

# DOE-2 USER NEWS

: A COMPUTER PROGRAM FOR BUILDING ENERGY USE ANALYSIS

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## INTRODUCTORY STATEMENT

The DOE-2 Building Energy Use Analysis Program was planned initially in 1976 to be a design and retrofit tool for the buildings of the US Department of Energy (then the Energy Research and Development Administration) and as the benchmark evaluation technique for the State of California's energy performance standards. Over the years the relationship of DOE-2 to the State of California was dropped and the subsequent development concentrated upon the needs of DOE. In recent times the development effort was focused upon those modifications required to make DOE-2 sufficient for use as the Standard Evaluation Technique (SET) of the congressionally mandated Building Energy Performance Standards (BEPS). With the release of the 2.1 version of the program the principle development phase has come essentially to a halt, and the period of support of the program has begun.

As part of that support a DOE-2 User Coordination Office (UCO) is being established at Lawrence Berkeley Laboratory. The UCO's purpose is to provide an interface between the engineers and computer scientists who designed and will maintain the program, and the user community. It plans to fulfill this purpose in several ways:

- 1) By maintaining and improving the documentation as errata or unclear portions are reported by users.
- 2) By creating and maintaining a set of computer files of data of interest to users.
- 3) By offering courses for trainers of DOE-2.1 users.
- 4) By interacting closely with the commercial computer service bureaus and with their programs of training and user assistance.

## AVAILABILITY OF DOE-2.1

The DOE-2.1 version of the program is now available for CDC and will soon be available for IBM computers. The tapes and documentation may be ordered through the:

National Technical Information Service  
U.S. Department of Commerce  
5285 Port Royal Road  
Springfield, VA 22161.

The cost of the tape (code number PB80-148398) may be ascertained by writing or calling NTIS at (703) 487-4650, FTS 737-4650. The documentation, which comprises the BDL Summary and Users Guide (Volume 1), the Sample Run Book (Volume 2) and the Reference Manual (Volumes 3 and 4), is available as a set at the following costs:

With binders (PB80-148380)  
@ \$150 (North America)  
@ \$300 (Foreign)  
Without binders (PB80-209307)  
@ \$130 (North America)  
@ \$260 (Foreign)

- 5) By publishing a quarterly DOE-2 USERS NEWS, of which this is the first issue.

The DOE-2 USERS NEWS will be used to keep the user community up to date with the state of the DOE-2 program and with the ways in which the DOE-2 program can be used. It will feature such sections as:

- 1) Report on all known bugs since the last DOE-2 USERS NEWS in the current version and possible interim solutions. Also a list of the bugs to be fixed in the updated program.
- 2) Report on documentation errata.
- 3) Report on new program features and modifications.
- 4) Articles on modeling methods using DOE-2 to achieve desired effects.
- 5) The "Heat Exchanger" — common questions from users and responses from the UCO.
- 6) Announcements of updated versions of the program and new documentation updates.

It is the intention of the UCO to serve the user community within the limits of the resources available to it. It is not intended that the UCO be the only source of user assistance, and users are encouraged to seek help from the appropriate person or group at the computer facility serving the user. The UCO will direct its efforts at the training of the staff at such local centers and to the answering of questions of those staff. As such local centers are identified, they will be reported in the DOE-2 USERS NEWS. On the other hand, if the user cannot get help from the local center, he/she should get in touch with the UCO at the address on the first page of this issue.

#### Program and Documentation Updates

Updates to the DOE-2 program and documentation are planned for issue at approximately six month intervals. The primary purpose of such updates is to correct errors in the program. With respect to documentation, passages which prove to be correct, but unclear, may also be

replaced. The current version of the program is DOE-2.1. Each successive update of the program will be labeled DOE-2.1A, DOE-2.1B, etc. Because DOE-2.1 is the SET for the proposed federal BEPS, no major augmentations or additions to the program are planned in the short run, with the possible exceptions of improvements in input and output formats and reports.

The next scheduled update of the program (DOE-2.1A) is set for November 1980. That version of the program will be free of the bugs listed in the DOE-2 USERS NEWS. Details for ordering the update will be in the next issue of the DOE-2 USERS NEWS.

#### Problems and Bugs

Although the program has been and is continuing to be extensively tested, users can expect to find combinations of keyword values which cause the program to give results unintended by the developers. Over time, the frequency with which bugs are discovered should decrease. Users are encouraged to report all suspected bugs and errata to their local centers to be forwarded to the UCO.

After an input deck has been prepared, nothing is more frustrating than to have the program either "blow up" during the simulation or produce numbers which do not seem to make sense. By far the most common cause for strange results is "strange" input. The vast majority of the time the program does exactly what it is told to do. The "strange" results can be traced back to the user's entering data (or failing to enter data and thus getting unintended defaults) which produce the results. The most productive approach for the user, when strange results appear, is to assume that the results make sense for the data provided. With this approach the source of the problem can usually be tracked down to an input flaw. The input flaw may have arisen because the user did not read the instructions carefully or because the documentation is confusingly written. Much effort has gone into writing checks on user-input values into the

program, so that ERROR messages are given when the input would otherwise cause the program to abort. These diagnostic messages are intended to be helpful to the user in correcting the input data. In spite of this careful checking, occasionally the user-input produces a program abort. This is a "bug", and should be reported to one's computer center, which will in turn report it to the UCO.

When the program does not abort, but yields answers that look incorrect, the situation is more complicated. This may or may not be a bug. A bug may be defined as follows:

A bug exists in a computer program when the program does not perform as conceptually designed. This can manifest in two ways: a) the program stops in the middle of a simulation, or b) the program runs and produces unintended results.

