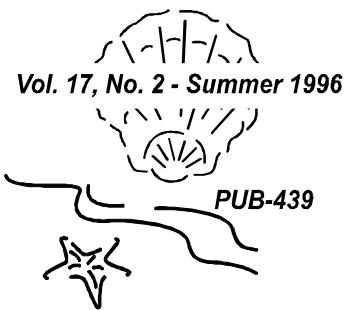


## Building Energy Simulation

# User News

For Users of DOE-2, SPARK, BLAST and their Derivatives



### What's New??

- **User News on the WWW** Look for this and future issues in the directory  
<http://eande.lbl.gov/BTP/SRG/UNews>  
You can download the newsletter in PDF format and read it with Adobe's "Acrobat" reader, available free of charge.
- **DOE-2.1E Documentation Correction**  
Turn to p. 8 for a correction to the *Supplement*.
- **NTIS: Inflate Before Ordering** Check out the hefty new prices for DOE-2.1E documentation, p. 26.
- **Free DOE-2 Help** Call or fax our modeling expert, Bruce Birdsall, for questions about DOE-2. If you need to fax an example of your problem, please telephone him beforehand. This free service is supported by LBNL's Simulation Research Group.  
Phone Bruce at (510) 829-8459 between the hours of 10 a.m. and 3 p.m. PDT.
- **Spectral Data for the WINDOW-4.1 Program** If you use WINDOW-4.1, you may download the NFRC Spectral Data Library (Version #3) from the world-wide web at  
<http://eande.lbl.gov/BTP/NFRC/NFRCsdlb/NFRCsdlb.html>.
- **Download Weather Data Sets** You may now download both TMY and TMY2 weather data sets from the world-wide web:  
**TMY:** [http://oipea-www.rutgers.edu/html\\_docs/TMY/tmy.html](http://oipea-www.rutgers.edu/html_docs/TMY/tmy.html)  
**TMY2:** <http://rredc.nrel.gov/solar/data/nsrdb/tmy2/>

### What's Inside??

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The *User News* is published by the Simulation Research Group at LBNL with cooperation from the BLAST Support Office at the University of Illinois. Direct comments or submissions to Kathy Ellington, Editor, MS: 90-3147, Lawrence Berkeley National Laboratory, Berkeley, CA 94720, or email [kathy@gundog.lbl.gov](mailto:kathy@gundog.lbl.gov) or send us a fax at (510) 486-4089. Direct BLAST-related inquiries to the BLAST Support Office, phone (217) 333-3977, send email to [support@blast.bso.uiuc.edu](mailto:support@blast.bso.uiuc.edu)

Energy and Environment Division  
Lawrence Berkeley National Laboratory  
University of California  
Berkeley, California 94720 USA

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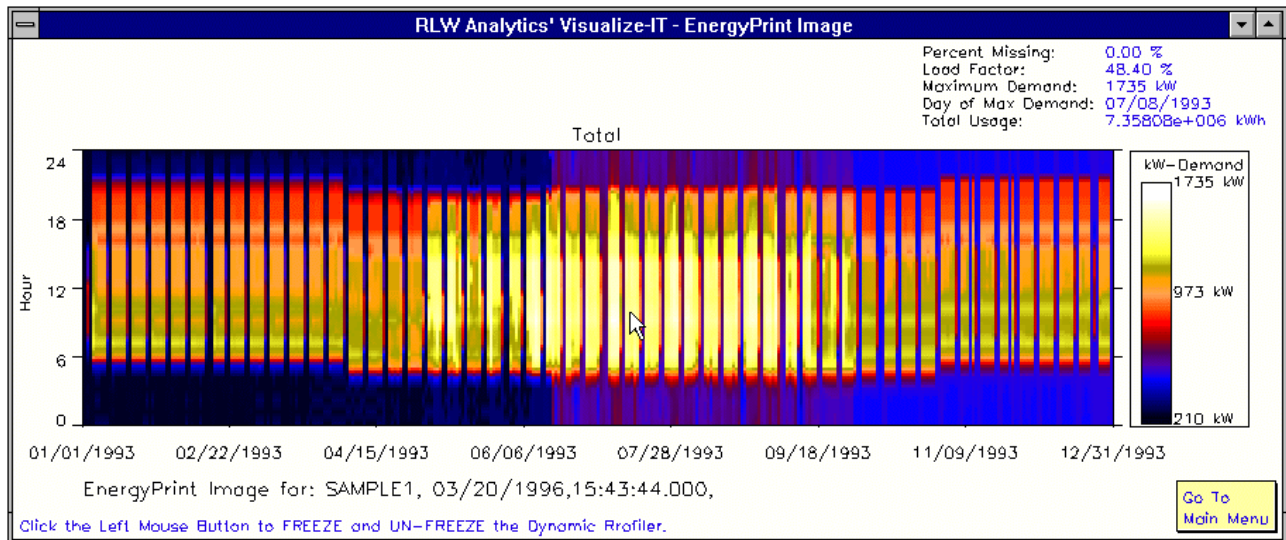
# New Data Visualization Tools for DOE-2.1E Calibration

from

**RLW Analytics, Inc.**  
**1055 Broadway, Suite G**  
**Sonoma, CA 95476**

RLW Analytics has developed two data visualization tools that will dramatically decrease the time it takes to calibrate a model to metered data and increase your understanding of both the building's and customer's behavior. These tools give you the power to explore your data in depth, with both visual and statistical tools.

The **Visualize-IT Energy Information Tool™** is used for exploring one data set (metered or DOE-2.1E hourly output) at a time. The **Visualize-IT Calibration Tool™** allows you to interactively explore the relationship between total load (or end-use) metered data and the DOE-2.1E hourly output from your model. This discussion will serve as a brief overview of both tools.



**Figure 1: Example of an EnergyPrint™ Image**

The primary visual building block for both tools is the EnergyPrint image, a 3D plot of interval (15 minute, half hour, or hourly) energy related data. In the graph, the three dimensions are the time of day (on the Y axis), the day of the period (on the X axis), and the demand for each interval (represented using color on the Z axis). Lighter colors (hot) represent higher intensity of energy use and darker (cool) colors represent lower intensity of energy use. Think of the EnergyPrint image (Figure 1) as a series of daily load shapes, stacked consecutively, color coded, and viewed from above. You get a quick overview of the hours of operation, seasonal patterns, and the influence of end uses such as lighting or HVAC.

### **Visualize-IT Energy Information Tool**

Many of the data analysis options available in the Energy Information Tool allow you to quickly generate familiar views of your data. They include average and single day load shapes, monthly peak demand and usage, load duration curves, and load shape comparisons for two periods. One of the unique options is the Dynamic Profiler, which gives you the ability to interactively explore your data by moving your mouse around the EnergyPrint and generating loadshapes for the specific day on which the mouse rests.

A second option that dramatically increases your understanding of your data allows you to display up to eight EnergyPrints on one screen. This has many potential applications: it shows you interactions between end uses, or effects of temperature on a load. Most of the data analysis options in the Energy Information Tool generate both graphic and numeric data. The graphics can be saved as bitmaps and the numeric data can be saved as comma separated files.

### **Visualize-IT Calibration Tool**

The Calibration Tool has many of the features of the Energy Information Tool with an emphasis on interval-by-interval comparison between metered (60-, 30-, or 15-minute) and DOE-2.1E hourly data. Like the Energy Information Tool, the Calibration Tool can save your analysis in graphic and comma-separated files. The options available in the Calibration Tool are listed below.

***Overview Screen*** - Shows EnergyPrints of the DOE-2 total load, metered total load, the residual load between the two total loads, and five DOE-2 end uses. This screen also displays the average weekday load shape for all the DOE-2 end uses and the metered total load. Lastly, it prints the monthly and annual MBE, CV(RMSE), and other statistics that describe the “goodness of fit” for the total loads for DOE-2 and metered data. An example is shown in Figure 2.

***Monthly Demand and Load - 2D Graphs*** - 2D Plots of the monthly demand and energy usage are displayed for the metered and DOE-2 end use.

