

DOE-2 USER NEWS

: A COMPUTER PROGRAM FOR BUILDING ENERGY USE ANALYSIS

PUB-391

Vol. 2 No. 2

MAY 1981

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Table of Contents

Bulletin Board.....	1
DOE-2.1A Completion.....	1
Automatic Custom Weighting Factors....	2
DOE-2.1 Output Reports.....	4
Sizing Fans for VAV Systems.....	7
Bugs Discovered and Interim Solutions.....	9
The Heat Exchanger.....	12

BULLETIN BOARD

- Item: The DOE-2 Verification Project, Phase 1, Interim Report has recently been published and is now available through NTIS. To order, see the back page of this issue for the address and phone number of NTIS.
- Item: The DOE-2 User Coordination Office is conducting a survey entitled the "Building Energy Analyst Inquiry". More information and a tear-out sheet containing a form for adding names to the mailing list appear on page 15.
- Item: The final article in the series of energy analyses of selected published buildings by Vladimir Bazjanac appeared in the April 1981 issue of Progressive Architecture. A review of the first year's program using DOE-2.1 accompanies the article.

DOE-2.1A COMPLETION

The DOE-2.1A modification tapes were sent at the end of May to the National Energy Software Center for testing and processing in preparation for release to the public. The documentation updates are nearly complete and will be sent to the printer in the near future. What this means is that DOE-2.1A should be available sometime this summer.

The new features in DOE-2.1A, other than bug-fixes about which we have told you and program messages to upgrade the quality of some algorithms, are few and relatively minor.

- 1) It is now possible to simulate strainer cycle and thermo-cycle behavior of cooling

towers to achieve "free" cooling in low humidity climates under moderate cooling load conditions.

- 2) A new code-word value for LIGHTING-TYPE has been introduced to simulate recessed, but non-vented fluorescent lamps (REC-FLUOR-NV).
- 3) A matched pair of code-words have been provided for the DIAGNOSTIC command. The default is LIMITS, which means the published limits are in effect, and the alternative is NO-LIMITS, which allows the brave user to enter values of keywords outside of the published range. There is reason for caution, since some of the limits represent the boundaries beyond which the algorithms are not applicable.
- 4) It will be possible to have custom weighting factors calculated automatically in LOADS without a separate LIBRARY-INPUT LOADS run. This feature is described in the article starting on page 2.
- 5) The peak loads calculated by LOADS at a constant temperature are not always appropriate for sizing equipment. In DOE-2.1A the ZONE keyword SIZING-OPTION set equal to the codeword ADJUST-LOADS will correct the peak loads for DESIGN-COOL-T and DESIGN-HEAT-T being different from the LOADS TEMPERATURE. Corrections are made for external wall exchange, internal wall exchange, and infiltration. This option also allows the DESIGN-COOL-T and DESIGN-HEAT-T to be specified in unconditioned and plenum zones (estimated winter and summer design temperatures) in order to allow for increased conditioned zone sizing to handle transfer from these spaces across internal walls. This feature will be described in detail in the next issue of the DOE-2 USER NEWS.
- 6) A new keyword, CRANKCASE-MAX-T, has been introduced in the SYSTEMS command to indicate the outside drybulb temperature above which the crankcase heater does not operate for DX, air-cooled systems.
- 7) There are two new SUMMARY REPORTS in LOADS, LS-E and LS-F, which are explained in the article beginning on page 4.
- 8) Similarly, there are two new SUMMARY reports in SYSTEMS, SS-I and SS-J.
- 9) The program will now work south of the equator, where LATITUDE is negative.
In development for DOE-2.1B are both vented and non-vented Trombe wall simulations, a residential evaporative cooler model, and a simulation giving credit for daylighting.

AUTOMATIC CUSTOM WEIGHTING FACTORS

A new feature in DOE2.1A simplifies the use of Custom Weighting Factors (CWF). Whenever FLOOR-WEIGHT = 0 is specified for a SPACE or a SPACE-CONDITIONS in INPUT LOADS, the CWFs for this space will be automatically calculated and passed to LOADS and SYSTEMS where they are used in the calculation of loads, extraction rates, and space temperatures. Previously it was necessary to make a separate LIBRARY-INPUT LOADS run to generate and store the CWFs in a library for later use. This can still be done, but most users will probably want to use the new automatic feature since it requires less input effort with a (small) decrease in BDL execution time. Note however that the BDL execution time in a regular LOADS run will now be increased.

As in previous versions of DOE-2, the program will use pre-calculated ASHRAE weighting factors (AWFs) for any space with FLOOR-WEIGHT > 0 assigned to it. However, the AWFs were computed for a prototypical space (a south-facing office module) with a geometry and construction which might or might not be a good representation of the building zones the user wants to model. CWFs, on the other hand, are tailored to the specifics of the space at hand. The CWFs can, therefore, be expected to give better modelling of the thermal storage effects of the building mass. In particular, the size and time of occurrence of heating and cooling load peaks, and the corresponding peak extraction rates, are more accurately determined, which has important implications for HVAC system sizing.