Note that the word used is "unintended" and not "unsatisfactory". A result may not be satisfactory, because the algorithm being used is not as sophisticated as the

user might desire. This is not a bug, but a potential place for program improvement.

Occasionally, the problem is really a bug. The program does not behave as the designers intended it to behave. In this case, it is important not only to the user in question but to all users to have the program corrected.

Very often the user will not be able to determine whether the problem is a bug or an input flaw and will want help to resolve the situation. The DOE-2 PROBLEM REPORT form, attached to this issue, should be used to transmit the problem description to the local computer center. It is imperative that the report be accompanied by an input and output listing of the user's program. This should include the "dayfile", which is the listing produced by the computer that describes the control card sequence and machine responses. The input deck which produced the suspected bug should also be made available. Do not change the deck, after discovering the bug. Make a copy of the deck and use the copy for further work, until the bug has been fixed.

## BUGS DISCOVERED IN DOE-2.1 AND INTERIM SOLUTIONS

BDL

- BDL aborts (rarely and randomly) with memory reference beyond field length when it is saving interior wall pointers for each space in the subroutine SPACEO.

Interim solution: Add dummy spaces to increase the field length. Fixed in DOE-2.1A.

- Commands that use another command's tables (synonym commands) can not be used in the SET-DEFAULT command. Therefore, SET-DEFAULT FOR ROOF and SET-DEFAULT FOR UNDERGROUND-FLOOR, will produce \*\*\*\*ERROR -- UNKNOWN COMMAND\*\*\*\*.

Interim solution: Instead of SET-DEFAULT FOR ROOF, use SET-DEFAULT FOR EXTERIOR-WALL; instead of SET-DEFAULT FOR UNDERGROUND-FLOOR, use SET-DEFAULT FOR UNDERGROUND-WALL. Fixed in DOE-2.1A.

- The Custom Weighting Factor calculation ignores quick interior surfaces with  $U > 0.709$  since such surfaces give negative convective air film resistance. The most common case where interior surfaces with a high U-value might be used is to model interior walls with open doors; the U-value in this case is often made larger than that of the wall itself in order to approximately account for convective heat transfer through the openings. There is a problem in the program in that these surfaces are not being properly excluded in the calculation of the matrix which gives the radiation exchange factors between pairs of surfaces. This problem occurs whenever there are quick interior walls or floors with  $U > 0.709$  in a LIBRARY-INPUT LOADS run.

Interim solution: There are two alternative solutions; the second solution is recommended one.

1) Remove the wall entirely from the Custom Weighting Factor calculation input, but leave as is in LOADS input.

2) If large U-value was chosen to account for convection through openings proceed as follows: in the Custom Weighting Factor input, ignore the openings, assign a U-value equal to the actual U-value of the wall (including air film resistances on both sides), and do not include the area of the openings in the wall area. Leave wall as is in the LOADS input. (Note: Rather than use a U-value in the Custom Weighting Factor input, it would be preferable to describe the wall as a delayed surface.) Fixed in DOE-2.1A.

- In the Custom Weighting Factor calculation, the effective area of furniture for radiative exchange is different from the corresponding area for convective exchange. This produces a  $\leq 10\%$  error in the weighted loads when furniture is defined in LIBRARY-INPUT LOADS. This will occur in any space where furniture is defined in the Custom Weighting Factor input.

Interim solution: Do not specify furniture in Custom Weighting Factor input. Fixed in DOE-2.1A.

- When furniture is specified in the Custom Weighting Factor calculation, the floor area is incorrectly multiplied by  $1 - (\text{FURN-FRACTION})$ . This reduces the contribution of the floor to the weighting factors.

Interim solution: Do not specify furniture in the Custom Weighting factor input. Fixed in DOE-2.1A.

- In the Custom Weighting Factor calculation, high order response factor terms are calculated using a factor proportional to  $(\text{common-ratio})^n$ . For small common ratio, this may cause underflow [  $(\text{common-ratio})^n < 10^{-293}$  on CDC 7600 machines]; on the LBL machine, this will give an error message each time such a underflow occurs. The Custom Weighting Factor calculation is unaffected since the underflow gets set to zero. This bug occurs when the Custom Weighting Factor input contains an extremely light delayed construction, e.g., a wall consisting only of  $\frac{1}{2}$ " of plywood.  
Interim solution: Change from delayed to quick surface (i.e., specify U-value) for very light walls. Fixed in DOE-2.1A.
- The Custom Weighting Factor calculation may fail for spaces of very light construction. The resulting ERROR message is:  
WEIGHTING FACTOR CALCULATION FOR SPACE <u-name>,  
WEIGHTING FACTOR TYPE <k>, FAILED IN DECONVOLUTION, SUBROUTINE WFDECN  
This may occur when all the surfaces in a space are of very light construction, e.g., an attic with a light roof and floor.  
Interim solution: Use ASHRAE weighting factors for these spaces (i.e., enter FLOOR-WEIGHT in LOADS input). Fixed in DOE-2.1A.
- In the Custom Weighting Factor calculation, the FURN-WEIGHT keyword has no effect.  
Interim solution: Do not specify furniture in the Custom Weighting Factor input. Fixed in DOE-2.1A.
- In the Custom Weighting Factor calculation, the characteristic weight of heavy furniture is mis-punched as 2.0 lb/ft<sup>2</sup>; it should be 20.0. However, this bug has no effect on results, since the characteristic weight is not used in DOE-2.1. Fixed in DOE-2.1A.
- If any surface has zero area or if any window, wall, underground floor, etc, has a MULTIPLIER=0, the Custom Weighting Factor calculation will fail, giving the ERROR message:  
WEIGHTING FACTOR CALCULATION FOR SPACE <u-name>,  
WEIGHTING FACTOR TYPE <k>, FAILED IN DECONVOLUTION, SUBROUTINE WFDECN  
Note, however, that LOADS will accept a zero-area surface.  
Interim solution: 1) Remove surface from input; or 2) give surface a very small area. Fixed in DOE-2.1A by assigning zero-area surfaces an area of 0.01 ft<sup>2</sup> in the Custom Weighting Factor calculation.
- The Custom Weighting Factor calculation fails for a space with quick underground walls or floors. It will also fail if the underground wall or floor is defined with LAYERS, but each of the MATERIALS in the construction is defined by a RESISTANCE rather than by THICKNESS, CONDUCTIVITY, DENSITY and SPECIFIC-HEAT.