***Max and Seasonal Load Shapes*** - Shows the daily load shapes for all metered and DOE-2 end-uses for the peak demand day (in the DOE-2 total load), and average weekday load shapes for Spring, Summer, Fall and Winter DOE-2 and metered total loads.

***Average Load Profiles for One End Use*** - Displays the load shapes for the average weekday, weekend, and week across a user-defined set of months for the metered and DOE-2 end use. An example is shown in Figure 3.

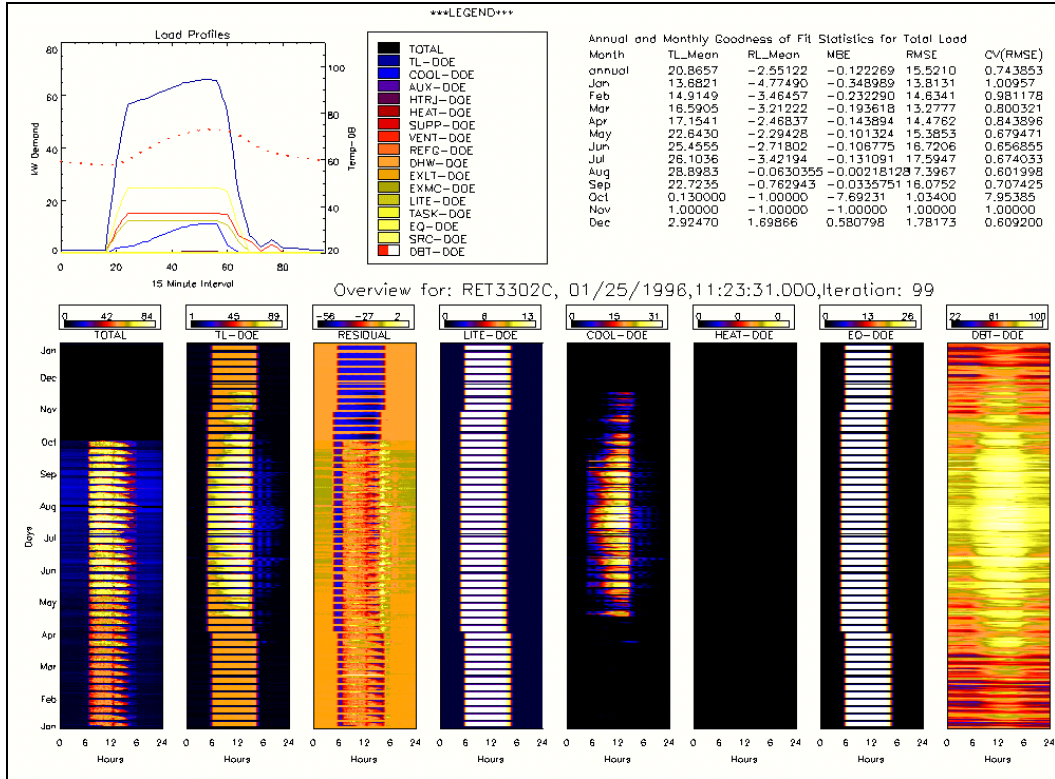


Figure 2: Overview Screen

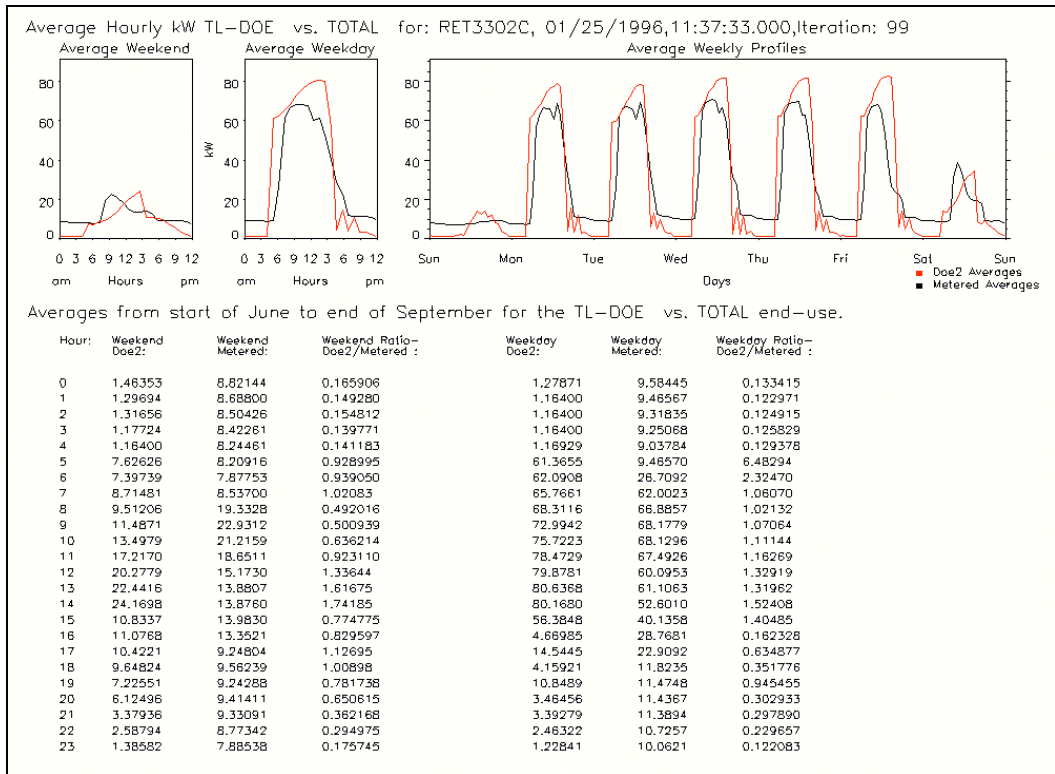


Figure 3: Average Load Profiles Screen

**End Use Residual Loads** - Provides the DOE-2 and metered data EnergyPrint for the end uses. Also displays the residual load EnergyPrint which shows the difference between the DOE-2 and metered end use. An example is shown in Figure 4.

**Monthly Average Weekday and Weekend Days** - Provides 24 load shapes for the one DOE-2 and one metered end use chosen. For each month a load shape for the average weekday and the average weekend is displayed. An example is shown in Figure 5.

**Normalized Monthly Average Weekday and Weekend Days** - This is the same as the Monthly Average Weekday and Weekend Days, but the Y axis is scaled from 0 to 1.