Following are some guidelines for using the automatic CWF feature in INPUT LOADS. (See also the documentation on generating CWFs using LIBRARY-INPUT LOADS: DOE-2.1 Reference Manual, p. III.A.11-20; DOE-2.1 Users Guide, Section 10; and the DOE-2 USER NEWS, Vol. 1, No. 2, August, 1980, p. 15-16. The physical meaning of weighting factors is discussed on p. 10-13 of the DOE-2 Users Guide.)

- 1) To get CWFs, specify FLOOR-WEIGHT = 0 for a SPACE or SPACE-CONDITIONS. If FLOOR-WEIGHT > 0, AWFs will be used. Mixing CWFs and AWFs in the same run is allowed.
- 2) Make all EXTERIOR-WALLS, INTERIOR-WALLS, and UNDERGROUND-FLOORS delayed. If a surface is quick, its thermal mass will not be accounted for in the CWF calculation. Because the response-factor calculation for delayed surfaces is expensive, users are advised to use library walls as much as possible.
- 3) Input all of the bounding surfaces of a space. This includes interior walls, floors, and ceilings across which there is negligible heat transfer. Such surfaces contribute to the radiation balance which is performed in calculating the CWFs. Also, interior surfaces, particularly

floors, often contribute substantially to the space thermal mass.

- 4) Use the full area of underground walls and floors, not just the perimeter area. This is especially important for slab-on-grade structures where most of the thermal mass could well be in the slab. To avoid unrealistically high heat transfer to the ground when the full slab area is used, a new keyword, U-EFFECTIVE, has been added to the UNDERGROUND-FLOOR command. It works as follows: if the UNDERGROUND-FLOOR is described as delayed (as it should be for CWFs) and if U-EFFECTIVE is input, then the response factors for this surface will be used in the CWF calculation, but the heat transfer in LOADS will be calculated as

$$(U-EFFECTIVE) * A_T * (T_G - T_R),$$

where

A_T = total slab area

T_G = ground temperature

T_R = LOADS calculation temperature.

Therefore, if the user is starting from a LOADS input where the full U-value, U_T , of the UNDERGROUND-FLOOR was used, along with a perimeter area, A_p , then: A_p should be changed to A_T ; a delayed construction should be assigned; and an effective U-value should be input, as calculated from

$$U-EFFECTIVE = U_T \frac{A_p}{A_T}$$

- 5) In existing input decks, pay special attention to quick INTERIOR-WALLS with U-value chosen to be large ($U > 0.709 \text{ Btu/ft}^2\text{-h-}^\circ\text{F}$) to account for heat exchange due to air movement through openings in the wall. For CWFs, an additional INTERIOR-WALL should be entered if an actual wall (as opposed to an imaginary partition) separates the zones. The additional wall should be delayed and its area should be exclusive of openings.

The result will be the following. The original wall will effect only the air-temperature weighting factor calculation. The added wall will participate in the detailed thermal balance calculation that produces the other weighting factors (i.e., the solar, lighting, people/equipment, and conduction weighting factors). Both walls will contribute to heat exchange in LOADS.

- 6) The approach to specifying SOLAR-FRACTIONS is somewhat different in DOE-2.1A:

- a) If no SOLAR-FRACTIONS are input for a SPACE, then the program will assume that 60% of the incoming solar radiation is absorbed by the floor; the remaining 40% will be distributed to the other surfaces (excluding windows) according to surface area. If there is no floor, the full 100% will be distributed according to surface area. Note that unless TILT = 180 is specified for an UNDERGROUND-FLOOR, it will not be considered a floor in the CWF calculation. (The default value for TILT is 90° for UNDERGROUND-FLOOR.) Similarly, if an INTERIOR-WALL is a floor in the space in which it is defined, it should have TILT = 180; if a ceiling, it should have TILT = 0.

This 60/40 split should give reasonable solar weighting factors for most situa-

tions. Since no SOLAR-FRACTIONS need be input in this case, it is the most convenient approach to use.

- b) To override the 60/40 split of SOLAR-FRACTIONS, the user can explicitly specify all of the SOLAR-FRACTIONS, or just some of them. In the latter case, the program will sum the ones that are specified and distribute 100% minus this sum to the other surfaces. Thus one could input SOLAR-FRACTION = 0.7 for the floor and have the program distribute the remaining 0.3 to the walls and ceiling.
- 7) The WEIGHTING FACTOR SUMMARY REPORT shows the weighting factors for each space, whether CWF or AWF. To get this report, specify VERIFICATION = (LV-K) in the LOADS-REPORT command.

DOE-2.1 OUTPUT REPORTS

One of the advantages of default values for keywords is that they substantially reduce the amount of input required to simulate a building. One of their disadvantages is that the hasty user, who allows many keywords to default, may end up in effect modeling a building which is different from the one desired. Seemingly the safest keywords to allow to default are those which specify which output reports should be produced. These do not affect the simulation of the building and, consequently, appear less important than the other keywords. If the user is interested only in total energy use and is satisfied that the building is being adequately modeled, this practice is harmless enough. The yearly or monthly energy values can be recorded and the conclusions drawn. A problem arises, however, when things do not go as anticipated. Then the user must move into a diagnostic mode of enquiry and for this purpose must have available to him or her the data which will point out the source of the surprising results. The practice of asking only for the default reports under these circumstances leads to frustration; the information which is required simply is not available.