Example: the following two underground surface inputs will cause the Custom Weighting Factor calculation to abort:

```
[1]  SLAB      =CONSTRUCTION  U-VALUE=0.7          ..
      FLOOR-1 =UNDERGROUND-FLOOR  CONS=SLAB  AREA=1176  ..
                                   SOLAR=FRACTION=0.7    ..

[2]  CONCRETE =MATERIAL  RESISTANCE=0.5          ..
      FL-TYPE  =LAYERS    MATERIAL=(CONCRETE)  I-F-R=0.92  ..
      SLAB     =CONSTRUCTION  LAYERS=FL-TYPE          ..
      FLOOR-1  =UNDERGROUND-FLOOR  CONS=SLAB          ..
                                   AREA=1176  SOLAR FRACTION=0.7 ..
```

Interim solution: Make all underground floors and walls delayed. At least one material in the construction must have THICKNESS, CONDUCTIVITY, DENSITY and SPECIFIC-HEAT specified. Fixed in DOE-2.1A.

- If a Custom Weighting Factor creation run is made for a single space and the WEIGHTING-FACTOR keyword is not specified, the results will be meaningless.

Interim solution: Be sure to specify WEIGHTING-FACTOR keyword. Fixed in DOE-2.1A.

- When (a) two spaces are defined in a LIBRARY-INPUT LOADS run; and (b) the first space has WEIGHTING-FACTOR=u-name specified; and (c) the second space is LIKE'd to the first space; and (d) FLOOR-WEIGHT is specified for the second space -- then the following will occur: (a) the Custom Weighting Factors requested for the first space will be assigned to the second space; and (b) the first space will end up with all weighting factors equal to zero.

Interim solution: In the above situation, do not LIKE the second space to the first space. Then the weighting factors will be correctly calculated for the first space, and none will be calculated for the second space. If the user wants weighting factors calculated for both spaces, WEIGHTING-FACTOR=u-name must be specified for both spaces, with unique u-names for each space. Fixed in DOE-2.1A.

### LOADS

- When a wall is too massive, the program aborts in subroutine WRITEN because the response factor common ratio cannot be reached in 100 terms, which is the maximum the program stores.

Interim solution: Use less massive walls. Three feet of dirt (density=60) is definitely too massive. The lower limit is presently unknown.

- The ground temperatures and clearness numbers on the weather file for Albuquerque (code name ALBUQUE) on the LBL computer are incorrect.

Interim solution: Input the values in the BUILDING-LOCATION command.  
Correct ground temperatures are:

67.5, 65.3, 65.5, 68.3, 72.8, 78.1, 82.3, 84.7, 84.4, 81.6, 76.9, 71.9.

Correct clearness numbers are:

1.05, 1.05, 1.05, 1.05, 1.15, 1.15, 1.15, 1.15, 1.15, 1.15, 1.05, 1.05.

SYSTEMS

When NIGHT-CYCLE-CTRL=CYCLE-ON-FIRST or CYCLE-ON-ANY and there is a cooling demand, heating energy is used to maintain the cooling set-point in those zones which are below the cooling set-point. NIGHT-CYCLE-CTRL should operate only to maintain the heating set-point.

Interim solution: Set cooling set-point during setup conditions to high value so that NIGHT-CYCLE-CTRL is not invoked. Fixed in DOE-2.1A.

- The airflow rate to a zone in a variable air volume system can go above the design flow rate for that zone, if the main air-handler fan is sized above the sum of the design flow rates for all the zones. This can occur only if SUPPLY-CFM times MAX-FAN-RATIO is greater than the sum of the design flow-rates. It will not happen if the main fan is sized for the coincident load.

Interim solution: If the user does not explicitly specify zone air-flow rates and does not specify SUPPLY-CFM, the SV-A Report should be examined to ensure that the above condition does not apply. If it does, design zone air-flow rates must be specified explicitly. Fixed in DOE-2.1A.

- In TPFC and FPFC systems, when the exhaust air quantity exceeds the outside air quantity, the program ignores the extra required make-up air.

Interim solution: Ensure that the minimum outside air flow rate is greater than or equal to the exhaust air-flow rate. Fixed in DOE-2.1A.

- In TPFC and FPFC systems, a cooling load is often reported in the winter, because no outside air is being simulated and thus the mixed air temperature is incorrectly calculated. This problem occurs whenever the outside air is specified by keywords other than MIN-OUTSIDE-AIR.