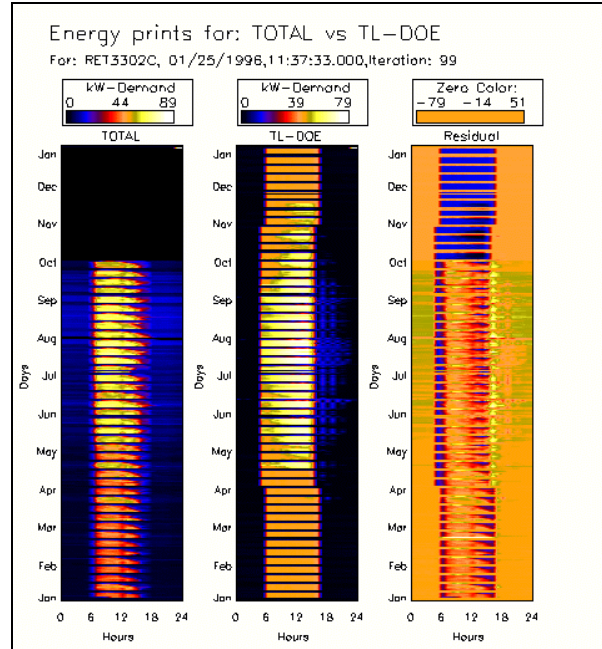


Figure 4: End-Use Residual Loads Screen

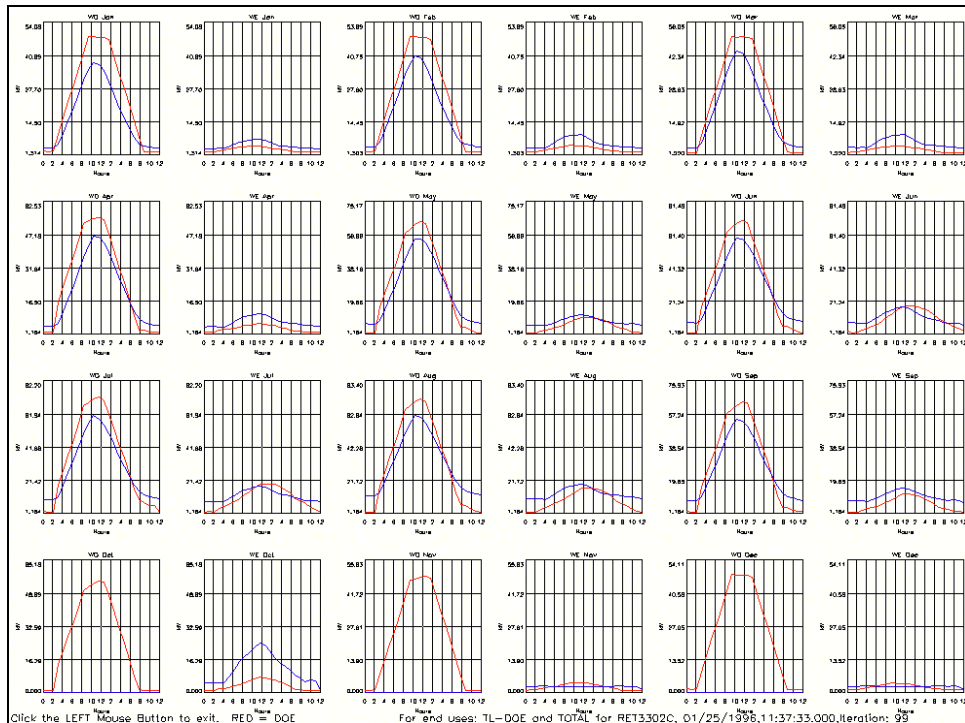
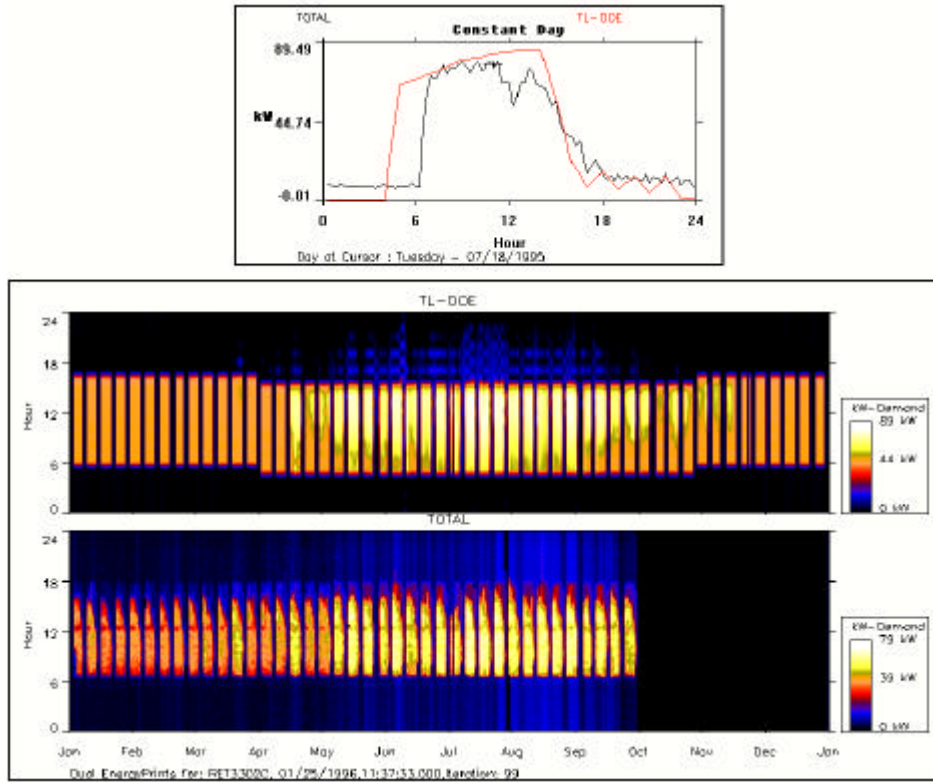


Figure 5: Monthly Average Week and Weekend Days Screen



**Figure 6: Comparison Dynamic Profiler**

**Comparison Dynamic Profiler** - This tool creates a new screen with two EnergyPrints, the DOE-2 end uses on top and one of the metered end uses on the bottom. As the analyst moves the mouse over either of the EnergyPrints, the daily load shape for both the metered and DOE-2 total load data is displayed in a smaller window. An example is shown in Figure 6.

**Comparison Dynamic Profiler - Normalized Data** - Similar to the Comparison Dynamic Profiler but the images are normalized with the colors in both EnergyPrints representing the same demand value so that a qualitative color comparison can be made.

**Temperature vs. kW** - Provides a scatter plot of the load of the chosen end use vs. demand for three temperature bins: 80-89°F, 90-100°F, and above 100°F.

**View Multiple EnergyPrints** - Allows the display of up to eight DOE-2 and metered end uses.

**Help on This Menu** - Provides a quick reminder of the tools available.

**Load New DOE-2 and Metered Data Files** - Choose a new set of data to investigate.

## Conclusion

This has served as an introduction to the Visualize-IT package of Visual Data Analysis tools. If you have any questions please contact either Jim McCray, Pat Bailey, or Jedd Parker at: RLW Analytics, Inc., 1055 Broadway, Suite G, Sonoma, CA 95476, Phone: (707) 939-8823 / Fax: (707) 939-9218

## Recent Reports: PowerDOE, Radiant Cooling, Data Visualization, Electrochromic Glazings, Evacuated Glazing

These two reports are available from Lawrence Berkeley National Laboratory. Please fax your request to Kathy Ellington at (510) 486-4089.

### **PowerDOE, A Windows-Based Visually Oriented Analysis Tool**

by  
*J. J. Hirsch*  
*Hirsch & Associates*  
*Camarillo, CA*

*F.C. Winkelmann, W. F. Buhl and K. L. Ellington*  
*Lawrence Berkeley National Laboratory*  
*Berkeley, CA*

*J. S. McMenamin, I. Rohmund and S. A. Criswell*  
*Regional Economic Research, Inc.*  
*San Diego, CA*

*A. Bhimani and B. Spurlock*  
*Southern Company Services*  
*Atlanta, GA*

*J. Borstein*  
*D. J. Borstein & Associates*  
*Los Altos, CA*

*K. F. Johnson*  
*Electric Power Research Institute*  
*Palo Alto, CA*

#### *Abstract*

PowerDOE, a new PC-based building energy performance simulation tool, combines the full capabilities of DOE-2.1E with an easy-to-use to-use flexible windows graphical user interface (GUI). This interface implements a number of unique approaches to facilitate developing an accurate building description. PowerDOE organizes architectural and HVAC elements in a hierarchy that is intuitive and familiar to designers and analysts. PowerDOE provides an interactive connection between the data input phase and the simulation, allowing the user to perform certain calculations prior to running the entire simulation. This paper describes the PowerDOE user interface and the methods used

to unify the building description and building analysis process. The simulation engine structure and the way in which the program allows the simulation engine and user interface to interact are also discussed.