Obviously, a compromise must be made between being overwhelmed by excessive output and being starved for diagnostic data. To assist the user in deciding which reports to request, the following summary has been developed, along with a modeling strategy.

Each simulation program has its own reports and, with judicious use, these can be requested and reviewed in order before going on to the next part of the simulation. It is recommended that the user make use of the ability to store the intermediate output files, so that a successful LOADS run, for example, need not be repeated, while one is getting SYSTEMS in order.

LOADS

The default report for LOADS is LS-D, the Building Monthly Loads Summary. This report gives for the whole building the summed monthly heating and cooling loads, along with the outdoor temperatures and the date and time of the coincident building peak in each month. It also gives the monthly sum and peak electrical loads from the data input in LOADS. What it does not tell the user is the peak heating and cooling load for each individual zone (LS-A), the breakdown of the peak load among the various building components either for the individual zones (LS-B) or for the building as a whole (LS-C). In particular, LS-D provides no information at all about unconditioned or plenum zones (if they are specified with ZONE-TYPE = UNCONDITIONED). If the monthly and yearly totals do not seem intuitively reasonable, the user who takes only the default report will have no hint about where the problem lies. As

pointed out in the last issue of USER NEWS, the verification reports can be used to validate that the input was as intended, but they cannot indicate what the effect of that input will be on the loads. Perhaps the large heating loads are the result of an overestimated infiltration, and the small cooling load is a consequence of forgetting to input a light schedule in one of the zones. These errors can be detected by scanning the LS-B or LS-C reports, which give the contribution of the building components to the peak load. An even more detailed description of the building components will be available in DOE-2.1A, where new reports LS-E and LS-F provide monthly and annual contributions to the zone and building loads, respectively, from each of the building components. If the user wants to calculate the size of the HVAC equipment for input to SYSTEMS, these other reports will be useful.

The above considerations suggest that the user obtain all the SUMMARY reports in the first run; check to see that the simulation is understood to this point; make a new run, requesting only the LS-D report (i.e., delete the LOADS-REPORT command); and store the results of this run.

SYSTEMS

Once the LOADS run seems acceptable, the input to SYSTEMS can be finished and executed. Again, if only the default reports are requested, i.e., if no entry is made for SYSTEMS-REPORT, the only output will be the SV-A and SS-A reports for each SYSTEM command entered. Unlike the LOADS verification reports, SV-A does not simply echo the user input, but reflects the results of any sizing calculation performed by the SYSTEMS program, based on the loads and the data provided by the user. The user should review these results to ensure that they make sense for the system that is to be modeled. The other default report (SS-A) will be described below.

The various SUMMARY reports in SYSTEMS can be divided into three groups: those that deal with individual systems (SS-A, SS-B, SS-C, SS-H, SS-I, SS-J), those that treat the behavior of the zones and the coils or baseboards located in the zones (SS-F and SS-G), and those that describe the totals for all the systems in a single PLANT-ASSIGNMENT (SS-D and SS-E).

Judiciously choosing, according to the type of system, as many of these reports as are appropriate for the first runs of the SYSTEMS program will allow the user to track down erroneous input when the SS-A reports yield surprising numbers. Having reassured oneself that the numbers make sense, the SYSTEMS output can be stored, the PLANT input completed, and then run.

System-Level Reports

The SS-A report (the default SUMMARY report) provides, generally, the monthly energy loads for cooling, heating and electrical operation being passed to PLANT for each system input by the user. For DX systems (RESYS, PSZ, PMZS, PVAVS, PTAC) only a utility load is passed to PLANT and SS-A provides only partial information. For example, the heating energy shows up as zero! To get a picture of the heating performed by these systems, one must look at the SS-B and SS-H reports. The SS-B report shows the heating done by zone coils (or gas or oil furnaces), baseboards, and preheat coils is summed for all zones in the system. This report also displays the cooling done by zone coils as in TPIU, FPIU, TPFC, FPFC, HP type systems. The cooling supplied by natural ventilation in the RESYS system is reported under the zone cooling column in this report. For only this system, the entries under PRE-HEAT COIL ENERGY are the electrical input (in BTU) for the furnace fan when the furnace is running.

Although the SS-A report includes information on the total electrical energy used for heating, cooling, fans, this information is aggregated with the electrical loads passed on from LOADS for lights and equipment. The detailed information on the consumption by the HVAC equipment is given in the SS-H report. This report lists the monthly total and peak consumption for fans, furnace fuel, electric heating, and electric cooling. The furnace fuel column will be used only if the furnace simulation in SYSTEMS is requested.

