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MODELS AND FEATURES IN HOT-2000 VERSION 6

Brian Bradley
Consulting Engineer, UNIES Ltd.
1666 Dublin Avenue
Winnipeg, Manitoba, Canada R3H 0H1

Mark Riley
Chief, Buildings Group, Energy Mines and Resources Canada
580 Booth Street
Ottawa, Ontario, Canada K1A 0E4

ABSTRACT

Hot-2000 is a computer model which assists builders, engineers, and architects in the design and simulation of residential buildings for thermal effectiveness, passive solar heating, and the operation and performance of heating and cooling systems. Many of the basic heat loss algorithms were derived or adapted from the National Research Council of Canada's HOTCAN 3.0 program. Major additions and modifications have been made, mainly in the simulation of heating, ventilation and cooling systems. Weather data libraries are available for 76 Canadian locations and for 194 U.S. locations.

The program includes facilities for viewing and editing weather data and fuel cost rate structures. An economics model may be used to estimate the pay-back of energy conservation measures. All reports may be viewed on screen, printed directly, or saved in ASCII files for later printing by either a built in or an separate print spooling utility. Either a mouse or keyboard may be used for navigation through the program menus and editing screens. Both MsDos and Macintosh versions are available for use.

BUILDING DESCRIPTION

Structural Components

The structural components of the building included in the model consist of ceilings, main walls, exposed floors, doors, windows (in eight directions), and four types of basement (crawl space, slab on grade, shallow, and full depth). Each of the 25 possible components may have as many as 10 different entries. The non-window data entries consist of area and effective R-value.

In version 6 of Hot-2000, the method of data entry has been changed to accept gross area, rather than net area for each component entry. This method is more flexible in design studies where the component areas might be frequently changed to investigate various alternatives.

Window data entries are the most complex since 8 directions are allowed, and overhang data is used (in all directions) to estimate solar shading coefficients. Window R-values and solar heat gain coefficients are now estimated by the program on the basis of a 6 digit code which defines the glazing type, coatings, gas fill, window type, spacer, and frame material. The effective R-value and solar heat gain coefficient are calculated using the rough opening dimensions (window width and height) using an algorithm and tables developed by Enermodal Engineering ("Procedure for Calculating Total Window U-Value and SHGC", Prepared for Energy, Mines and Resources Canada, Nov 1990). Alternatively, as many as 12 "user defined" codes may be entered in a table and referenced in the window data entries.

Now that overhang data is provided by the user for all windows, it is now possible to "Rotate" the house by any 15 degree increment by simply selecting a new direction in which to point the South windows. (Currently only the window heat gain is affected by direction). A further option allows the windows to be "shuffled" the in any arbitrary manner.

The natural air leakage characteristics of the house may be specified either by entering fan depressurization test results (CGSB, 1985), or by selecting one of four categories of air tightness.

HVAC Systems

Forced mechanical ventilation may be specified for a heat recovery ventilator (HRV) and/or exhaust fans. For the HRV, Hot-2000 uses effectiveness and fan power data derived from test results measured at 0 C and -25 C at a balanced airflow of 55 L/s (CSA, 1985). The user may elect to size the ventilation system according to the CSA standard F326 (CSA, 1990), by specifying the number of rooms of each type to the program. Checks will then be performed to insure that either the total of the specified exhaust flow rates, or the HRV supply flow rate is sufficient to meet the standard. The selected ventilation rate is assumed constant for the whole year.

The space heating system for the house can include a furnace and a heat pump. Furnace type, fuel type, capacity, steady state efficiency, and pilot light energy consumption may be specified by the user. Electric or natural gas fired heat pump systems utilizing ambient air, groundwater, or earth coupled heat sources may be selected. User inputs include heat pump capacity, COP, and temperature cut-off type (balance point, restricted or unrestricted). The space heating system fan operating mode (continuous or auto) and power may be specified if applicable.

Three types of air conditioning systems may be specified, including conventional, ventilation cooling, and economizer modes (with dry bulb or enthalpy control). The user can select the rated COP, sensible heat ratio, indoor fan volume flow rate, cooling ventilator flow rate, fraction of window area that can be opened, fan control (continuous or auto), and the rated capacity. Calculations for sizing the air conditioning system

(CSA, 1989) are included to provide defaults if user values have not been selected.