Interim solution: For these systems, specify MIN-OUTSIDE-AIR when ventilation air is desired. Fixed in DOE-2.1A.

- The sensible cooling load in the RESYS system is independent of the user-input for DUCT-DELTA-T.

Interim solution: None. Fixed in DOE-2.1A.

- When a zone has zero net loads in any hour, the program simulates heating to maintain the zone temperature. This results from a bug in the algorithm which currently attempts under these conditions to maintain a zero extraction rate. It should supply heat only when the zone temperature falls into or below the heating throttling range.

Interim solution: None. Fixed in DOE-2.1A.

- When the zone temperature is between the heating and cooling throttling ranges, the program attempts to maintain a zero extraction rate. Depending upon the system type it should maintain the extraction rate at the bottom of the cooling throttling range throughout the dead band.

Interim solution: None. Fixed in DOE-2.1A.

- The WARMEST and COLDEST options for COOL-CONTROL and HEAT-CONTROL, respectively, cause a reset of the supply air temperature to the average over all zones of the DESIGN-COOL-T or DESIGN-HEAT-T, respectively. It should set the upper supply air temperature limit for COLDEST and the lower limit for WARMEST to the mixed air temperature passed

when the outside air dampers are in their minimum position or to the preheat coil exit temperature.

Interim solution: None. Fixed in DOE-2.1A.

- The COLDEST option for the HEAT-CONTROL is reset based upon the COOL-TEMP-SCH rather than the HEAT-TEMP-SCH.

Interim solution: Do not use HEAT-CONTROL=COLDEST. Fixed in DOE-2.1A.

- When HEAT-CONTROL=COLDEST, the supply temperature is reset to a value which supplies only 0.75 of the full heating capacity, even when full capacity is requested by zones. This will result in loads-not-met even though the system is adequately sized.

Interim solution: Do not use HEAT-CONTROL=COLDEST. Fixed in DOE-2.1A.

- In the hourly reports there may appear negative sensible heat capacities and mixed air humidity ratios larger than 1.0. This will occur for that hour immediately following one in which there is no infiltration and no outside air.

Interim solution: Make sure there is a negligible but non-zero amount of outside air or infiltration at all hours. Fixed in DOE-2.1A.

- In dual duct systems (MZS, PMZS and DDS), the hot supply air temperature is occasionally higher than design by twice the DUCT-DELTA-T. This occurs when heating is off and mixed air is being passed or when HEAT-CONTROL=COLDEST and no zones are asking for heating.

Interim solution: Ignore the hourly reports for the hot supply air temperature under these conditions. There is no effect upon the energy reported. Fixed in DOE-2.1A.

- For VAVS, PAVS, RHFS and CBVAV systems, the automatic sizing routine uses MAX-SUPPLY-T for the design maximum air temperature, if HEAT-SET-T is not specified and COOL-CONTROL=CONSTANT. This introduces a main heating coil, even when the user does not desire one.

Interim solution: Specify HEAT-SET-T to a low value, when no main heating coil is desired. Fixed in DOE-2.1A.

- The program uses the value of 1st hour's variables (temperatures, extraction rates, etc.) to estimate this hour's values for these variables. This can produce unrealistic temperatures and extraction rates when the zone temperatures change radically during an hour, e.g., immediately following a night set-back or set-up. A better estimate should be made under these circumstances.

Interim solution: None. Fixed in DOE-2.1A.

- The SYSTEMS program does not pass the peak domestic hot water load (BUILDING-RESOURCE command) to PLANT so that boilers or domestic hot water heaters can be appropriately sized.

Interim solution: Do not allow PLANT to size boilers or domestic hot water heaters, when domestic hot water heaters are present. Fixed in DOE-2.1A.

- The value reported in the BEPS report in PLANT for NATURAL-GAS used for heating is incorrectly inflated by the amount of the gas used for any purpose in LOADS. This occurs whenever SOURCE-TYPE=GAS in the SPACE-CONDITIONS command or when the GAS-THE keyword is used in the BUILDING-RESOURCE command.

Interim solution: In the BEPS report, subtract the value reported under NATURAL-GAS for MISC EQUIP from that reported for SPACE-HEAT to obtain the correct value for SPACE-HEAT. Fixed in DOE-2.1A.

- In SYSTEMS reports the value of the wetbulb and drybulb temperatures at peak heating loads are incorrectly reported when they are negative.

Interim solution: None. Fixed in DOE-2.1A.

- The outside air as specified in the ZONE command (or ZONE-AIR) is ignored for TPIU and FPIU systems.

Interim solution: Use MIN-OUTSIDE-AIR command in the SYSTEM command (or SYSTEM-AIR command) to specify outside air for these systems. Fixed in DOE-2.1A.

- The recovery of heat through the RECOVERY-EFF keyword does not take into account the value of DUCT-AIR-LOSS.

Interim solution: None. Fixed in DOE-2.1A.

- The report SS-F provides the maximum and minimum zone temperatures only during those hours that the fans are running. Thus, when baseboards are providing heating, but the fans are off, these temperatures are not correct. There is no affect on the energy calculation from this bug in the report.

Interim solution: None. Fixed in DOE-2.1A.

- When the PLENUM-NAMES list has more than one zone in it for a SYSTEM-TYPE for which PLENUM-NAMES is unused, EDL will abort in routine KODER with no error message.

Interim solution: Remove the PLENUM-NAMES keyword and make those zones unconditioned with LIGHT-TO-SPACE=100.