When one is using a system that has both heating and cooling available at the same time, there is the danger that energy is being wasted by heating air that the system has already cooled. This information is given in the SS-C report which describes month-by-month the total number of cooling, heating, and concurrent cooling-heating load hours, as well as, the heating and electrical load at the time of the cooling peak load for the system.

There are two new SYSTEMS reports in DOE-2.1A. These are SS-I and SS-J. The first reports on a monthly basis the total sensible and latent cooling. In addition to these monthly totals, SS-I reports the maximum cooling load in the month, the sensible heat ratio at the maximum load and the day and hour of the maximum. SS-J presents an hourly report for the days containing the maximum cooling (sensible and latent) and maximum heating loads. The outside wetbulb and drybulb temperatures are given hourly along with the cooling load and the heating load, respectively.

Zone-Level Reports

If one wants to know how well the system was sized, it is necessary to know how well the temperature set-points are kept. It may also be important to know what contribution the baseboards made to meeting the heating load. The SS-F report provides information on the heat extraction and addition loads in the zone, the heating done by baseboards in the zone, the temperature extremes in the zone during conditioned (fan operating) hours and the number of hours the zone is either under-heated or under-cooled (i.e., outside twice the throttling range). The last information often reflects how well the system is able to meet the start-up loads in the morning.

The SS-G report displays for the zone level coils, the same information as appears in the SS-A report for the entire system, i.e., a monthly total heating, cooling, and electrical energy consumed. The total of the values in the SS-G reports for all the zones in a system should yield the values printed in the SS-A report.

PLANT-ASSIGNMENT-Level Reports

The SS-D report (which is printed first in the output, since it is the overall summary for all the systems) is the monthly loads summary for the entire plant, i.e., the sum of all the systems-level (SS-A) reports. This report specifies exactly what loads are being passed to PLANT to be met there. For DX systems only an electrical load will appear here. For other system types there will generally be both a cooling load and a heating load being passed to PLANT.

The SS-E report summarizes for all the systems combined the information given in the individual SS-C report for each system.

PLANT

In addition to the PV-A verification report, which simply records the sizes of the various equipment entered into the simulation, the default reports provided by the program are the PS-A, PS-B and the PS-D reports. These reports provide in turn the following information:

PS-A A breakdown of monthly energy loads and fuel use by end use, i.e., total heating, cooling, and electrical loads; recovered energy and wasted recovered energy; heat and electric input for cooling; fuel and electric input for heating; fuel input for electricity; total fuel input; total energy used at the site; and, finally, the total energy used at the source.

PS-B A monthly summary by fuel or utility type of total energy and peak energy demand, along with the day and time at which the peak occurred.

PS-D A summary showing for each type of equipment what fraction of the load that was met by that type of equipment and what fraction of the load was not met by the plant.

There is much about the performance of the PLANT equipment that is missing from these reports and that can be found in other reports. For example, to maximize the energy conversion efficiency it is important that each piece of equipment operate at its optimum part-load ratio. The PS-C report shows the number of hours each type of equipment operates in each 10% segment of its part-load curve. The report also summarizes the annual load seen by that equipment and the fuel or electricity used to meet the load. By examining this report decisions can be made about alternative choices of numbers and sizes of equipment of each type and about the kind of load management that will increase the overall efficiency of operation. Also useful for this purpose is the PS-H report. This report supplements PS-C by providing the average operating ratio, the maximum load and the time of occurrence, and the number of hours of operation for each size of that equipment type for each type of equipment.

The practice of electrical utilities to charge in part based upon peak loads and/or the time of day and the desire of engineers to find ways to lower the peak requires knowing how much of the electrical load occurs at what hour of the day. A scatter plot of the number of hours during the year of an electrical load in each of 13 bins is displayed for each hour of the day in the PS-G report. This chart is useful when peak shaving strategies are being considered.

Assuming the user has entered appropriate cost information for the equipment used, there are two reports which summarize the life-cycle energy, equipment and operating costs. The PS-I report will summarize the life-cycle equipment costs for each type and size of equipment installed. The PS-J report describes

the plant operation over the life-cycle of the building. Included here are the energy and operating costs for the entire life-cycle with a year-by-year breakdown of these costs discounted in terms of present dollars. This report is essential, if the user intends to do a retrofit study. The input for the BASELINE command in ECONOMICS is taken from this report.

The last report in PLANT is the BEPS report. This report was developed for the Building Energy Performance Standards and provides an attribution of annual utility and fuel use among the categories: space heating, space cooling, standard HVAC auxiliary equipment (including fans and pumps), domestic hot water, auxiliary equipment associated with an active solar system, lights, vertical transportation, and other miscellaneous equipment. It also reports the total site and source energy in thousands of Btu per square foot.

Afterword

For the most part this article has treated only the SUMMARY reports. The VERIFICATION reports should not be overlooked as well. These reports reproduce the user's input in a different format. Often glaring input errors will show up by perusing these reports. Having input errors that do not cause a programmed abort are the most insidious of the errors, since they mean that the program is simulating a different building than envisioned by the user.