Internal gains due to people, appliances, and domestic hot water (DHW) are specified by the user. Hot-2000 DHW systems (primary and secondary) can include solar water heaters rated in accordance with Canadian Solar Industries Association criteria.

HOT-2000 MODELS

Prior to attempting annual calculations, or printing a report, a data checking procedure is carried out to insure that all required data has been defined properly. The net area of each of the components is determined, based on the user specified locations for the door and window components. Each of the data entries for doors and windows include a location name for one of the main wall, ceiling or door (in the case of windows), or basement wall above grade entries. The checking routines insure that all location references are legal, and that all calculated net areas are greater than zero. Many parts of the checking routine are also carried out during the data editing phase so that the user can be alerted to improper definitions at the earliest possible time.

Although the time step for reports in Hot-2000 is one month, the EKB model (Erbs, Klein, Beckman, 1983) is used to divide each month into 32 temperature bins. Briefly, the EKB model assumes the frequency distribution of air temperature is an exponential whose "width" is a function of the long term variability of the monthly average temperature for the site. Calculations of heat loss and equipment operation are carried out in each bin (if applicable) in order to more precisely account for temperature dependant effects.

Natural air infiltration is estimated in each temperature bin using a variation of the model developed by Shaw (Shaw, 1987). The model accounts for air tightness, average monthly wind speed, and the effects of mechanical ventilation if present. If a furnace with a chimney has been specified, the increased infiltration during the furnace off-cycle is also estimated.

Heat recovery ventilators (HRV) are modeled assuming the heat recovery effectiveness varies in a piece-wise linear manner with air temperature. Equations developed by G.K. Yuill and Associates (Wray, 1986) define the sensible heat recovery efficiency, fan power, and pre-heater power as a function of bin (outdoor air) temperature.

A monthly heat balance is carried out in order to estimate the gross thermal heating load. For months in which there is a heating load, the ratio of solar gains to heating load is used to determine the solar utilization factor (Barakat and Sander, 1982). After the utilized solar gains have been subtracted from the gross heating load, an internal gains utilization fraction is calculated (Hot-2000 Technical Manual, 1989). The net heating load remaining after the utilized internal gains have been subtracted must be provided by the space heating system.

The operation space heating system (heat pump + furnace) is simulated for each temperature bin in which auxiliary heating is required. Depending upon the load to be met in each bin, the heat pump and/or the furnace contributions are then determined. Furnace operation includes the effects of part load losses, pilot light and fan energy, and increased ventilation induced by chimney during the on cycle. Monthly and annual estimates are made of the overall system COP, and the seasonal efficiency of the furnace.

In a similar manner, a bin method is used for simulation of air conditioner operation. The model accounts for: the variation of capacity and COP with outdoor temperature, the part-load losses, the effect of ventilation on sensible and latent loads, and dehumidification by the air conditioner. The latent load modelling allows for calculation of the indoor humidity in each temperature bin (C. Barringer, private communication, 1991, Ortech International, Mississaugua, Ontario).

Monthly and annual energy costs are calculated for each fuel type (Electricity, Natural gas, Propane, Oil, Wood) if the user has assigned fuel rate structures. The fuel rates may be selected for each fuel type on a monthly basis to accommodate utilities whose billing rates vary monthly or seasonally.

USER INTERFACE SOFTWARE

General

The program is written almost entirely in structured Fortran 77, and in such a manner that the code is almost machine independent. The "core" of the program, including the calculations and report printing modules are completely machine independent. This is easily accomplished by avoiding compiler extensions to the language.

Only the "Front-end" of the program has been made machine dependant, mostly in order to provide the Macintosh version with a compatible top level menu bar. At the top level, Macintosh users may switch to other applications if running under MultiFinder, and may also select any available desk accessory. This "Macintosh" mode is also implemented while the user is browsing through program reports to allow pasting of selected sections into the clipboard or scrapbook for use in spreadsheet or word processing software. A third party package called FaceWare provides the drivers for the menu bar and windowing.

Character String Database

All the text information which appears on the screen or in printed reports is stored in a separate "resource" file for easy translation into other Roman languages. Another advantage of this approach is that minor changes can be made to the output without changing the program.

