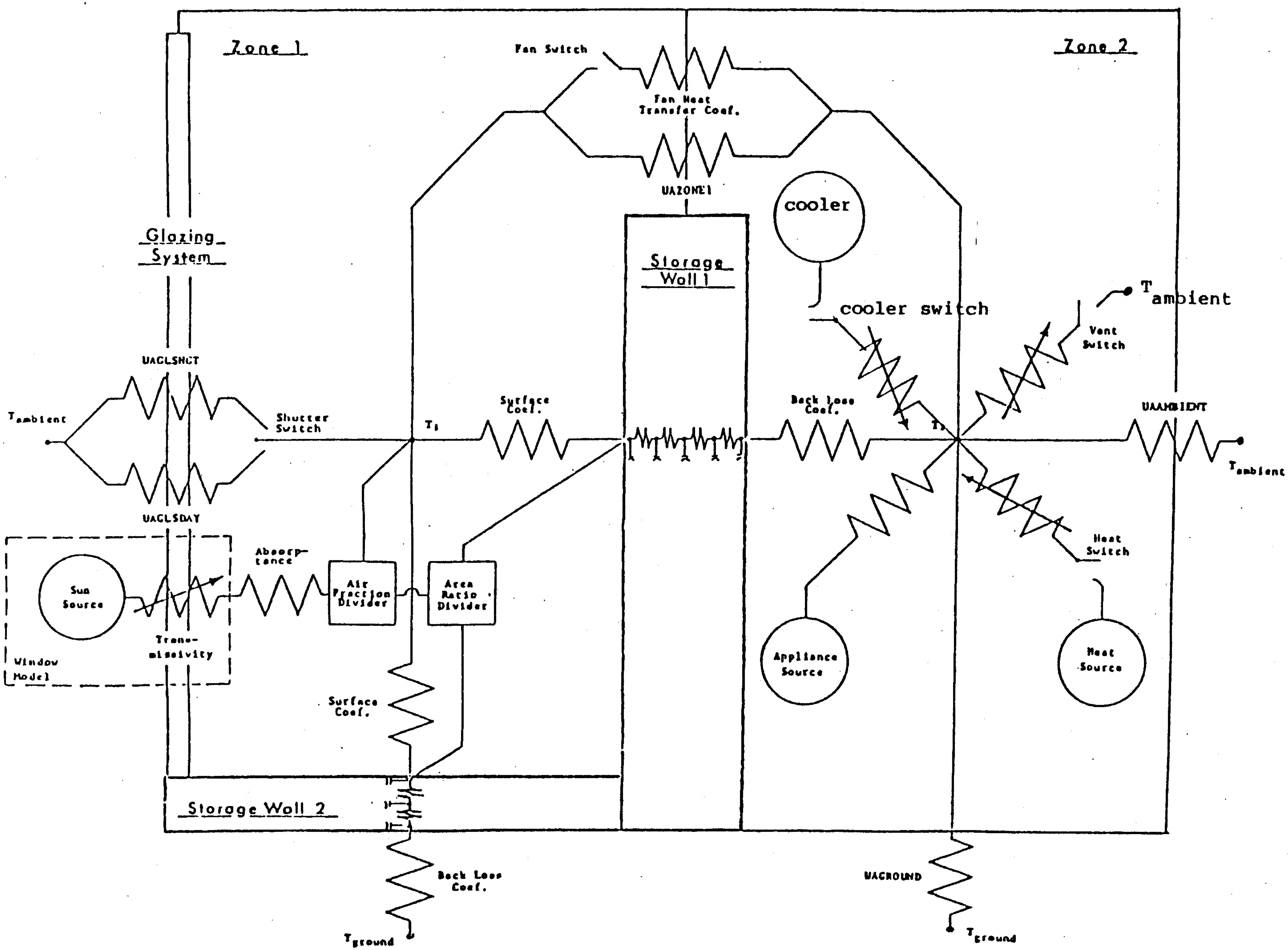

Fig. 1 Thermal Network of Sample Passive House

equipment. Some of the entering solar energy goes directly to the sunspace air temperature node, while the rest is distributed to the storage elements.