The reports are generated by DOE-2 after each simulation program. Thus the SYSTEMS reports are assembled after the SYSTEMS simulation has gone through the entire RUN-PERIOD. This means that if the program is interrupted or aborts during SYSTEMS, for example, there will be no output reports for SYSTEMS.

Finally, the user should look into the use of hourly reports, especially when there are results that look strange in the standard reports. By examining the appropriate variables over several days of simulated behavior, one is often able to detect the effect of mistaken input or program deficiency. A later article will discuss the hourly reports.

FAN SIZING FOR VAV SYSTEMS

The underlying principle that leads to the use of a variable air volume (VAV) system is to move only that mass of air that is required to maintain space set-point temperatures. Such a principle permits a savings, compared to constant volume systems, of fan electrical energy in addition to lowered heating and cooling coil loads. The designer desires to choose a fan that will perform efficiently during most of the operational hours. The peak flow-rate is to be determined such that the peak coincident load of the conditioned spaces is just met by the system. The minimum flow-rate ideally would be determined either by the peak heating load or by the ventilation requirement, but quite often is set by the surge point of the fan. Another consideration that affects the minimum flow-rate selected is the load during morning warm-up or cool-down. When the fan is sized by the coincident peak (steady state) load, during a morning warm-up or cool-down period all the zone VAV boxes may be wide open and asking for more air (the non-coincident flow-rate) than may be available from the fan. Finally, the minimum flow rate may be chosen for reasons of moisture control. As the space sensible load decreases, the air-flow volume decreases. Since the space latent load does not necessarily decrease by an equal amount and since the dehumidification process is tied to the rate of air-flow across the cooling coil, the relative humidity is likely to increase. If the relative humidity increases to an unacceptable degree, the air-flow rate will have to be increased to handle the moisture problem.

In DOE-2.1, the hour-by-hour behavior of a VAV system can be simulated quite well. How well the program works for a particular project will depend upon how closely and completely the user-supplied data (or the program defaults) describe the parameters of the system, thereby ensuring that the issues mentioned above can be handled in a meaningful way.

If no flow-rate (ASSIGNED-CFM) has been specified for a zone, the maximum flow-rate to the zone is calculated by the program to be the amount required to meet the peak sensible heating or cooling load calculated by LOADS and reported in LS-B. The minimum flow-rate to the zone (or the heating flow-rate, if there is no reverse action) is calculated from the maximum flow-rate using MIN-CFM-RATIO, if this is input by the user. Otherwise, the minimum flow-rate is calculated as the maximum of that required to meet the ventilation requirements (including exhaust make-up) and the peak heating load as calculated in LOADS. The sum of the zone design maximum flow-rates is the non-coincident peak flow-rate.

If the user has specified a SUPPLY-CFM that is not equal to the non-coincident flow-rate calculated by the program, the program will adjust the calculated maximum zone flow-rates by a factor equal to the ratio of the SUPPLY-CFM and the previously calculated non-

coincident flow-rate. Thus if one wants to specify a coincident flow-rate (SUPPLY-CFM) that is different from the sum of the non-coincident zone flow-rates, all the zone flow-rates (ASSIGNED-CFM) must be specified. The program will ensure on an hourly basis that the total flow-rate will not exceed the product of SUPPLY-CFM and MAX-FAN-RATIO. The values of MAX-FAN-RATIO and MIN-FAN-RATIO control the range of allowable flow-rates through the main system fan. If the MIN-CFM-RATIO is less than the MIN-FAN-RATIO (the fan surge point), the program simulates a fan bypass to maintain the flow.

If the user does not specify a SUPPLY-CFM, the program calculates one as follows. If there is only one system in the PLANT-ASSIGNMENT and SIZING-OPTION is COINCIDENT (the default for VAV systems), the program uses the building coincident peak loads calculated in LOADS and reported in LS-C. In all other cases the program must use the non-coincident sum of the zone peak flow-rates. It should be noted that the coincident load calculated by LOADS may not be a very good value, and the user is urged to check the ratio of the coincident to non-coincident flow-rates for reasonableness. A common error is that the calculated coincident flow-rate is far less than the non-coincident flow-rate, resulting in a significant cool-down problem in the morning or a very inefficient operation.

The closing of the VAV box in each zone is controlled by the space thermostat. The program assumes that the VAV box is fully open whenever the zone temperature is greater than or equal to the value of COOL-TEMP-SCH plus $\frac{1}{2}$ the THROTTLING-RANGE. It also assumes that the box is at its minimum flow (MIN-CFM-RATIO) whenever the zone temperature is less than the value of COOL-TEMP-SCH minus $\frac{1}{2}$ the THROTTLING-RANGE. Unless a REVERSE-ACTION thermostat is specified, the flow-rate remains at this minimum throughout and below the heating throttling range.

If COOL-CONTROL is WARMEST, the program divides the throttling range around the value of COOL-TEMP-SCH into two equal sub-ranges. The top half is used to control the flow-rate and the bottom half is used for a temperature reset signal to the cooling coil controller. If any zone is in the top half of its cooling throttling range, the coil reset signal is asking for the coldest possible air. This ensures that the volume is at its minimum in all zones before the coil temperature is allowed to float upward and avoids controller oscillation.

