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DOE-2 USER NEWS

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:A COMPUTER PROGRAM FOR BUILDING ENERGY USE ANALYSIS

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Building Energy Simulation Group

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BULLETIN BOARD

Item: NTIS is now taking orders for the DOE-2.1A update package to the documentation. Deliveries will begin in mid-June. The back page of this issue is a tear-out sheet containing an order form.

Item: Efforts to make available new machine-compatible versions of the code are continuing. Recently released, in addition to the CDC and IBM, are VAX and DEC-10 versions of DOE-2.1A. Honeywell, Data General, and Cray versions are being prepared and should be available soon from the National Energy Software Center. Call or write NESC at Argonne National Laboratory, 9700 South Cass Avenue, Argonne, IL 60439, (312) 972-7250 for the status of these versions.

Item: There has been a change made in the name of our group. Instead of Building Energy Analysis, we are now known as the Building Energy Simulation group (BES), to reflect our interest in, and direction toward, a new generation of computer simulation programs. DOE-2 will continue to be developed and supported, but our long-term objectives also include the development of higher-order, as well as simplified, building energy-use analysis computer programs.

DOE-2.1N AND RESEARCH ACTIVITIES AT LBL

Collaborative efforts between the Building Energy Simulation group and other research groups at the Laboratory focus on the development of building performance models and energy-efficient designs. Data collected from laboratory testing facilities lead to new algorithms. Introduced into our developmental version of DOE-2, these algorithms are tested and validated on a multi-group basis; the resultant new modelling capabilities benefit researchers and program users alike.

A number of significant results from recent studies on window glazing, daylighting, and infiltration are contributing to future versions DOE-2.

• Studies of the combined solar, infiltration, conductive/convective, and radiative heat transfer through windows as a function of window type, orientation, and changing weather conditions are being conducted by the Windows and Daylighting Program in their Mobile Window Thermal Test facility (MoWiTT). THERM, a window heat-transfer program, and SUPERLITE, which computes illumination in interior spaces, also contribute considerable information leading to improved design strategies. As a result of this research, modifications are being made to allow DOE-2 to accurately model the thermal and daylighting characteristics of window shading devices and of advanced glazing systems.

• Another testing facility that provides unique modelling capabilities is the artificial sky dome, which allows scale model studies for daylighting. The sky simulator evaluates the effects of uniform luminance, overcast skies, and clear sky conditions. It also simulates the effect of ground reflected light. Working with the Daylighting group, we have developed new daylighting algorithms, and have now installed an hour-by-hour daylighting model in DOE-2.1B.

• A major achievement of the Energy Performance of Buildings group has been the development of a model for characterizing infiltration losses in residential buildings. This model uses a new parameter — effective leakage area — which can be a powerful tool for architects and builders interested in reducing infiltration in new residential structures. Results of this research has led to a new infiltration algorithm in DOE-2.1B.

The EPOB group has also been responsible for the development of simplified residential energy calculation algorithms suitable for mi-

(Continued on back page)

CIRA^{tm}: RESIDENTIAL ENERGY ANALYSIS ON A MICROCOMPUTER

Some time ago, we published an article which addressed the issue of running DOE-2 on a microcomputer. The conclusion drawn then, that it was highly impractical given the size of the program and the current technology, still remains true. Since then, however, a new program has been developed by the Energy Performance of Buildings group at LBL called CIRA^{tm} — Computerized Instrumented Residential Audit, which is designed specifically for micros.

CIRA is a user-friendly, interactive, residential building energy analysis program which takes advantage of many of the algorithms in DOE-2 as well as the latest developments in simplified computer models. An input session on CIRA consists of questions posed by the computer, in English, and responses chosen by the user from a displayed menu of choices. Detailed explanations of questions are provided upon request, built-in default values, often computed from one or more previous responses, are available, and the user has the ability to change the input to any variable at any time during the session. Friendly, indeed.

The impressive output capabilities of CIRA include standard tables and customized plots of design energy analysis, a retrofit report, an interactive calculator, and the ability to store the output on disk or send it to a line-printer.