An energy balance is written for each node. The solution of the resulting set of equations is approximated by numerical techniques such as forward finite differencing.

The accuracy of simulation results depends in part on the number of nodes chosen for each wall. By increasing the number of nodes and observing the change in the results, one can determine whether more nodes are necessary. In principle, results of any degree of accuracy can be obtained at the cost of increased execution time. SUNCODE automatically calculates the minimum number of time steps required per hour to satisfy user-set convergence limits, and offers the user the option of increasing the number of time steps if desired.

SUNCODE-PC is primarily a thermal loads model. It models both thermal and latent loads, but does not simulate equipment efficiencies. In other words, the heating and cooling loads are calculated, but the actual energy needed to supply those loads with specific equipment is not calculated. SUNCODE-PC can track air moisture levels; latent heat, changing dewpoint temperatures, and moisture transport may be simulated. The effect of air conditioner operation on both zone temperatures and air moisture levels can therefore be modelled.

EXECUTION TIME

It is interesting to compare the execution time requirements of SUNCODE (SERI/RES) running on a mainframe computer with those of SUNCODE-PC running on a microcomputer. Processing a relatively detailed and complex building description and producing 60 pages of output required the following:

SUNCODE CPU time:	
DEC System 20	4.3 minutes
VAX 11/780	9 minutes
SUNCODE-PC execution time:	
IBM PC/XT	75-80 minutes
IBM AT with 80287	40+ minutes
COMPAQ Deskpro 8MHz	39 minutes

As these figures show, running SUNCODE-PC on a fast microcomputer is similar to having the power of a quarter of a VAX. In addition, the interactive screen entry and editing capabilities of SUNCODE make entering building descriptions much faster.

PROGRAM VERIFICATION

It is important for users of simulation programs to have confidence in the basic validity of the calculations performed by the program. SUNCODE-PC's precursor programs, SUNCAT and SERI/RES (SUNCODE), have been in extensive use both in the United States and abroad for over five years, and they have been subjected to a variety of tests.

SERI/RES has been chosen as one of the standard simulation programs by researchers in 14 countries. These researchers have used and tested it extensively, comparing results with measured data and with results from other simulation programs. Since SUNCODE-PC is functionally equivalent to SERI/RES, it too is validated by this work. In addition, both SUNCAT and SERI/RES have been tested in a variety of ways in the United States.

Comparison of results with measured data is the only testing method which can detect the type of errors due to an inadequate level of detail in the engineering assumptions of the model. The SUNCAT program was extensively tested with six months of hourly measured data at the National Center for Approriate Technology. Generally, agreement with the measured data was excellent [1]. Floating temperatures in the direct gain test units were matched with a root mean square error of 2 degrees F over the heating season. Since SERI/RES results for the same test matched SUNCAT results to five decimal places, the test validates SERI/RES as well. Also, R. Judkoff of the Solar Energy Research Institute has repeatedly tested several programs, including SERI/RES, by comparing results with measured data from several test buildings [2,3].

Software-software comparisons have been completed by many groups. This type of testing requires accurate and equivalent input of the building description; once that hurdle is overcome, software comparison can reveal major algorithm errors because programs without major errors will tend to yield similar results. The System Simulation and Economic Analysis working group, headed by William Wray of Los Alamos National Laboratory, has compared results of simulating several simple passive solar buildings using standard weather data [4]. Participant programs included SUNCAT, PASOLE, DEROB, DOE 2.1, CALPAS3, TRNSYS10, FREHEAT, and SUNSPOT. Software comparison tests of SERI/RES have also been undertaken at SERI [2].

The best way to find errors due to programming and calculation mistakes is to compare program results with a known analytic solution. The SUNCODE authors have performed extensive tests of this type. Sinusoidal inputs (temperature, solar radiation) were used to produce both analytical and simulated results. When recommendations for wall node spacing were followed, results from the two methods differed by less than three percent.

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