If a value for MAX-HUMIDITY has been specified, the program simulates control of the return air relative humidity at the specified set-point. This control is accomplished by overriding the specified COOL-CONTROL mechanism and resetting the cold supply air temperature downwards toward MIN-SUPPLY-T. If the supply

air temperature is already at MIN-SUPPLY-T, then no further dehumidification can occur.

If additionally a REVERSE-ACTION thermostat is specified, the program simulates the VAV box reopening to its maximum as the zone temperature falls through the throttling range surrounding the value of HEAT-TEMP-SCH. This strategy makes sense, of course, only if a reheat coil (which the program sequences on first) is placed in the zone or if the supply temperature is elevated during the heating season. Otherwise, opening the box in the zone would force the temperature in the zone to an even lower level.

It should have become apparent by now that many of the potential control systems for VAV systems have conflicting actions. This is the case in the real world and is not simply a defect in DOE-2. This being the case, it is important to understand the interaction among the control systems. A low MAX-HUMIDITY can

effectively counteract the use of COOL-CONTROL = WARMEST. Conversely, using a WARMEST control in a VAV system can cause humidity problems. A low coincident to non-coincident ratio can cause a severe cool-down problem. Steady state heating requirements which govern the MIN-CFM-RATIO can cause severe warm-up problems unless a REVERSE-ACTION thermostat is specified. These are just a few of the system interactions the designer should take into account.

Whatever the strategy the user intends to model, he/she is advised to check both the heating and the cooling flow-rates for reasonableness. The ratio of the coincident to the non-coincident flow-rates should also be checked as acceptable. Future program development will lead hopefully to an even more intelligent sizing method for VAV fans. Even then, however, the user should check the design parameters as well as the simulation results for reasonableness.

NEW BUGS DISCOVERED IN DOE-2.1 AND FIXED IN DOE-2.1A

The following is a list of new bugs discovered in the DOE-2.1 version of the code since the last issue of the DOE-2 USER NEWS, dated February, 1981. They have been fixed in DOE-2.1A, which will soon be available through NTIS. An update package to the documentation to accompany DOE-2.1A will also be published at that time.

CLASSIFIED INDEX

This index is intended to cross-reference bugs by 1) abort routine, 2) system-type affected (except those affecting all systems), 3) report affected, and 4) subject matter, command, and/or keyword.

<u>ABORT ROUTINE</u>	<u>SYSTEM-TYPE</u>	<u>SUBJECT/COMMAND/KEYWORD</u>
DESIGN: 131	HVSYS: 132	Baseboards: 128
DDSF: 122, 127	SZCI: 124	Deadband heating and cooling: 124
LSDFIL: 119		Exhaust: 127
OUTFIE: 133		LIKE: 119, 120, 121, 122
SDSF: 122, 127		MIN-CFM-RATIO: 126, 131
SZCI: 124		MIN-HUMIDITY: 130
Various routines: 122, 131		SCALE: 121
		Systems design: 126
		Supply air calculation: 123, 125, 126
		Variable air volume systems: 129

BDL

[118] The default performance curves for PLANT equipment have been given u-names (see Reference Manual, V.42-43). If, in the EQUIPMENT-QUAD command, the user substitutes the u-name of a default curve for one type of equipment with a different type of equipment, the program will ignore the substitution and use the default curve for the second piece of equipment. For example, the user desires the single-stage and the double-stage absorption chillers to have similar part load curves and enters for ABSOR2-HIR-FPLR the u-name HIRPLR1 (the default curve for ABSOR1-HIR-FPLR). The program will ignore this input and will use the default curve HIRPLR2 for ABSOR2-HIR-FPLR.

Interim solution: The coefficients of the desired default curve should be entered into a CURVE-FIT command and given a new u-name. The program will recognize the new u-name.

[119] If a user LIKEs a command to one which has not previously been defined, the program issues the error message, ***SYMBOL PREVIOUSLY UNDEFINED***. However, if the undefined command has been referenced previous to the LIKE instruction (e.g., with a NEXT-TO keyword), then the program will not issue an error message, but will abort in routine LSDFIL. For example, the following will cause an abort:

```

IWALL-1 =INTERIOR-WALL AREA=1001 CONS=IW-1
        NEXT-TO SPACE-1 ..
SPACE-2 =SPACE LIKE SPACE-1 ..
SPACE-1 =SPACE AREA=1200 VOLUME=3500 ..

```

Interim solution: Re-arrange input.

[120] If the user LIKEs one command to another, and if that command contains keywords that take a list, then, if the user inputs an incomplete list in the second command, the remainder of the list will taken from the first command. This is an undesirable feature of the way LIKE works. For instance, if one system is defined with two plenums and a second system LIKEd to it has only one plenum specified, the LIKE will cause the second plenum in the first system to be also in the second. This will usually result in an error.

Interim solution: If the systems have unequal numbers of plenums, define the system with the least number of plenums first, with the next larger number second, etc.