To summarize the calculation methodology briefly: For each month, an energy balance is calculated separately for day and night. First, a heat-transmission coefficient is calculated to determine how much heat the house loses per month and per degree of temperature difference between indoors and outdoors. To this coefficient is added the effect of infiltration, computed on a monthly basis using information on the leakage area of the house, the type of terrain, and the type of shielding surrounding the house. For terrain and shielding classes, CIRA will display descriptive tables on request. Leakage area is generally measured with a so-called "blower door", a fan-like device that creates an over- or under-pressure in the house and measures the amount of air flow through the fan necessary to reach several special levels of pressure. Alternatively, CIRA estimates the leakage area from information on the air tightness of windows, walls, doors, and all other building components. Dynamic defaults are available to provide what the user may not know.

CIRA presently has weather data files for 12 U.S. cities which include all data for the air infiltration and the solar gains calculations.† Solar gains are computed by taking into account weather-averaged solar radiation, the shading effects of trees, nearby buildings and overhangs, and the optical characteristics of windows and walls. The shading effects of overhangs and the reflection of glazed surfaces are modelled by using correlation methods developed at Los Alamos National Laboratory. The solar gains, together with other internal gains and radiation losses to the sky, are used to compute an effective outdoor temperature, which is usually higher than the monthly average temperature. The monthly values of effective outdoor temperature, indoor thermostat setting, and heat-transmission coefficient are used in a variable base degree-day model to compute monthly heating and cooling loads for day and night. These loads are corrected if night and day thermostat settings are different. Seasonal heating and cooling efficiencies are figured for each month based on 1) heating and cooling loads, 2) specifications of the heating and cooling equipment, 3) part-load efficiencies, and 4) ambient-dependent output capacities. Finally, heating and cooling loads and efficiencies are combined to arrive at monthly energy consumptions for heating and cooling.

Results of CIRA runs for seven different cities and two thermostat schedules have been compared with those of DOE-2.1, and, in general, discrepancies between the two programs were found to be on the order of ± 10%.

The program (actually a collection of programs) was designed for a wide variety of microcomputers with the following hardware requirements: Z80, 8080 or 8085 family of microprocessor, CP/M ‡ operating system (version 2.0 or greater), 64K of random access memory, two 8-inch single density disk drives or equivalent (2x240K or 480K bytes total), an 80-column cursor-addressable video terminal, and a 132-column printer.

Purchasing information for the CIRA Manual and disks is available from the Technical Information Department, Lawrence Berkeley Laboratory, (415) 486-6782.

† TRY Weather files are being developed for 280 cities.

‡ CP/M is a trade-mark of Digital Research, Inc.

A DOE-2 COMPARISON WITH CERL DATA FOR VAV AND REHEAT SYSTEMS

A draft report which was completed in November 1981 by the Construction Engineering Research Laboratory, located in Champaign, Illinois, describes a comparison of DOE-2.1A computer simulation runs to measured data collected by CERL. The results of CERL's original data collection were reported in Validation System for Mechanical Systems Algorithms in Building Energy Analysis Programs, Interim, dated May 1981. Work in progress will allow updates to include multi-zone and rooftop unit system types.

The DOE-2.1A program was used to simulate two HVAC system types: namely, VAV with reheat, and terminal reheat (Constant Volume). Forty-nine test cases were prepared as input to DOE-2.1A and the simulation results were then compared to the test data collected by CERL.

It was found that DOE-2.1A produced results that were in agreement with the CERL data as follows:

These results may not appear to be outstanding, but put in the light that the loadings on the equipment ranged from 0% to 100%, the results were better than expected. Upon close examination it was found that the CERL data for heat balance on the air side deviates from the heat balance on the water side. These deviations are of the same magnitude as the deviations between DOE-2.1A and the CERL data as reported below. This is not meant to fault the data collection, but to give full recognition to the difficulty of collecting HVAC part load data. The best data were for those test cases in which the equipment was fully loaded, and invariably resulted in excellent heat balances. These were also the most easily simulated conditions, and the agreements here were of the order of ± 2% for all variables.