### **LBL-37300**

### **Development of a Simulation Tool to Evaluate the Performance of Radiant Cooling Ceilings**

by  
*C. Stetiu, H. E. Feustel and F.C. Winkelmann*  
*Energy and Environment Division*  
*Lawrence Berkeley National Laboratory*  
*Berkeley, CA 94720*

#### *Abstract [abridged]*

A significant amount of the electrical energy used to cool non-residential buildings equipped with all-air systems is drawn by fans that transport the cool air through the thermal distribution hydronic cooling systems have the potential to reduce the amount of air transported through the building by separating the tasks of ventilation and thermal conditioning. Due to the physical properties of water, hydronic cooling systems can transport a given amount of thermal energy using less than five percent of the otherwise necessary fan energy. This improvement alone significantly reduces the energy consumption and peak power requirement of the air conditioning systems. The evaluation of the theoretical performance of hydronic cooling systems is most conveniently made by computer models. The scope of this project is the development of a model that can accurately simulate the dynamic performance of hydronic radiant cooling systems. The model was created with LBNL's Simulation Problem Analysis and Research Kernel (SPARK), which provides a methodology for describing and solving the dynamic, non-linear equations that correspond to complex physical systems.

The next two reports were printed in the proceedings of the IBPSA Building Simulation '95 Conference, held in Madison, WI, August 14-16, 1995; they are **not** available from LBNL. Conference proceedings may be purchased from IBPSA, Attn. Larry Degelman, College of Architecture, Texas A&M University, College Station, TX 77843-3137. Fax: (409) 845-4491. Cost of BS-95 is \$70US for IBPSA members, \$105US for non-members. For more information on IBPSA membership and to order proceedings from past conferences, see *User News*, Vol. 16, No. 3, p.16-17.

### **Using Data Visualization Tools for the Calibration of Hourly DOE-2 Simulations**

by

*J. McCray, P. Bailey, and J.L. Parker*

*RLW Analytics, Inc.*

*1055-G Broadway*

*Sonoma, CA 94576*

and

*Richard Gillman*

*Electric Power Research Institute*

*Retail Market Tools and Services*

*P.O. Box 10412*

*Palo Alto, CA 94303*

#### *Abstract*

The volume of annual, monthly, and hourly simulation output developed by building simulation packages such as DOE-2 presents the building modeler with significant challenges. Developing hourly total load and end-use estimates of building performance calibrated to fifteen-minute or hourly metered total load or end-use data requires new analytic tools that allow the modeler to quickly review the results and make iterative changes to the models. This paper suggests that engineering model calibration can quickly go beyond monthly customer billing data to minimize self-cancelling errors where under-predictions in one end-use cancel out over-predictions in another end-use. New visual data analysis techniques can provide the modeler with tools that improve the accuracy of hourly total load and end-use data while minimizing modeling

costs. This paper presents four calibration approaches and supporting statistical measures that can be used as iterative diagnostic tools for the building modeler.

### **VISUALIZE-IT™ Model Calibration Tool Kit**

by

*J. McCray, P. Bailey, and J.L. Parker*

*RLW Analytics, Inc.*

*1055-G Broadway*

*Sonoma, CA 94576*

#### *Abstract*

VISUALIZE-IT is a visual data analysis tool kit. RLW Analytics, Inc., has developed a number of specific data visualization tools for the study of the total load and end-use data produced by the DOE-2 building simulation package. The DOE-2 VISUALIZE-IT Calibration Tool is designed to allow an analyst to calibrate simulation results against metered total load or end-use data. These data visualization techniques allow the user to quickly and easily view and analyze data sets that can contain several hundred thousand data points.

#### **DOE-2.1E Documentation Update**

**DOE-2.1E Supplement, page 3.63**  
**Under the PLANT-ASSIGNMENT**  
**command in SYSTEMS, the keywords**  
**in the left-hand column**  
**are incorrect. Change the**  
**-HT- to -HP- throughout.**

**DOE-2.1E BDL Summary**  
**No change - keywords are correct**



*The following three reports are available from Pat Ross of the Building Technologies Program at Lawrence Berkeley National Laboratory. Please fax your request to her at (510) 486-4089; be sure to include the report name and number.*

**LBL-35486 - OM-328**  
**A Review of Electrochromic Window Performance Factors**

by  
*S. Selkowitz, E. S. Lee and R. Sullivan*  
*Energy and Environment Division*  
*Lawrence Berkeley National Laboratory*  
*Berkeley, CA 94720*

*Abstract*

The performance factors which will influence the market acceptance of electrochromic windows are reviewed. A set of data representing the optical properties of existing and foreseeable electrochromic window devices was generated. The issue of reflective vs. absorbing electrochromics was explored. This data was used in the DOE-2 building energy model to calculate the expected energy savings compared to conventional glazings. The effects of several different control strategies were tested and significant energy and peak electric demand benefits were obtained for some electrochromic types. Use of predictive control algorithms to optimize cooling control may result in greater energy savings. Initial economic results considering annual savings, cooling equipment cost savings, and electrochromic window costs are presented. Calculations of thermal and visual comfort show additional benefits from electrochromics but more work is needed to quantify their importance. The design freedom and aesthetic possibilities of these dynamic glazings should provide additional market benefits, but their impact is difficult to assess at this time. Ultimately, a full assessment of the market viability of electrochromics must consider the impacts of all of these issues.

**LBL-37211**  
**Reducing Residential Cooling Requirements Through the Use of Electrochromic Windows**

by  
*R. Sullivan, M. Rubin and S. Selkowitz*  
*Energy and Environment Division*  
*Lawrence Berkeley National Laboratory*  
*Berkeley, CA 94720*

*Abstract [abridged]*

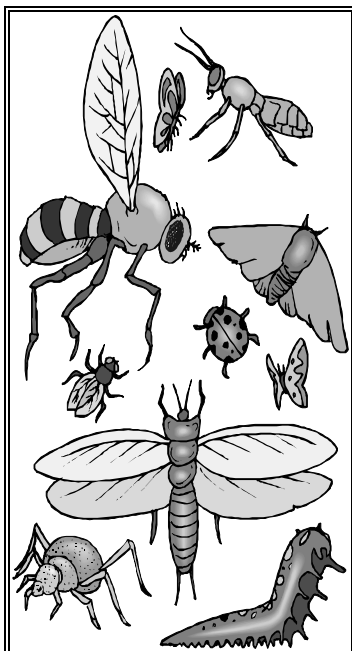
This paper presents the results of a study investigating the energy performance of electrochromic windows in a prototypical residential building under a variety of state switching control strategies. We used the DOE-2.1E energy simulation program to analyze the annual cooling energy and peak demand as a function of glazing type, size, and electrochromic control strategy.

**LBL-37130**  
**Energy Performance of Evacuated Glazings in Residential Buildings**

by  
*R. Sullivan, F. Beck, D. Arasteh and S. Selkowitz*  
*Energy and Environment Division*  
*Lawrence Berkeley National Laboratory*  
*Berkeley, CA 94720*

*Abstract [abridged]*

This paper presents the results of a study investigating the energy performance of evacuated glazings or glazings which maintain a vacuum between two panes of glass. Their performance is measured by comparing results to prototypical highly insulated superwindows as well as a more conventional insulating glass unit with a low-E coating and argon gas fill. We used the DOE-2.1E energy analysis simulation program to analyze the annual and hourly heating energy use due to windows of a prototypical single-story house located in Madison, Wisconsin.



## DOE-2.1E Bug Fixes 59 through 88

Following are bug fixes 59 through 88. Shown at the left is the version number of DOE-2.1E, which is incremented for each new set of fixes. This is followed on the same line by the subprograms to which the fixes were made (bdl = Building Description Language Processor, lds = LOADS program, sys = SYSTEMS program, etc.). Then comes a short description of the set of fixes corresponding to that version number. The author's initials and date of each fix are also shown. Note that a particular version will include all fixes made up to and including that version number. So Version 005, for example, includes the fixes listed under "-005" as well as those listed under "-003" and "-004". You can easily determine what version number of DOE-2.1E you are currently using by checking any of the DOE-2 output reports, where version *NNN* is indicated as "DOE-2.1E-*NNN*".

These bug fixes are also available via FTP from the Simulation Research Group at LBNL. Turn to p. 18 of this newsletter for instructions.