#### PLANT/Solar Simulator

- CBS only will meet the systems coil loads; the loop losses will be met only by the boiler. This causes the boiler to operate a large number of hours at an extremely low efficiency when the solar system should be able to meet the entire load.

Interim solution: When using the solar simulator, do not simulate loop losses, i.e., set HCIRC-LOSS and HCIRC-HEAD to zero. Fixed in DOE-2.1A.

- When heating loop loss is less than pump heat gain, more pump heat is allowed into the heating loop than there is loop loss by conduction. This can result in negative heating loads.

Interim solution: Do not use the keyword HCIRC-LOSS, or make sure that the pumping heat (from HCIRC-HEAD and HCIRC-IMPELLER-EFF) is less than loss. Fixed in DOE-2.1A.

- The program will abort in subroutine READSP if a domestic hot water heater is not explicitly sized.

Interim solution: Always specify the size of domestic hot water heaters. Fixed in DOE-2.1A.

- The tower fan cycling algorithm is incorrect. This bug will sometimes cause the tower to be cycled on longer than one hour each hour, or to cycle a negative period of time. This will occur when the cooling tower has a small cooling load. Its effect is much worse on hourly/peak electric load than on total load.

Interim solution: None. Fixed in DOE-2.1A.

- A storage tank is counted as operating in Report PS-C anytime it stores or gives out heat. It should be counted only when giving out heat.

Interim solution: The HOURS AT PERCENT PART LOAD RATIO portion of Report PS-C should be disregarded for storage tanks. The simulation is unaffected by this bug. Fixed in DOE-2.1A.

- The heat recovered from the diesel or gas turbine exhaust gas is less than it should be when a solar absorption chiller is used. This occurs when a user specifies a solar absorption chiller and heat recovery from diesel or gas turbine exhaust, but does not input steam pressure, in which case the program sets the steam pressure to 150 psi.

Interim solution: Explicitly input STM-PRES. Fixed in DOE-2.1A.

Note: Users of the program on the LBL computer are restricted in the number of commands they can input. The LBL CDC 7600 machine small core memory is not large enough to accommodate the full extent of maximums on commands as given in the documentation. This problem is most usually encountered when a building has roughly more than 20 thermal zones and their accompanying surfaces are input.

The program will fail in routine SYS 3. The dayfile message will read:

\*\*REQUESTED FLS EXCEEDS MACHINE SIZE

There is no solution to this problem other than to trim down the number of commands input.

Note: The user should be very careful in allowing the program to use defaults for SUPPLY-DELTA-T and SUPPLY-KW. The defaults are used if both of these two keywords are not specified and SUPPLY-STATIC and SUPPLY-EFF are also not specified. We have found that for standard applications the present defaults are in some cases two to three times higher than would be expected. This can cause fan energy to be greatly over estimated. Future versions of the program will replace these defaults with curves expressing the values as a function of supply air flow rate.

## DOCUMENTATION UPDATES

BDL Summary

- On page 8, the default for FURNITURE-TYPE is HEAVY, not LIGHT.
- On page 52, under SYSTEM-AIR for RESYS, the default for VENT-TEMP-SCH is HEAT-TEMP-SCH, not COOL-TEMP-SCH.

Users Guide

- Pages I-4 and 1-4, and pages A2-46 and A3-46 were interchanged by the printer. You should receive corrected pages with your set of documentation. Please notify NTIS if that is not the case.
- On page 5-4, Figure 3, the U-value should read 1.5, not 10.0, to agree with the example input.
- On page 7-3, line 4, the figure in "a maintenance cost of \$350/year" is incorrect. The figure should read \$250.
- On page A2-38, in the first paragraph, the units are incorrectly expressed. The paragraph should read:

The information in these 12 columns is site energy use in MBTU ( $10^6$ Btu). For electrical energy the entry followed by an E is the energy in MWH (thousands of kWh).

Sample Run Book

- On page 4, Introduction, change "In the plant, the diesels generate all of the electrical energy used" to:

In the plant, the diesels generate all of the electrical energy used, except for a small percentage which is purchased from the utility to handle electrical loads (such as lighting on weekends and holidays and from midnight to 7 AM) that are less than 352kW. This is the minimum output of one of the diesel generators. This minimum is given by the diesel capacity ( $6 \times 10^6$  Btu/h/[3413 Btu/kWh] = 1758 kW) times the default minimum part load ratio of 0.2.

- On page 25, add PEOPLE-HEAT-GAIN=400 in the SPACE command for the LOADS input of Simple Structure, Run 2. As the input stands, there is no load from occupants since PEOPLE-HEAT-GAIN defaults to zero.
- On page 33, remove the Reset description. Supply air temperature in Simple Structure, Run 3 and Run 3A is not reset.