These CERL reports will be made available through NTIS upon completion of the tests.

VAV: 21 Test Cases

	Average Deviation
Cooling Coil	+2%
Heating Coil	+4%
Electrical	-10%
Natural Gas	+9%
Space Temperatures	+1%

Reheat: 28 Test Cases

	Average Deviation
Cooling Coil	+3%
Heating Coil	-4%
Electrical	+3%
Natural Gas	+12%
Space Temperatures	+1%

* * * * *

BUILDING ENERGY SIMULATION BIBLIOGRAPHY — UPDATE

ASHRAE Papers: The following papers were presented at the last two ASHRAE semi-annual meetings, held in June 1981 and January 1982. Copies are available from the ASHRAE Publications Sales Department, (404) 639-8400.

ANALYTICAL DEVELOPMENTS IN INTERZONE AND SYSTEM COUPLING METHODOLOGY, Z. O. Cumali, June 1981.

THE CUSTOM WEIGHTING-FACTOR METHOD FOR THERMAL LOAD CALCULATIONS IN THE DOE-2 PROGRAM, J. F. Kerrisk, B. D. Hunn, N. M. Schnurr, and J. E. Moore, June 1981.

MEASUREMENT AND INTERPRETATION OF AIR TIGHTNESS, M. H. Sherman, June 1981.

THE DETERMINATION OF THE DYNAMIC PERFORMANCE OF WALLS, M. H. Sherman and R. C. Sonderegger, January 1982.

THE IMPACT OF VENTILATION RATES ON THE DESIGN OF OFFICE BUILDINGS, H. Ross, M. Goodman, and B. Birdsall, January 1982.

ENERGY-CONSERVING RETROFITS AND INDOOR AIR QUALITY IN RESIDENTIAL HOUSING, C. Hollowell, J. V. Berk, R. A. Young, and S. R. Brown, January 1982.

MANUAL AND GRAPHIC PASSIVE SOLAR DESIGN TOOLS, J. D. Balcomb, June 1981.

MICROCOMPUTER AND COMPUTER DESIGN METHODS, R. D. Busch, June 1981.

EVALUATION OF EXISTING PROGRAMS FOR SIMULATION OF RESIDENTIAL BUILDING ENERGY USE, R. L. Merriam, January 1982.

USING THE DOE-2 COMPUTER PROGRAM FOR RETROFIT ENERGY STUDIES, C. C. Copeland, January 1982.

(Continued on page 5)

USING DOE-2 IN THE DESIGN PROCESS

DOE-2 can be a very useful tool for optimizing the energy usage of a building still in the early design stages. However, most people avoid using the program at this stage because much is yet unknown about the building. Also, the effort of describing the successive changes in DOE-2 can be laborious. Use of the PARAMETER command can greatly simplify the effort.

Suppose the user is designing a highrise building. He/she would like to use DOE-2 to help determine the shape of the building, the number of floors, the type and area of windows, and the cost-effectiveness of an energy efficient lighting system. Each floor can be modelled as four exterior zones and one core zone. Part of the input would be as follows:

```
PARAMETER
   BLDG-LENGTH=100  NUM-MIDDLE-FLOORS=5
   BLDG-WIDTH=50    NUM-WINDOWS-NS=20
   CORE-LENGTH=70   NUM-WINDOWS-EW=10
   CORE-WIDTH=20    LITES-WATTS-FT2=1.5
   FLOOR-HEIGHT=12  WINDOW-GLASS-TYPE=5 $ GLASS
                                   TYPE CODE ..
```