### **-059 lds plt**

Fix a bug in PLANT that would generate a division by zero with RESOURCE=CHILLED-WATER [WFB/RM 12/09/94]

### **-060 lds**

Adds more information to the LS-B Report. In addition to the peak hour DBT and WBT, the total horizontal solar radiation, the windspeed at the space location and the cloud amount will be printed. [RM 06/07/94]

### **-061 drlc**

Adds more information to the LS-B and LS-C Reports. In addition to the peak hour DBT and WBT, the Global Horizontal Solar Radiation will be printed. [RM 5/26/94]

### **-062 rlc**

While adding new outdoor data in reports LS-B and LS-C, we noticed that the number of format had to be increased. That number was set to 40 and the present mod increases it to 60. [RM 07/20/94]

### **-063 lds**

Adds more information to the LS-C Report. In addition to the peak hour DBT and WBT, the total horizontal solar radiation, the windspeed at the building location and the cloud amount will be printed. [RM 11/07/94]

### **-064 sys**

This mod adds more information to SS-N (Relative Humidity Scatter Plot). It prints relative humidity when fans are on in 10 percent increments [RM 07/18/94]

### **-065 dedt**

Increases the size of the array from 200 to 250 to carry changes in the AA array [RM 07/18/94]

**-066 bdl drlc**

Increases the space available for the NSS block of the array result of changes in SS-N [RM 07/19/94]

Adds more information to the SS-N report; specifies that the hours reported are **only** the hours when the fans are on. [RM 07/20/94]

**-067 hrp**

Changes some formats in the hourly reports to make the transfer of formatted output into a spreadsheet easier. The fields for the month, hour, and day were changed to 3 characters instead of 2. [RM 07/20/94]

**-068 sys**

This mod does **not** allow a negative value for DHW-PUMP-SCH; this would result in a negative pumping energy [RM 11/30/94]

**-069 lds**

Prevents divide by zero in shade luminance calculation when shade height or width is zero. [FW 12/13/94]

**-070 sys**

RHFUNC in SYSTEMS, which calculates relative humidity given temperature, humidity ratio, and atmospheric pressure, can return relative humidities greater than 100. [WFB 12/23/94]

**-071 drlc**

Fixes headers in the PLANT-ASSIGNMENT hourly report variables as well as metric conversion error (variables 92-100, building resources energy use in SYSTEMS) [RM 01/23/95] [corrected for missing mod from 1992 - added back in JJH 1/26/95] -

**-072 lds**

In LOADS subr misc an incorrect pointer value of <MZNEXTTO> = 0 is used for sunspace interior walls of type ADIABTIC and INTERNAL. This gets a wrong zone multiplier value for these walls and results in an incorrect calculation of the total inside surface area, <ARZ>, of the sunspace, and, consequently, an incorrect calculation of the solar distribution in the sunspace. This is only a problem if a space is a sunspace (SUNSPACE=YES) and the space has ADIABATIC or INTERNAL interior walls. [EE 01/13/95]

In loads: the DUMPIT call for the interior wall data on the design file is incorrect; it is dumping a lot of trash. [WFB 01/20/95]

**-073 wth**

In the weather processor add a PACK type TRYSLM. This tells the weather processor to process data in the TRY format and to create ersatz solar data using the SOLMET cloud cover regressions. [WFB 01/19/95]

Also in the weather processor, rewrite the CD144 and CD144-3 data processor so that data records do not have to occur every hour or every third hour, but rather any hour during the year. Thus any CD144 data file should be able to be processed without hand editing to add or eliminate data records. [WFB 01/19/95]

**-075 bdl**

Sets the maximal number of variables to their effective number given in HDRFIL.out. This was a problem for printing variables greater than 120 in SYSTEMS, VARIABLE-TYPE=U-name of PLANT-ASSIGNMENT. [RM 01/24/95]

**-076 dkey lds sys**

Add a new dimming option LIGHT-CTRL-TYPE = CONTINUOUS/OFF to the daylighting calculation. In this option the lights dim continuously to <MIN-LIGHT-FRAC>, <MIN-POWER-FRAC> as daylight illuminance increases and then turn off completely if there is a further increase in daylight illuminance. For the existing option LIGHT-CTRL-TYPE = CONTINUOUS the lights dim to minimum power but stay on at that power if there is a further increase in daylight illuminance. [FW 2/3/95]

In SYSTEMS the holidays defined in ALT-HOLIDAYS in LDL were being ignored in SYSTEMS. There is no work-around for this bug. The problem was that a common block length was changed in LOADS but not in SYSTEMS. This resulted in the design file read in SYSTEMS not picking up the alternate holiday information correctly.[WFB 2/6/95]

**-077 plt**

In PLANT, when there are two chillers, one making ice and the other meeting space loads, neither chiller operates correctly. The user indicates the ice-making chiller by calling it either an OPEN-CENT-CHLR or an OPEN-REC-CHLR. This chiller is then supposed to use the TES keywords COMP-KW/TON-START, COMP-KW/TON-END, REFRIG-T-AT-PC, EVAP-DELTA-T, and PER-COMP-REDUCT/F to calculate its decreased capacity and increased EIR when making ice. As simulated, the capacity reduction is correctly calculated, but the TES keywords are ignored when calculating the EIR. Instead the curve -EIR-FT is used, with the chilled water temperature (CHWT) used being the CHWT for ice making (32 degrees or less). This temperature is outside the range of the -EIR-FT curve's range of applicability. The EIR during ice making may actually end up too large. Note that the CHWT is calculated correctly: it is the correct CHWT for ice making. When ice is not being made, it reverts to the usual CHWT if COMP-MODE-DCHG= RATED-T.

The non ice-making chiller is denoted by being entered as either HERM-CENT-CHLR or HERM-REC-CHLR. This chiller's capacity is also calculated correctly, but its EIR is calculated using the low CHWT HERM-CENT-CHLR or HERM-REC-CHLR. This chiller's capacity is also calculated correctly, but its EIR is calculated using the low CHWT used for ice making. Thus its EIR ends up much too large.

There is no good work around for this problem. The desperate user might consider changing the -EIR-FT curves. For the ice-making chiller, the curve would have to be refit to a larger range of CHWT covering the CHWT used for ice making. For the non ice-making chiller, the existing -EIR-FT curve would have to be altered to eliminate the CHWT dependence. This could be done by substituting CHWT=44 (or the value of CHILL-WTR-T for the given input) in the -EIR-FT curve for this chiller, resulting in a curve that only depends on entering condenser temperature.

This mod fixes the problem. Basically the two chillers no longer change each others' data. Two CHWT's are maintained, one for ice making and the other for space heating. [WFB 2/8/95]

**-078 dkey sys**

Makes possible the use of HEAT-SIZING-RATIO and COOL-SIZING-RATIO as described in the documentation. The work around is to enter these keywords as HEAT-SIZING-RAT and COOL-SIZING-RAT. [RM - 02/13/95]

Change lower limit on U-values and conductance keywords to not allow a value of zero (this causes a divide by zero runtime error in LOADS). [JJH 4/12/95]

Fix a problem in the MAX-HUMIDITY control. The formula for the calculation of the coil condition needed to satisfy the MAX-HUMIDITY specification was incorrect. WCOLM was used in place of WCOL and a plus (+) was used in place of a minus (-) on one term. The problem was introduced into the DOE-2.1E version prior to initial release. There is no work-around. [JJH/SDG 2/21/95]

**-079 bdl drlc plt sys**

Fix EQUIPMENT-QUAD curve type for TWR-FAN-FPLR; it had been set to BI-QUAD and was changed to CUBIC. [JJH 4/20/95]

Correct a poor conversion IP to SI for the throttling range (variable 55) in SYSTEMS, VARIABLE-TYPE=u-name of ZONE. [RM - 02/17/95]

This fixes a minor problem with PLANT summary report PS-B. The second line of a column for STEAM or CHILLED-WATER contained nulls (char(0)) rather than blanks. This is now filled with UTILITY. Eliminate error message lines that are duplicated in earlier JHVER2 that had typo's [JJH 3/29/95]

Fix problem with end uses not getting combined when on; specified meter as outlined in documentation. To separate, just specify a meter - even the default meter. By not using a meter keyword some end uses are added together as follows:

- 1) Add source kw to equipment kw
- 2) Add heat rejection kw to auxiliary kw
- 3) Add HP supp kw to heat kw
- 4) Add HP supp heat fuel to heat fuel

[JJH 4/13/95]

**-080 sys**

In SYSTEMS, no natural ventilation was being simulated when VENT-METHOD=S-G was chosen for system types RESYS2 and PSZ.