The resource file is organized in random access mode. The character data is packed so that the information appears to be one continuous string. Any particular string (# Id) may be retrieved by a statement of the form "Call GETSTR (Id)". Memory resident directory tables locate the requested string in the file. The database file includes two classes of data, simple strings, and string lists. The lists may be printed directly to the screen, or attached as pop-up items to dialogues.

Dialogue Manager

All data editing is managed by a dialogue manager which handles all user/screen interactions. Typically, the user selects an item from a menu in order to edit the underlying data set.

Each editing screen consists of three parts, static text, data items, and control buttons. The static text is specified as an "ID" code which points into the string database. Similarly, the properties of the data items are specified by a pointer to an items list. Data item types include character strings, floating and fixed point numbers, pop-up lists, and toggles. In the case of numerical data items, if range checking has been specified, only values within the specified range are accepted. A pop-up window is displayed to show the value entered, the minimum and maximum values, and recommended range of values if applicable.

A table of item properties is used to specify the screen location, type, range, and format of each item. Dialogue lists consisting of entry numbers in this table are used to identify the data items for each editing screen. Two types of lists have been implemented, scalar lists, and array lists. Scalar lists are used for screens consisting of arbitrary data sets, and array list types are used for editing tabular data. In array lists, only the items in row 1 are explicitly specified, the remaining rows are cloned from this template.

The control buttons for a dialogue are specified by an "ID" code in the string table. For example, a typical button string is " 23 <Cancel> Done ". The dialogue manager interprets and displays this as two buttons located on line 23 of the screen, and returns a 1 or a 2 depending on which button the user selects to exit from the editing screen.

Data is passed into and out of the dialogue manager using scratch arrays of type character, integer, and real (floating point). The calling routine must set the desired program data values into these arrays before the call, and extract them upon completion of the call. Since any editing is done on a copy of the data, no special program actions are needed to recover if the user decides to quit by selecting <Cancel>.

All data relating to the appearance of the editing screens is stored in external files which are in turn generated by a separate "resource compiler". It is thus possible to make major changes in the appearance of the screens without modifying Hot-2000. A separate and much smaller program is used solely for the purpose of fine-tuning existing screens, and developing new screens for inclusion in Hot-2000.

In addition to the already mentioned advantages of externalizing these program resources, a further benefit is the reduction in memory requirements. For Hot-2000, this saves about 40k of memory. The main disadvantage of this approach is that the program now frequently accesses the file, so it is no longer practical to run from a diskette.

Many of the options presented to the user are in the form of pop-up lists. When activated, a box containing the available items is displayed on top of the existing screen. After a selection is made or the user presses <Esc>, the screen is restored and updated to show the new selection. For example, the 6 digit code used to define window type is developed from a series of pop-up windows which select glazing type, coatings, gas fill, window type, spacer, and frame material.

Machine Dependant Features

All machine dependant features in the program relate to file access, the keyboard or mouse, and the screen. If a full Macintosh style interface were adopted, considerable revision of the entire data editing system would be required.

Access to files on the Macintosh is readily available through built-in "ToolBox" routines which completely handle the standard "File-Open" dialogue. In MsDos, the file directory routine was written in assembly language, and a screen handler was written in Fortran to allow the user to navigate the file system in order to choose a file.

ANSI Fortran does not include screen management routines (EG Cls, Locate, etc). In order to avoid graphics mode with its attendant overhead, the screen is managed in Text mode (emulated on the Macintosh which has no Text mode!). A standard set of "low-level" routines were developed for each machine, using assembly language or the ANSI driver in MsDos, and calls to the Macintosh ToolBox. (So many MsDos users have had problems getting the ANSI driver loaded that the next release of the program will avoid using it).

A file transfer facility will allow MsDos and Macintosh users to exchange most user defined data files. The user weather data and fuel cost library files are always written in ASCII format. A small translation program will be provided to convert the house data files to and from binary to ASCII format. The ASCII files can then simply be transferred from one machine to the other, either directly by diskette (via the Macintosh SuperDrive), or with the use of communications programs. The ASCII house description files may also be used as input to the batch version of Hot-2000.

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