- On page 84, the ECONOMICS input for Simple Structure, Run 3A, keywords REPLACE-COST OPERATIONS-COST, ENERGY-COST, ENERGY-USE-SITE and ENERGY-USE-SRC should correspond exactly with the output of Run 3, Report PS-J, page 73. The small discrepancies in the input will not significantly affect the results of the ECONOMICS simulation for Run 3A.
- On page 170, replace "Building total of 660,00 ft<sup>2</sup>" with "Building total of 660,000 ft<sup>2</sup>".
- On page 271, in the SYSTEMS input for the 31-story office building, Run 5, MIN-CFM-RATIO should be 0.3, not 0.5. As it stands, Runs 4 and 5 are identical.
- On page 306, in the specifications for the 31-story Office Building, Run 7, and on page 309, in the SYSTEMS input, the supply and return air flow rates are too low. The supply air CFM should be 517,474 CFM, which is based on the coincident peak load for the perimeter zones plus the storage area. The return air CFM does not have to be input; it will be automatically calculated from supply and outside air CFM. The supply air CFM can be determined from Report SV-A of any of the previous variable-volume system runs (e.g., Run 6) by subtracting the total supply CFM for the interior zones (5916 + 30 \* 4702) from the SUPPLY FAN CFM (664423) to yield 517,447 CFM.
- On page 468, in the LIBRARY-INPUT LOADS input for single family residence, and again on page 508, single family residence, passive solar modification, FURNITURE-TYPE=LIGHT should be specified under SPACE-CONDITIONS. This is required in order to be consistent with the specifications for furniture on page 463, which give an average furniture density of 40 lb/ft<sup>3</sup>. As the input currently stands, the default value for FURNITURE-TYPE, which is HEAVY, (corresponding to a density of 80 lb/ft<sup>3</sup>) will be used in the Custom Weighting Factor generation. LIGHT vs. HEAVY furniture for these examples produces less than a 1% difference in annual energy use.
- On page 507, in the input for custom weighting factor generation for the single family residence, passive solar modification, the resistance for floor tile should be 0.05, not 2.08 (which is the resistance for carpet plus pad). Therefore change:

```
TILE-1      =MAT      RES=2.08      $CARPET-PAD$      ..
```

to:

```
TILE-1      =MAT      RES=0.05      $ABS-VINYL TILES$ ..
```

The corresponding input for the LOADS run, page 511, is correct.

This change produces a sizable effect on the solar weighting factors since the coupling between slab and room air is increased and more of the solar radiation absorbed by the floor is stored in the slab. The overall effect, however, is to reduce the Design Energy Consumption by only 4%.

#### Reference Manual

- On page II.5, add a sixth rule for the LIKE keyword as follows:
  6. The code-words identifying materials and walls in the standard library are not u-names and cannot be LIKEd.

- On page III.25, add the following warning to the discussion of BUILDING-LOCATION defaults:

If the BUILDING-LOCATION keywords are allowed to default, the program will take its values for LATITUDE, LONGITUDE, TIME-ZONE, GROUND-T, and CLEARNESS-NUMBER from the weather file. All weather files which come with the program have all of these parameters defined. If other weather files are used, not all of these parameters may be defined. In that case, one can get very strange results. For example, if TIME-ZONE is not defined the program will treat the value as zero and will calculate solar angles as though they were occurring in Greenwich, resulting in no solar gains in the Western Hemisphere. No warning messages are given in this case, although, if DIAGNOSTIC COMMENTS or DEFAULTS is specified, the output will indicate that TIME-ZONE=0. Generally speaking, it is not a good idea to allow these keywords of the BUILDING-LOCATION command to default.
  
- On page III.31 add the following note at the end of the discussion of BUILDING-SHADE,

Note: since X, Y, Z, AZIMUTH, and TILT of the shading surface are defined in the building coordinate system, a rotation of the building (accomplished by changing AZIMUTH in the BUILDING-LOCATION command) will carry all building shading surfaces along with the building, even those which are detached, such as adjacent buildings and trees. Care must therefore be taken to adjust the X, Y, Z, AZIMUTH and TILT of such detached shading surfaces each time the building is rotated, so that these surfaces stay fixed with respect to the global (earth) coordinate system.
  
- On page III.59, the keyword INF-CFM/SQ-FT should read INF-CFM/SQFT.
- On page III.88, in the input example, all eight occurrences of the year 79 should read 1979.
- On page III.A.16, the default for FURNITURE-TYPE is HEAVY, not LIGHT.
- On page III.A.16, under WEIGHTING-FACTOR, change "accepts as input a U-name" to "accepts as input a U-name of 8 or fewer alpha-numeric characters."
- On page IV.51, add to VENT-TEMP-SCH:

If VENT-TEMP-SCH is not specified, it will default to the heating setpoint schedule defined by HEAT-TEMP-SCH.
  
- On page IV.51, starting on line 4 of the paragraph discussing DAY-SCHEDULE, change "will provide more cooling than would be provided by the mechanical system with the windows closed" to "will reduce the space temperature to the temperature specified by VENT-TEMP-SCH without mechanical cooling."

- On page IV.52, change:

7,8      74° max ....      to:      7,8      85° max ....

and

18,22      74° max ....      to:      18,22      85° max ....

- On page IV.194, under SYSTEM-AIR, the default for VENT-TEMP-SCH should be HEAT-TEMP-SCH, not COOL-TEMP-SCH.

- On page IV.220, starting on line 6 of the second to last paragraph, change the sentence:

The REVERSE-ACTION type of thermostat (see THERMOSTAT-TYPE) is intended for variable air volume systems.

to:

The REVERSE-ACTION type of thermostat (see THERMOSTAT-TYPE) is applicable only for variable air volume systems, and then, only when appropriate.

- On page V.10, the formula for the SIZE of a storage tank is in error. It should read:

$$\text{SIZE} = (\text{size in gallons}) * 8.34 \left[ \frac{\text{lb}}{\text{gal}} \right] * 10^{-6} \left[ \frac{\text{MBTU}}{\text{lb}^{\circ}\text{F}} \right] * \text{DT}.$$

- On page V.11 in Table V.2, two code-words, HERM-CENT-CHLR and HERM-REC-CHLR are in the wrong column. They should be shifted over to the Code-Word column opposite their descriptors.