**-081 lds**

In the daylighting calculation, this corrects a bug that gave negative direct illuminance at a reference point in the following situation: the angle between the window outward normal and the ray from reference point to any point on the window is greater than 90 deg. In this case light cannot directly reach the reference point from the window. But the program tried the calculation anyway in DCOF and could get negative values of sky luminance because of incorrect values of sky element altitude, PHRAY, in the call to DSKYLU. This problem usually occurs when windows are mis-positioned relative to the reference point(s), for example, if a horizontal roof with a skylight has  $Z = 0$  (i.e., incorrectly positioned at floor level) and so is below the reference point(s). [FCW 5/23/95]

This fixes a bug in report LV-D (Details of Exterior Surfaces in the Project) in which the outside air film conductance was not included in calculating the window frame U-value. This was a problem in the report only; it did not affect the hourly frame heat transfer calculation. [FCW 5/31/95]

**-082 dedt dkey plt sys**

Fix bug for engine driven chiller in PLANT. When no heat recovery is specified, for hours when the engine chiller is on, the plant heating load is zeroed. Work around is to specify heat recovery. If no heat recovery is desired, set ENG-CH-JAC-EFF and ENG-CH-EXH-EFF to small numbers. Note that this bug was introduced in version 2.1E-052. fix bug in the service hot water heat pump simulation in SYSTEMS. The cooling effect of the evaporator is acting to increase the zone cooling load rather than reduce it. There is no work around.

**-083 bdl sys**

Metric conversion for DAY-RESET-SCHEDULEs in SYSTEMS does not work. This makes the conversion work as described in the 2.1E Supplement, page 1.40.

**-084 dedt**

Change the type of <LIGHT-RAD-FRAC> from integer to real. This does not affect the results, since <LIGHT-RAD-FRAC> is not used in loads, it is used in weighting factor calculations in BDL.

**-086 sys**

Prevent divide by zero when night venting cfm is zero. [FCW 8-14-95]

**-087 sim**

In Functions : Correct calculation for reverse \*\* operation. Reverse \*\* is caused by expressions of the form : "variable\*\*(expression)" where expression has more than one variable in it and the value of expression is not an integer. Also, print the value of X in X \*\* Y when X < 0 . [EE 1/19/96]

Reverse \*\* is caused by expressions of the form : "variable\*\*(expression)" where expression has more than one variable in it and the value of expression is not an integer. Also, print the value of X in X \*\* Y when X < 0 . [EE 1/19/96]

In Functions :After a call to GETAA(n) , IAX = the pointer to free space can not be incremented, because IAX is not in the global variables table in loads or systems. Therefore successive calls to GETAA(n) return the same pointer. Also the newly allocated space is not zeroed. In loads functions the pointer returned by GETAA(n) might be already in use. This fix auto increments IAX when GETAA(n) is called. Workaround: make only one call to GETAA() with a safety margin. e.g.

Instead of

ix = GETAA(n)

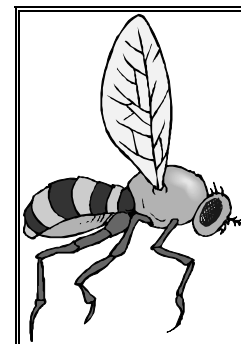
use

ix = GETAA(n+4000) + 4000

[EE 1/19/96]

**-088 bdl dedt dkey drlc lds sim sys**

Add surface temperature calculations to DOE-2.1E. The modifications ident name is MODST. [Markus Koschenz 5/31/95, EE 8/3/95]



# DOE-2 DIRECTORY

## Program Related Software and Services

*Contact the vendors for prices and ordering information*

*Caveat : We list third-party DOE-2-related products and services for the convenience of program users, with the understanding that the Simulation Research Group does not have the resources to check the DOE-2 program adaptations and utilities for accuracy or reliability.*

### Mainframe and Workstation Versions of DOE-2

<b>DOE-2.1D and 2.1E</b> (Source code, executable code and documentation) For 2.1E DEC-VAX, Order #000158-DOVAX-02 For 2.1E SUN-4, Order #000158-SUN-0000 For 2.1D DEC-VAX, Order #000158-D6220-01 For a complete listing of the software available from ESTSC order their "Software Listing" catalog ESTSC-2. [See <i>User News</i> Vol. 16, No. 3, p. 21]	Energy Science / Technology- Software Center (ESTSC) P.O. Box 1020 Oak Ridge, TN 37831-1020 Phone: (615) 576-2606 Fax: (615) 576-2865 email:ESTSC@ADONIS.OSTI.GOV www: <a href="http://www.doe.gov/html/osti/estsc/estsc.html">http://www.doe.gov/html/osti/estsc/estsc.html</a>
<b>FTI-DOEv2.1E</b> (Source code and documentation) Combined source code package for both VAX and SUN versions of DOE-2.1E. Available on most distribution formats and for most operating systems (1/4" QIC tape, TK50 tape, 3.5" floppy, etc). Note: this is the distribution package only, no executables. Complete documentation for DOE-2.1E, digitally reproduced, spiral bound, and separated into multi-volume sets. [See <i>User News</i> Vol. 12, No. 4, p. 16]	Finite Technologies, Inc 3763 Image Drive Anchorage, AK 99504 Contact: Scott Henderson Phone: (907) 333-8933 Fax: (907) 333-4482 email: <a href="mailto:info@finite-tech.com">info@finite-tech.com</a> www: <a href="http://www.finite-tech.com/fti/home.html">http://www.finite-tech.com/fti/home.html</a>

### PC Versions of DOE-2

<b>ADM-DOE2</b> ADM-DOE2 (DOE-2.1E) is compiled for use on 386/486 PCs with a math coprocessor and 4MB of RAM. It runs in a DOS or Windows environment and is a highly reliable and tested version of DOE-2 which contains all of the 1994/95 enhancements to the program. The package contains everything needed to run the program: program files, utilities, sample input files, and weather files. More than 300 weather files are available (TMY, TRY, WYEC, CTZ formats) for the U.S. and Canada. [See <i>User News</i> Vol. 7, No. 2, p. 6]	ADM Associates, Inc. 3239 Ramos Circle Sacramento, CA 95827 Contact: Marla Sullivan, Sales Phone: (916) 363-8383 Fax: (916) 363-1788
<b>CECDOEDC (Version 1.0A)</b> A microcomputer version of DOE-2.1D with a pre- and post-processor designed strictly for compliance use within the State of California. It generates some of the standard compliance forms as output. Order P40091009 for the CECDOEDC Program with Manuals. Order P40091010 for the DOE-2.1 California Compliance Manual. [See <i>User News</i> Vol. 12, No. 4, p. 13]	MS: 13 -- Publication Office California Energy Commission P.O. Box 944295 Sacramento, CA 94244-2950 Phone: (916) 654-5106 <a href="http://agency.resource.ca.gov/cectext/ETEC.html">www:http://agency.resource.ca.gov/cectext/ETEC.html</a>
<b>DOE-24/Comply-24</b> DOE-24 is a special DOE-2 release which is both a California-approved compliance program for the state's non-residential energy standards, and a stand-alone version of DOE-2.1E that includes a powerful yet easy-to-use input preprocessor. A demonstration program is available upon request. [See <i>User News</i> Vol. 12, No. 2, p. 2]	Gabel-Dodd Associates 1818 Harmon Street Berkeley, CA 94703-2416 Contact: Rosemary Howley Phone: (510) 428-0803 Fax: (510) 428-0324