The middle floors use the PARAMETER input as follows:

```
NORTH-MIDDLE = SPACE
   MULTIPLIER=NUM-MIDDLE-FLOORS
   SHAPE=BOX
   HEIGHT=FLOOR-HEIGHT
   WIDTH=BLDG-LENGTH
   DEPTH=15  $ AVERAGE DEPTH
   AZIMUTH=180   $ SO FRONT FACES OUT
   LIGHTING-W/SQFT=LITES-WATTS-FT2
   EQUIPMENT-W/SQFT=.00058  $ ACTUALLY PEOPLE
   EQUIP-SENSIBLE=.55
   EQUIP-LATENT=.45
        .
        .
        .               ..
N-MID-WALL = EXTERIOR-WALL   LOCATION=FRONT
        .
        .
        .               ..
N-MID-WIN = WINDOW  HEIGHT=5       WIDTH=4
                    MULTIPLIER=NUM-WINDOWS-NS ..

EAST-MIDDLE = SPACE  LIKE NORTH-MIDDLE
                     AZIMUTH=270
                     WIDTH=BLDG-WIDTH  ..

          EXTERIOR-WALL LIKE N-MID-WALL ..

          WINDOW LIKE N-MID-WIN
                MULTIPLIER=NUM-WINDOWS-EW ..
             .
             .
             .
CORE-MIDDLE = SPACE  LIKE NORTH-MIDDLE
                     AZIMUTH=0
                     WIDTH=CORE-WIDTH
                     DEPTH=CORE-DEPTH ..

             INTERIOR-WALL
                     LOCATION=BACK
                     NEXT-TO=NORTH-MIDDLE
             .
             .
             .                          ..
```

Now if the user wants to change the shape of the building, he/she need only change the PARAMETER values and all floor areas, wall areas, and volumes will be automatically rescaled. In this example, the sensible and latent people heat gains were input as equipment loads so that they would be automatically scaled with the floor area (400 Btu/person, 200 ft^2/person).

SYSTEMS files can also be set up so that all changes are made through the PARAMETER command.

Once the initial files are defined correctly, the changes can be made easily with no mistakes. If all of the changes are made through the PARAMETER command, the input is self-documentary — in fact, all parametric runs can be made with a DIAGNOSTIC=NO-ECHO placed after the PARAMETER input to save paper and speed up the printing of the output.

Finally, if the user's parametric input is flexible enough, the user can use the file to simulate any similar highrise building.

BUGS DISCOVERED IN DOE-2.1A AND INTERIM SOLUTIONS

Since the last issue of the newsletter, only six new bugs in DOE-2.1A have been identified. All of them are in the SYSTEMS subprogram. Referenced keywords and phrases appear in bold-face.

[27] If, for a ZONE-TYPE=PLENUM, the keyword **MULTIPLIER** is specified, the program will give incorrect results, the severity of which increases in proportion to the value specified for MULTIPLIER.

Interim solution: None; do not use **MULTIPLIER** for ZONE-TYPE=PLENUM. Specify each zone separately.

[28] The values for the system-level **HOURLY-REPORT** variables 78, 79, and 80 are not reported out.

Interim solution: None.

[29] Some underheating and undercooling may be incorrectly reported in SS-F when COOL-CONTROL=WARMEST or **HEAT-CONTROL=COLDEST**. This is due to the use by the program of an incorrect value for the zone thermostat throttling range in the calculation of supply temperature. The value used is one-half the actual value. This bug effects only the calculation of the supply temperature; other calculations use the correct value for the throttling range.

Interim solution: There is no way to avoid this bug entirely when using the COLDEST/WARMEST options, but specifying a THROTTLING-RANGE that is two to three times the normal range will minimize the underheating/undercooling problem. This may, however, require adjusting the setpoints to ensure that average zone temperatures are maintained as desired.

[30] If the value input for DESIGN-HEAT-T for a zone is equal to the value input for MAX-SUPPLY-T, <u>or</u> if it is equal to the sum of MIN-SUPPLY-T and REHEAT-DELTA-T, <u>and</u> MIN-CFM-RATIO has not been specified, the program will abort in routine **DESIGN**.

Interim solution: Change either the DESIGN-HEAT-T or MAX-SUPPLY-T, or the MIN-SUPPLY-T, such that they are not equal.