- On page VII.96, change the first paragraph to read:

The information in this report is site and source energy use in MBTU ( $10^6$ Btu). For electrical energy the entry followed by an E is the energy in MWH (thousands of kWh).

- On page VIII.49, the ground temperatures and clearness numbers for Albuquerque (code name ALBUQUE) are incorrect. They are incorrect on the weather tape as well, and must therefore be input in the BUILDING-LOCATION command by the user. See LOADS Bug above for correct data.

## SOME GUIDELINES FOR PREPARING INPUT FOR CUSTOM WEIGHTING FACTOR GENERATION

Appendix III.A of the Reference Manual describes the method used by DOE-2.1 to account for the thermal mass of the building and outlines the input for creating custom weighting factors for the building being modeled, should the user desire to use them in the place of the pre-calculated weighting factors, derived from those provided in the ASHRAE 1977 Handbook of Fundamentals. The following guidelines are intended to amplify the discussion in the Reference Manual.

- 1) In Custom Weighting Factor (CWF) input, all walls which have a mass greater than approximately  $3 \text{ lb/ft}^2_{\text{wall}}$  should be described as delayed surfaces. This includes interior walls and underground walls and floors. The reason for this is that if a wall is described as a quick wall, that is, with a U-value, its thermal mass will not be included in the determination of the weighting factors for the space.
- 2) In the LOADS input, an effective area (e.g. perimeter area) which is substantially less than the actual area is sometimes used for underground walls and floors. In the CWF input, however, the full area should be used for these surfaces —and they should be described as delayed surfaces— in order to account for their full thermal mass.
- 3) To simplify LOADS input, two or more adjacent rooms are often combined into a single space. If the internal walls separating these rooms have an overall mass which is comparable to the mass of the bounding surfaces of the space, these internal walls should be included in the CWF input (but not the LOADS input). This can be done by inputting these surfaces as delayed INTERIOR-WALLS, as follows.

Normally, interior walls are used to separate two spaces in a building. However, in the CWF generation, it is possible to define an interior wall to be entirely within a space. For example, assume that ROOM-A and ROOM-B are combined into a single space called ROOM-AB. Let WALL-AB be an interior wall between the rooms. In a CWF generation run, WALL-AB can be specified to be next to ROOM-AB:

```
ROOM-AB =SPACE
```

```
.
```

```
.
```

```
.
```

```
WALL-AB =INTERIOR-WALL
```

```
NEXT-TO ROOM-AB
```

```
SOLAR-FRACTION=(f,0) ..
```

In the above, f equals the sum of the actual solar fractions on both sides of the wall. Note that this wall should be removed from the LOADS input because its mass and other thermal properties are accounted for in the Custom Weighting Factors for the space.

This procedure for handling internal walls in combined rooms is only approximate. Because of this we recommend not combining rooms which are separated by massive walls.

For cases where the internal walls are relatively light, such as the interior walls in a one-zone house, an alternative approach is to include the mass of the partitions in the furniture weight. This is done by calculating the total weight of the partitions, dividing by the floor area of the zone, and adding the result to the value of FURN-WEIGHT due to the actual furnishings in the zone.

- 4) If moveable insulation is used on a window, there is some question of what conductivity to use in the CWF calculation, since this value cannot be scheduled in CWF as it is in LOADS. The recommendation is to use a time-average value. For example, if the glass conductance is  $1.0 \text{ Btu}/(\text{hr-ft}^2-$

F) without insulation and 0.2 with it, and if the glass is insulated 11 hours a day, the time-average conductance would be

$$\frac{13(1.0) + 11(0.2)}{24} = 0.63$$

- 5) In the CWF input, all surfaces in a space should be described in order to obtain an accurate set of weighting factors. This means that not only the exterior walls, windows, and underground surfaces should be described, but also any interior walls, ceilings, or floors lying between the

space and adjacent spaces. However, in a conceptual design energy analysis, where only a sketchy idea of the geometry and constructions of space is usually available, it may be preferable to ignore most interior surfaces and use the approximate ASHRAE weighting factors which depend only on the FLOOR-WEIGHT (and LIGHTING-TYPE) of the space. Custom weighting factors would then be generated in the later, design development phase, where a fuller description of the building is available.

## THE HEAT EXCHANGER

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

Question: What kinds of weather data tapes can I use, and where do I get them?

Answer: The only types of weather tapes acceptable to DOE-2.1 are TMY, TRY and TDE 1440. You should order them from:

National Climatic Center  
Federal Building  
Asheville, NC 28801  
(704) 258-2850, ext. 203  
FTS 672-0683

Be sure to specify either a 9-track ASCII tape or a 9-track EBCDIC tape, with density 1600 bpi and even parity. If you wish to order the most recent year (currently 1979), you must request the Center to convert it from CD 144 format to TDF 1440 format. Archival tapes are already in TDF 1440 format. In DOE-2.1A, either format will be acceptable.

\* \* \* \* \*

Question: Why do loads passed from SYSTEMS to PLANT differ? I mean, why aren't the figures in Reports SS-D and PS-A equivalent?

Answer: The difference is usually due to heat gain from pumping. Refer to the Users Guide, Appendix 2 for full explanations of these Reports.

\* \* \* \* \*

Question: I have actual on-site weather data. Can I use it in DOE-2.1?

Answer: Only if you put your data in TMY format and pack it. See the Reference Manual, Appendix VIII.C for instructions for the preparation of a packed weather tape.

\* \* \* \* \*

Question: Exactly what is the value of the LOADS Verification Reports? They are so voluminous that I hesitate to request them, much less wade through them!