## PC Versions of DOE-2 (continued)

<p><b>DOE-Plus™</b> DOE-Plus, a complete implementation of DOE-2.1D, is used to interactively input a building description, run DOE-2, and plot graphs of simulation results. Features include interactive error checking, context-sensitive help for all DOE-2 keywords, a 3-D view of the building that can be rotated, and several useful utilities.</p> <p>Also from ITEM Systems: <b>Demand Analyzer™</b>, uses templates of building types and vintages to simplify DOE-2 input requirements. Online help feature. <b>Prep™</b>, a batch preprocessor, ideal for parametric studies, that enables conditional text substitution, expression evaluation, and spawning of other programs. [See <i>User News</i> Vol. 11, No. 4, p. 4 and Vol. 13, No. 2, p. 54, and Vol. 16, No. 1, p. 28-32]</p>	<p>ITEM Systems 1402 - 3rd Avenue, #901 Seattle, WA 98101 Contact: Steve Byrne Phone: (206) 382-1440 Fax: (206) 382-1450 email: byrne@item.com</p>
<p><b>EZDOE</b> EZDOE is an easy-to-use PC version of DOE-2.1D. It provides full screen, fill in the blank data entry, dynamic error checking, context-sensitive help, mouse support, graphic reports, a 750-page user manual, extensive weather data, and comprehensive customer support. EZDOE integrates the full calculation modules of DOE-2 into a powerful, full implementation of DOE-2 on DOS-based 386 and 486 computers. [See <i>User News</i> Vol. 14, No. 2, p. 10 and No. 4, p. 8-14]</p>	<p>Elite Software, Inc. P.O. Drawer 1194 Bryan, TX 77806 Contact: Bill Smith Phone: (409) 846-2340 Fax: (409) 846-4367 email: 76070.621@compuserve.com</p>
<p><b>FTI-DOEv2.1E</b> Highly optimized version of DOE-2.1E software, available for most computing systems. Current support: MSDOS and Windows 3.x, Windows NT, OS/2, RS/6000 (AIX), NeXT, SUN, UNIX (most systems). Call for platforms not listed. Documentation and weather files are available. Also FTI-DOEv2.1E source code, highly optimized and portable version; will compile for most systems. [See <i>User News</i> Vol. 12, No. 4, p. 16]</p>	<p>Finite Technologies, Inc 821 N Street, #102 Anchorage, AK 99501 Contact: Scott Henderson Phone: (907) 272-2714 Fax: (907) 274-5379 email: info@finite-tech.com <a href="http://www.finite-tech.com/fti/home.html">http://www.finite-tech.com/fti/home.html</a></p>
<p><b>MICRO-DOE2ä</b> MICRO-DOE2 (2.1E), which runs in a DOS or windows environment, is a widely used, reliable, and tested PC version of DOE-2. It includes automatic weather processing, batch file creation, and a User's Guide with instructions on how to set up a RAM drive. System requirements: 386/486 PC with 4 MB of RAM and math co-processor.</p> <p>Also from Acrosoft, International, Inc.:</p> <p><b>NETPath</b>, a network edition of MICRO-DOE2, allows you to store and run DOE-2 application files on one machine using input files from another machine. The result is improved space usage and project file management.</p> <p><b>POWERPath</b>, for single machines, allows you to keep MICRO-DOE2 application files in one directory and submit input from any other directory.</p> <p><b>BDL Builder</b> is a pre-processor for DOE-2.1E that allows you to describe specific building and HVAC characteristics by preparing databases, or building blocks, and then selecting records from the databases to assemble a complete input.</p> <p><b>E2BB</b> translates DOE-2.1E text input to <b>BDL Builder</b>. [See <i>User News</i> Vol. 7, No. 4, p. 2; Vol. 11, No. 1, p. 2; Vol. 15, No. 1, p. 8; Vol. 15, No. 3, p. 4; Vol. 16, No. 2, p. 1,7; Vol. 16, No. 4, p. 7-8]</p>	<p>Acrosoft International, Inc. 3435 South Yosemite St., #220 Denver, CO 80231 Contact: Gene Tsai Phone: (303) 696-6888 Fax: (303) 696-0388 email: 102447.2611@compuserve.com</p>



## PC Versions of DOE-2 (continued)

<p><b>PRC-DOE2</b> A fast, robust and up-to-date PC version of DOE-2.1E. Runs in extended memory, is compatible with any VCPI compliant memory manager and includes its own disk caching. 377 weather data files available (TMY, TRY, WYEC, CTZ) for the U.S. and Canada</p> <p>Also from the Partnership for Resource Conservation: <b>PRC-TOOLS</b>, a set of PC programs that aids in extracting, analyzing and formatting hourly DOE-2 output. Determines energy use, demand, and cost for any number of end-uses and periods. Automatically creates 36-day load shapes. Custom programs also available.</p>	<p>Partnership for Resource Conservation 140 South 34th Street Boulder, CO 80303 Contact: Paul Reeves Phone or FAX: (303) 499-8611 email: paulreeves@aol.com</p>
<p><b>VisualDOE-2.0 for Windows™</b> VisualDOE-2.0, which uses DOE-2.1E as the calculation engine, enables architects and engineers to quickly evaluate the energy savings of HVAC and other building design options. Program is supported by context-sensitive on-line help. Program includes climate data for the 16 California weather zones. [See <i>User News</i> Vol. 15, No. 2, p. 10; Vol. 16, No. 4, p. 9-16]</p>	<p>Eley &amp; Associates 142 Minna Street San Francisco, CA 94105 Charles Eley or John Kennedy Phone: (415) 957-1977 / Fax: -1381 email: celey@eley.com www: http://www.eley.com</p>

## Pre- and Post-Processors for DOE-2

<p><b>Visualize-IT™ Visual Data Analysis Tools</b></p> <p>The <b>Energy Information Tool™</b> is a Microsoft Windows 3.1 program for looking at and understanding metered or DOE-2.1E hourly input data. It provides the unprecedented ability to see all 8760 (or 35040) data points for a year's worth of data. You get an overview of the data with an EnergyPrint™ and can then explore the data with a variety of tools including load shapes, load duration curves, etc. This program requires a 486 computer and SVGA graphics capabilities.</p> <p>The <b>Calibration Tool™</b> is a Microsoft Windows 3.1 program for comparing DOE-2.1E hourly output data to total load and/or end-use metered data. Options include monthly demand and load 2D graphs, maximum and seasonal load shapes, average load profiles, end use residuals, monthly average week and weekend days, and dynamic comparison load shapes. This program requires a 486 computer and SVGA graphics capabilities. [See <i>User News</i> Vol. 17, No. 2, p. 2-6]</p>	<p>RLW Analytics, Inc. 1055 Broadway, Suite G Sonoma, CA 95476 Phone: (707) 939-8823 Fax: (707) 939-9218</p> <p>Contact: Jim McCray jam@rlw.com Pat Bailey patb@rlw.com Jedd L. Parker jeddlp@rlw.com</p>
<p><b>DOE123</b> Uses Lotus 1-2-3 to graphically display DOE-2.1D output as barcharts, pie charts, and line graphs. [See <i>User News</i> Vol. 10, No. 3, p. 5]</p>	<p>Ernie Jessup 4977 Canoga Avenue Woodland Hills, CA 91364 Phone: (818) 884-3997</p>
<p><b>Graphs for DOE-2</b> 2-D, 3-D, hourly, daily, and psychrometric plots [See <i>User News</i> Vol. 13, No. 1, p. 5]</p>	<p>Energy Systems Laboratory Texas A&amp;M University College Station, TX 77843 Contact: Jeff Haberl Phone : (409) 845-6065 Fax: (409) 862-2762</p>
<p><b>Pre-DOE</b> A math pre-processor for BDL.</p>	<p>Nick Luick 19030 State Street Corona, CA 91719 Phone: (714) 278-3131</p>