[121] The SCALE and BIAS options in the DAY-SCHEDULE command do not work properly. The keywords are underlined, with the warning "PREVIOUSLY GIVEN A VALUE" and is ignored by the program. Also, when LIKE is used in another DAY-SCHEDULE, the SCALE and BIAS of the second one are not picked up.

Interim solution: None.

- [122] If an "unused" keyword is used in a system and then another command is LIKEd to this first command, and if that second command also has the "unused" keyword specified, then BDL forgets that the keyword is unused in the second command. This can sometimes cause an abort in DDSF, SDSF, or some other routine in SYSTEMS. Example; the following input will cause an abort:

```

US1=SYSTEM      SYSTEM-TYPE=TPFC
                  FAN-CONTROL=SPEED ..
US2=SYSTEM      LIKE US1
                  FAN-CONTROL=SPEED ..

```

Interim solution: None; do not use "unused" keywords and attempt to LIKE them.

SYSTEMS

- [123] The MIN-SUPPLY-T and MAX-SUPPLY-T are intended to be limits to the temperature of supply air entering the zone after active heating or cooling. If the mixed air temperature calculated for the hour is below MIN-SUPPLY-T or above MAX-SUPPLY-T and if no coil is active to treat the air (mixed air passes into the space), the program incorrectly changes the temperature of air entering the space to keep within these limits. This will have a significant effect if either of these two values is significantly different from the range of expected mixed air temperatures.
- Interim solution: If the mixed air temperature can be expected to fall occasionally outside of the range MIN-SUPPLY-T to MAX-SUPPLY-T, lower and raise the MIN- and MAX-SUPPLY-T, respectively. The coil can be manually sized, if a different size is required from that calculated using these new design temperatures.
- [124] If, in system SZCI, during the first simulation hour the fans are on, the first zone is in its deadband, the program aborts in routine SZCI. During other hours, the return air temperatures from zones within their deadbands are calculated incorrectly. Except for the case causing the abort, this bug does not cause a major miscalculation.
- Interim solution: None, except to try switching the zone list order, or making sure that the RUN-PERIOD starts when zones will not be within their deadbands.
- [125] When there is a large cooling load in the winter (low wetbulb and drybulb temperature) and a fixed small amount of OA (so that very little cooling can be done with OA), the calculated coil capacity can be estimated as too low (< 50 per cent design). This is due to the poor capacity functions (linear) in the program as well as the program extrapolating the curves beyond a reasonable value -- they are taken to 55 degrees wetbulb. This will be changed to 60 degrees wetbulb.
- Interim solution: Raise the capacity or input a new function for capacity (both sensible and total -- could be constant equal to 1.0).
- [126] If no MIN-CFM-RATIO is input at the system or zone level, it is calculated on the maximum of the ventilation or heating requirement zone by zone. If the ventilation requirement is input at the system level only, it is not used for this calculation. Therefore, MIN-CFM-RATIO will be calculated for the zone LOADS heating peak only.
- Interim solution: If the user wants the program to calculate MIN-CFM-RATIO, then OA must be specified at the zone level.
- [127] When all air is exhausted from the zone instead of centrally, the program aborts in either routine SDSF or DDSF with an indefinite result.
- Interim solution: None; do not allow 100 per cent zone exhaust.
- [128] When baseboards are used in conjunction with an air system with a reheat coil, the baseboards are supposed to sequence on first in response to a heating load. Instead, the reheat coil is coming on first.
- Interim solution: None. There is no energy effect.
- [129] In a variable air volume system (usually with a fixed amount of OA) or a constant volume system where there is no central heating, the supply temperature from the main air-handler can be estimated high or low by a few degrees. It is estimated high in the variable air volume system due to the use of the design CFM instead of the CFM from the previous hour. It is estimated low in the other systems when the scheduled supply temperature is above that obtainable from the mixed air and there is no heating coil available.
- Interim solution: The variable air volume high estimate can be cured by increasing the total and the sensible capacity of the cooling coil by a large amount. There is no cure for the low estimate at this time.

- [130] When MIN-HUMIDITY is high enough to cause condensation on the coil at the given supply temperature, it is possible for the program to incorrectly calculate a heat generation in the duct or "positive heating load". Thus, some of the heating energy or peaks may be positive, or a negative electric heating load may be reported.
Interim solution: Remove the MIN-HUMIDITY keyword, or give it a value of 20-30, instead of > 30.
- [131] If, in a system-type that allows MIN-CFM-RATIO < 1 and the heating airflow rate is zero (no peak heating, no exhaust, no ventilation, or MIN-CFM-RATIO is 0.0), then the program will use this zero in the denominator of a calculation and thus abort, in routine DESIGN.
Interim solution: Add a small value for MIN-CFM-RATIO, exhaust, or ventilation.
- [132] When using HVSYS system, if both HEAT-CONTROL and HEAT-SET-T are allowed to default, then a constant CFM of hot air is created whenever the fans are on. This results in much overheating and a large heating load.
Interim solution: Always specify HEAT-SET-T equal to or less than DESIGN-HEAT-T and also specify a REHEAT-DELTA-T for zone heating when using HVSYS system. This bug will be fixed by changing the default for HEAT-SET-T to be the weighted average DESIGN-HEAT-T under these circumstances.