**Answer:** The LOADS Verification Reports are very valuable for quite a few reasons.

1. You can check the overall geometry of the building you input, e.g., the number of walls, the arrangement of the spaces, the azimuth, and the tilt angles of roofs, walls, overhangs, etc.
2. You can ensure that walls which you intended to be quick or delayed surfaces are in fact being treated as such.
3. The weather tape used in the run is reported here.
4. Schedules assigned for people, lighting, equipment, shading, etc. are reported.
5. Summaries of window glass types are given.

\*\*\*\*\*

**Question:** In specifying GLASS-TYPE, how do I choose between using SHADING-COEFFICIENT vs. GLASS-TYPE-CODE?

**Answer:** The answer depends on whether the glass is shaded by blinds, drapes, louvers, etc., or is unshaded (shading here does not refer to that from fins, overhangs, etc.).

If the glass is unshaded, determine from manufacturer's data the value of transmittance at normal incidence (for the total solar spectrum, not just the daylight portion). Use this value, plus the number of panes and whether or not the glass has a reflective coating, to choose the closest corresponding value of GLASS-TYPE-CODE from table III.1 on p. III.50-51 of the Reference Manual. This approach guarantees that the program will use the proper dependence of the transmission and absorption coefficients on the angle of incidence of solar radiation.

If the glass is shaded, then the SHADING-COEFFICIENT should be specified. The value to use can be obtained from manufacturer's data, and will generally depend on whether blinds or drapes cover the windows. For example, one manufacturer gives shading coefficients for light and medium venetian blinds, and for light, medium, and dark draperies. The disadvantage of this approach is that the program uses the angular dependence of the transmission and absorption coefficients for a single pane of 1/8 inch thick clear glass, even if PANES=2 or 3 is specified. This gives the wrong angular dependence for large angles of incidence (i.e. glancing incidence) for double and triple pane; however the solar gain is usually relatively small at these angles, so the overall error in the solar heat gain calculation will probably be negligible.

Sometimes, parametric runs are made, changing from no shade to varying degrees of shading on the glass. In this case, for consistency, SHADING-COEFFICIENT should be used for each step, even the unshaded case. (Manufacturers' also give shading coefficients for unshaded glass.)

When using SHADING-COEFFICIENT, it is possible to schedule the change in shading coefficient and conductance due to the condition of the shading device (for example, an exterior blind may be fully retracted or fully closed or fully down but open at a certain angle for daylighting purpose). To do this, use SHADING-SCHEDULE and CONDUCT-SCHEDULE in the WINDOW command.

\* \* \* \* \*

Question: I want to model a zone with high electrical demand. The maximum value of EQUIPMENT-KW is too low for my needs and when I input a value higher than the max, I get a CAUTION message. What is the program doing with my value and how can I, in general, change the upper limits of the variable ranges?

Answer: This question brings up several points on limits. First, there are two types of upper limits on variable ranges; those that, if exceeded, simply produce a CAUTION message to alert you to possible input error, and those that produce an ERROR message. The DOE-2.1 BDL Summary indicates for each keyword which type it is by underlining the max of the latter type.

In the first case, don't worry about the CAUTION message if the input is as intended. The latter situation, however, requires the addition of a new code-word option to the DIAGNOSTIC command in your input deck. This command,

DIAGNOSTIC NO-LIMITS

is not yet documented and should be used with great care. Verify both your minimums and maximums as the use of NO-LIMITS over-rides the ERROR message routine. Only CAUTIONS will be issued.

The second point concerns the limits imposed on the number of times a command may be used, and also the total number of u-names allowed. These limits may be expanded by a programmer who has access to your DOE-2.1 source code.

Question: In SYSTEMS, I input an outside air quantity which exceeded the MIN-CFM-RATIO of 0.3 and I got 100% outside air at a quantity less than my input outside air quantity during certain hours of the day. How come?

Answer: The program does not presently adjust the minimum cfm ratio to account for the outside air requirement. In other words, MIN-CFM-RATIO over-rides MIN-OUTSIDE-AIR. In DOE-2.1A, the over-ride will be reversed.

\* \* \* \* \*

Question: How do I get a BEPS Report if I don't have a plant?

Answer: In PLANT, input a very small domestic hot-water heater (e.g., SIZE=0.000001) or a cooling tower which you permit the program to size.

\*\*\*\*\*

Question: Suppose I want to purchase steam, chilled water and electricity. In other words, there is no PLANT equipment. How do I input this?

Answer: There are several methods. As it works at present, PLANT requires at least one piece of equipment be specified. A 1 Btu electric steam boiler is adequate and should not affect the reported loads significantly. The following input for PLANT will suffice:

```
INPUT PLANT ..
DUMMY=PLANT-EQUIPMENT TYPE=ELEC-ST-BOILER
SIZE=0.000001 ..
ENERGY-COST RESOURCE=STEAM UNIT=100000
UNIFORM-COST=0.70 ..
ENERGY-COST RESOURCE=CHILLED-WATER
UNIT=100000 UNIFORM-COST=3.40 ..
ENERGY-COST RESOURCE=ELECTRICITY UNIT=3413
UNIFORM-COST=0.05 ..
END ..
COMPUTE PLANT ..
```

\*\*\*\*\*

The DOE-2 User Coordination Office encourages users to forward any questions and comments to:

The Heat Exchanger  
DOE-2 User Coordination Office  
Building 90, Room 3147  
Lawrence Berkeley Laboratory  
University of California  
Berkeley, CA 94720