[31] The program may abort in routine **HTPUMP** if cooling is scheduled on in a HP system, but heating is scheduled off. This should be a rare occurrence in this system since it defeats the normal purpose.

Interim solution: Schedule both heating and cooling on.

[32] If SYSTEMS is run with DESIGN-DAY RUN-PERIODs only and **SUMMARY** reports are requested, they will be produced, but with incorrect or all zero values. Note, however, that no SYSTEMS SUMMARY reports are intended to be produced for DESIGN-DAY RUN-PERIODs; DESIGN-DAY runs are intended only for PLANT sizing.

Interim solution: None; ignore the SYSTEMS SUMMARY reports.

Documentation Note:

Values of -99999, -88888, and -77777 are not allowed as input to <u>any</u> keyword in DOE-2, even though they may be within the range, e.g., for HEAT-CAPACITY. These values are reserved for internal program use and are not interpreted as numerical values. Unpredictable results may be encountered from the use of these values. No WARNING message is issued, so be aware.

* * * * *

BUILDING ENERGY SIMULATION BIBLIOGRAPHY — UPDATE — Continued

<u>THE THEORETICAL BASIS OF THE DOE-2 BUILDING ENERGY-USE ANALYSIS PROGRAM</u>, R. B. Curtis, April 1981. LBL Publication, LBL-12300.

<u>USE OF A DIESEL ENGINE-DRIVEN EMERGENCY POWER GENERATING SYSTEM FOR PEAK SHAVING IN BUILDINGS</u>, S. Choi, J. Hirsch, and B. Birdsall, January 1982. LBL Publication, LBL-12299.

<u>LIFE-CYCLE COST AND ENERGY-USE ANALYSIS OF SUN-CONTROL AND DAYLIGHTING OPTIONS IN A HIGH-RISE OFFICE BUILDING</u>, F. C. Winkelmann and M. Lokmanhekim, May 1981. LBL Publication, LBL-12298.

<u>GLAZING OPTIMIZATION FOR ENERGY EFFICIENCY IN COMMERCIAL OFFICE BUILDINGS</u>, R. Johnson, S. Selkowitz, F. C. Winkelmann, and H. Zentner, October 1981. LBL Publication, LBL-12764.

Copies of LBL publications are available from the authors, until their stock is depleted. Thereafter, orders are taken by NTIS. The LBL Telephone Information number is (415) 486-6111.

THE HEAT EXCHANGER

This section is devoted to questions from users and responses from the Building Energy Simulation group and its consultants. Your questions and comments are most welcome.

* * * * *

Question: There is considerable interest in residential ground water heat pumps here in the Northern climates. Although DOE-2 does not specifically address this system type, is there a way to approach it using the HP (closed loop water/air heat pump) system type?

Answer: Yes, a ground water or ground source heat pump can be modelled in an approximate manner. To do so, use the HP system with several parameters changed to model the ground source. First, to prevent a free source during the transition from heating to cooling, set the FLUID-HEAT-CAP to a small value (= 10). Next, to correctly represent the source temperature, set the MAX-FLUID-T and MIN-FLUID-T equal to the average ground source temperatures during the cooling and heating seasons, respectively. These values should take into account any temperature rise in supplying fluid to the unit. (Values of 75 and 50 for the maximum and minimum are suggested.) Suggested values for COOLING-EIR and HEATING-EIR are 0.31 and 0.38, respectively.

Be sure to schedule both heating and cooling on, at least during the daytime. (Bug 32 describes why.)

Additionally, we must account for the energy used for pumping the ground water from the well. In PLANT, therefore, we must enter commands to add this cost. For the heating mode pumping energy, we enter an ENERGY-COST command with RESOURCE=STEAM and a UNIFORM-COST of .02 for a UNIT equal to 1,000,000 Btu's. If the ground water is also used for the cooling mode source, a similar command is entered for the CHILLED-WATER utility. If a cooling tower or evaporative cooling is used in the cooling mode, this is not necessary. If the ground itself is a source rather than ground water (a buried condenser), the pumping energy may be reduced or eliminated, depending on the arrangement.