ECONOMICS

- [133] The program aborts in routine OUTFIE if an ECONOMICS run is made with no COMPONENT-COST command.
Interim solution: None; Use at least one COMPONENT-COST command when doing an ECONOMICS run.

THE HEAT EXCHANGER

This section is devoted to common, and uncommon, questions from users and responses from the DOE-2 User Coordination Office. Your questions and comments are most welcome.

* * * * *

Question: One of the popular conservation measures is the reduction of domestic hot water (DHW) temperatures. There seems to be no way to do this in DOE-2.1, since the temperature of the DHW never appears as a keyword. Do you have a trick?

Answer: In some future version of DOE-2 it would be desirable to change the algorithm for the domestic hot water heater so that it would respond to user-input of entering and leaving water temperatures. The entering water temperature should be schedulable with the monthly ground temperatures as a default. In the meantime it is necessary to go back to the definition of the HOT-WATER keyword in the BUILDING-RESOURCE command. If G is the maximum number of gallons of hot water used in an hour, then:

$$\text{HOT-WATER} = 8.33 \times G \times (T_{\text{out}} - T_{\text{avg. in}}),$$

where T_{out} is the set-point for the DHW heater and $T_{\text{avg. in}}$ is the average input water temperature to the DHW heater. When the DHW set-point is changed, then HOT-WATER must be changed accordingly.

* * * * *

Question: Another energy conservation measure, related to that above, is to use the recovered heat from a double bundle chiller to heat up the DHW. Unfortunately, in DOE-2.1 the hierarchy for the HEAT-RECOVERY command places the DBUN-CHLR below that for PROCESS-HEAT. Is there some way around this?

Answer: The hierarchy in the HEAT-RECOVERY command indicates the relative supply and demand temperatures under "normal" or conventional operation. Thus, usually the output temperature from the double bundle chiller is below that required to heat the DHW. Since the program does not check to see that the temperatures are appropriate before transferring the heat, a WARNING message is given to alert the user that the 2nd Law of Thermodynamics would be violated under conventional conditions, if the hierarchy is not obeyed. If the user knows that the DHW temperature is below that produced by the DBUN-CHLR, the WARNING message may be ignored.

* * * * *

Question: I entered a cooling tower in PLANT, set the SIZE = -999.0 so that the program would size the equipment, and stated that both the INSTALLED-NUMBER and the MAX-NUMBER-AVAIL were 1. The PV-A report sized the tower at 0.762 MBTU, but indicated that both the INSTALLED-NUMBER and the MAX-NUMBER-AVAIL were 2. Is this a bug?

Answer: No, the situation is as follows. The keywords INSTALLED-NUMBER and MAX-NUMBER-AVAIL for a cooling tower refer not to the number of cooling towers, but to the number of cells in a single cooling tower. The program algorithms assume that a cell can not be larger than 1.5 MBTU in capacity. Since the heat rejection capacity of the cooling tower in your case was sized to be 1.524 (0.762 times 2), the program added another cell and divided the capacity between the two of them.

* * * * *

Question: In the ECONOMICS report ES-C, the BASELINE REPLACEMENT COSTS are subtracted from the INVESTMENT THIS RUN to arrive at the INCREMENTAL INVESTMENT. Since the INVESTMENT THIS RUN includes the first cost of PLANT equipment, if I do not have any HOURS-USED, why are only the BASELINE REPLACEMENT COSTS subtracted? I think that the first costs of PLANT equipment in the baseline run should be subtracted as well. Otherwise, there is no way to compare different plants in a design situation.

Answer: The program was written to satisfy a now out-dated DOE procedure for buildings to be retrofitted. In that situation the HOURS-USED for PLANT equipment would be non-zero and no first costs would enter into the calculation. We intend to redo this part of the code to make the ECONOMICS portion more generally applicable. In the meantime you can get the statistics you want by entering the total of FIRST-COST and REPLACE-COST as the value for REPLACE-COST in the BASELINE command in ECONOMICS. This will make the OVERALL LIFE-CYCLE COSTS table in the ES-C report wrong, but will give you the correct INVESTMENT STATISTICS.

* * * * *

The DOE-2 User Coordination Office encourages user response to this section. Please send questions and comments to:

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In order to better serve our user public, the DOE-2 User Coordination Office is conducting a survey. We will use the data collected to construct profiles of the different types of users and to develop ways to meet your various needs. In order to reach the widest possible audience, we are including this mailing list form for the "Building Energy Analyst Inquiry". If your name is not on the subscription list to the DOE-2 USER NEWS, and you would like to participate in this survey, please fill out the form. Feel free to recruit names of your other, non-subscribing, colleagues.

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350/5-81 This work was supported by the Assistant Secretary for Conservation and Solar Energy, Office of Buildings and Community Systems, Buildings Division of the U.S. Department of Energy under Contract W-7405-ENG-48.