The comparison to RESYS systems with air-to-air heat pumps and straight electric resistance heating appears to be realistic. However, one should not use the NATURAL-VENT-keywords as these are not applicable to SYSTEM-TYPE=HP and the primary interest is the comparison of heating energy. Zone inputs should be limited to a single zone for both HP and RESYS systems.

Another refinement is to edit the PLANT reports by altering the term STEAM to GROUND-WATER in the PS-B and BEPS reports.

* * * * *

Question: Can a steam turbine used to shaft or electrically drive a centrifugal chiller be modelled?

Answer: Yes. Equivalent thermodynamic models can be constructed for this and other equipment combinations. In your example, the turbine and chiller must be taken as a single unit which requires steam as an energy source (with possibly a small amount of electrical auxiliary power) and provides cooling.

This description matches the absorption chiller model. All that is required is a change to the HIR value and its associated curves to represent the heat input to cooling output relationship of the turbine chiller combination you are contemplating. The same method can be used to model a piggyback arrangement where the turbine shaft drives a centrifugal chiller and the waste heat drives an absorption machine. Use of the LOAD-MANAGEMENT and LOAD-ASSIGNMENT commands can allow switching between this special absorber and more conventional equipment based on load or time.

The drawback to this model is that no waste heat can be recovered for the special absorption machine and be used for the other heating requirements unless they can be combined in a single representative machine.

* * * * *

Information Sheet and Order Form:

DOE-2 Building Energy Use Analysis Program

Version 2.1A

The following may be ordered by telephone, (703) 487-4650 or FTS 737-4650, or by mail. The current costs may be obtained by writing or calling NTIS. Please refer to the PB order numbers when ordering by telephone.

______ copies CDC DOE-2.1A Program Tapes PB82-141458

______ copies IBM DOE-2.1A Program Tapes PB82-201237

______ copies IBM DOE-2.1A Update Mod (only) Tapes PB82-141466†

(The tape will be 9-track, 1600 bpi, unless otherwise specified)

Character Type:

☐ EBCDIC ☐ ASCII

______ sets Complete DOE-2.1A Documentation PB82-141474

______ sets DOE-2.1A Documentation Update PB82-141482
(replacement sheets only)

______ subscriptions to the quarterly DOE-2 USER NEWS PB81-912100
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† Current owners of the IBM DOE-2.1 tape need only order the update tape.

crocomputer applications. For more information, see the article inside on Computerized Instrumented Residential Analysis.

• In collaboration with Los Alamos National Laboratory, we are beginning to integrate models of certain passive solar elements into the developmental version of DOE-2. Already in DOE-2.1B is a model of a Trombe wall, both vented and unvented.

• In addition, on-going studies in the LBL Passive Research and Development group into passive cooling strategies in commercial buildings, particularly natural convection and radiative cooling, are leading to improved knowledge of how structures interact with their environment, and better techniques for properly controlling them. Detailed numerical models are being developed which will be introduced into future versions of DOE-2.

• Research into new structural designs, such as supply- and return-side hollowcore systems, is also being conducted. These systems utilize precast hollowcore planks through which supply/return air flows via connected cores in the plank.

• Recent investigations into residential air-to-air heat exchangers in the Ventilation and Indoor Air Quality group stem from the rising need to alleviate indoor air quality problems caused by reduced infiltration. Five commercially-available models are currently being tested for thermal and fan system performance. Implementation of an air-to-air heat exchanger is planned for DOE-2.1C.

• Algorithms have been designed and implemented in a developmental version of DOE-2 for the simulation of earth-bermed buildings, including the heat transfer through underground walls and floors. These algorithms use a mathematical technique similar to the response factor technique used for standard walls and floors, but they employ a longer time-step. These algorithms take into account the ground surface interface in addition to the interfaces with walls, floors, and the internal environment. The algorithms in this developmental version of the code are currently being validated against measured data. When their accuracy has been established, they will be released in the official version, (possibly DOE-2.1B, but more likely, DOE-2.1C).

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