## TOOLS AND TRAINING

<p><b>User News (a quarterly newsletter)</b> Sent without charge to DOE-2 and BLAST users, the newsletter prints documentation updates and changes, bug fixes, inside tips on using the programs more effectively, and articles of special interest to program users.</p> <p>Regular features include a directory of program-related software and services and an order form for documentation. The winter issue features an index of articles printed in all the back issues.</p>	<p>Simulation Research Group Bldg. 90, Room 3147 Lawrence Berkeley National Laboratory Berkeley, CA 94720 Contact: Kathy Ellington Fax: (510) 486-4089 email: kathy@gundog.lbl.gov</p>
<p><b>Help Desk Bruce Birdsall</b></p> <p>Call or fax Bruce Birdsall if you have a question about using DOE-2. If you need to fax an example of your problem to Bruce, please be sure to telephone him prior to sending the fax. This is a free service provided by the Simulation Research Group at Lawrence Berkeley National Laboratory.</p>	<p>Bruce Birdsall Phone/Fax: (510) 829-8459</p> <p>Monday through Friday 10 a.m. to 3 p.m. Pacific Time</p>
<p><b>Training</b> DOE-2 courses for beginning and advanced users.</p> <p>DOE-2 training for small groups and individuals.</p>	<p>Energy Simulation Specialists 64 E. Broadway, Suite 230 Tempe, AZ 85282 Contact: Marlin Addison Phone: (602) 967-5278</p> <p>Gary H. Michaels, P.E. 1512 Crain Street Evanston, IL 60202 Phone: (708) 869-5859</p>
<p><b>Instructional DOE-2 Video and Manual</b> Takes you step-by-step in DOE-2.1D input preparation and output interpretation.</p>	<p>Contact: Dr. Moncef Krarti Acting JCEM Director JCEM/U. Colorado CEAE Dept CB 428 Boulder, CO 80309-0428 Phone: (303) 492-3389 or 7317</p>

### DOE-2.1E Bug Fixes via FTP

If you have Internet access you can obtain the latest bug fixes to DOE-2.1E by anonymous ftp. Here's how...

ftp to either gundog@lbl.gov or to 128.3.254.10

login: *type* anonymous

passwd: *type in your email address*

After logging on, go to directory `pub/21e-mods` ; bug fixes are in files that end with `.mod` . A description of the fixes is in file `VERSIONS.txt` in directory `pub` . Each fix has its own version number, `nnn` , which is printed out as DOE-2.1E- `nnn` on the DOE-2.1E banner page and output reports when the program is recompiled with the fix. You may direct questions about accessing or incorporating the bug fixes to Ender Erdem (ender@gundog.lbl.gov).

## WEATHER RESOURCES

<p><b>TMY2</b> weather data for DOE-2. ENERGOS will provide TMY2 data for 239 cities converted for use with DOE-2 for PC versions of the program (DOE-2.1C through DOE-2.1E).</p>	<p>Kurmit Rockwell ENERGOS 1705-14th Street, #401 Boulder, CO; 80302 Phone: (303) 499-7907 / Fax: (303) 449-7605</p>
<p>Comprehensive collection of <b>TRY</b>, <b>TMY</b> and <b>CTZ</b> weather file libraries, from NCDC, which can be used on all PC versions of DOE-2. Includes original source data and pre-formatted packed versions on a single IBM format CD. For Canadian users, the CD contains five weather files representing the five climate regions established by the Canadian energy codes. Individual sites available.</p>	<p>Jenny Lathum or Martyn Dodd EnergySoft 100 Galli Drive, Suite 1 Novato, CA 94949 Phone: (800) 467-4738 / Fax: (415) 883-5970</p>
<p><b>European Weather Files</b></p>	<p>Andre Dewint Alpha Pi, s.a. rue de Livourne 103/12 B-1050 BRUXELLES, Belgium Phone: 32-2-649-8359 / Fax: 32-2-649-9437</p>
<p><b>TMY</b> data sets - download from the world wide web <b>TMY2</b> data sets - download from the world wide web</p>	<p><b>TMY:</b> <a href="http://oipea-www.rutgers.edu/html_docs/TMY/tmy.html">http://oipea-www.rutgers.edu/html_docs/TMY/tmy.html</a> <b>TMY2:</b> <a href="http://rredc.nrel.gov/solar/data/nsrdb/tmy2">http://rredc.nrel.gov/solar/data/nsrdb/tmy2</a></p>
<p><b>TMY</b> (Typical Meteorological Year) <b>TRY</b> (Test Reference Year)</p>	<p>National Climatic Data Center 151 Patton Avenue, #120 Asheville, NC 28801 Phone: (704) 271-4871 order / Fax 271-4876</p>
<p><b>CTZ</b> (California Thermal Climate Zones)</p>	<p>California Energy Commission Bruce Maeda, MS-25 1516-9th Street Sacramento, CA 95814-5512 1-800-772-3300 Energy Hotline</p>
<p><b>WYEC</b> (Weather Year for Energy Calculation)</p>	<p>ASHRAE 1791 Tullie Circle N.E. Atlanta, GA 30329 Phone: (404)636-8400 / Fax: (404)321-5478</p>
<p>Canadian Weather Files in <b>WYEC2</b> Format [Note: the original long-term data sets, up to 40 years of data, from which the CWEC files were derived can also be obtained directly from Environment Canada. contact Mr. Robert Morris at (416) 739-4361.]</p>	<p>Dr. Didier Thevenard Watsun Simulation Lab University of Waterloo Waterloo, Ont., N2L-3G1 Canada Phone: (519) 888-4904 / Fax: (519) 888-6197 watsun@helix.watstar.uwaterloo.ca</p>

## DOE-2 ENERGY CONSULTANTS

<p><b>Consulting Engineers</b> Charles Fountain Burns &amp; McDonnell Engineers 8055 E. Tufts Avenue, #330 Denver, CO 80237 (303) 721-9292</p>	<p><b>Consultant</b> Greg Cunningham Cunningham + Associates 512 Second Street San Francisco, CA 94107 (415) 495-2220</p>
<p><b>Consultant</b> Philip Wemhoff 1512 South McDuff Avenue Jacksonville, FL 32205 (904) 632-7393</p>	<p><b>Consultant</b> Jeff Hirsch 12185 Presilla Road Camarillo, CA 93012 (805) 532-1045</p>
<p><b>Consultants</b> Charles Eley, John Kennedy Eley Associates 142 Minna Street San Francisco, CA 94105 (415) 957-1977</p>	<p><b>Computer-Aided Mechanical Engineering</b> Mike Roberts Roberts Engineering Co. 11946 Pennsylvania Kansas City, MO 64145 (816) 942-8121</p>
<p><b>Consultant</b> Steven D. Gates, P.E. Building HVAC Design/Performance Modeling 11608 Sandy Bar Court Gold River, CA 95670 (916) 638-7540</p>	<p><b>Consultant</b> Donald E. Croy CAER Engineers, Inc. 814 Eleventh Street Golden, CO 80401 (303) 279-8136</p>
<p><b>Mechanical Engineer</b> Chuck Sherman Energy Simulation Specialists 64 East Broadway, #230 Tempe, AZ 95282 (602) 967-5278</p>	<p><b>Energy Engineering: Commercial &amp; Institutional</b> Michael W. Harrison, P.E. 139 Bluebird lane Whitehall, Montana 59759 (406) 287-5370</p>
<p><b>Consultant</b> Shiva Subramanya Criterion, Inc. 5331 SW Macadam Ave., Suite 205 Portland, OR 97201 (503) 224-8606</p>	<p><b>Hourly Calibrated DOE-2 Analysis</b> Jeff S. Haberl Energy Systems Laboratory Texas A&amp;M University College Stn., TX 77843-3123 (409) 845-6065</p>
<p><b>Consultant/Building Systems Analysis</b> Robert H. Henninger, P.E. GARD Analytics, Inc. 1028 Busse Highway Park Ridge, IL 60068-1802 (847) 698-5688</p>	<p><b>Energy Management Specialist</b> Hank Jackson, P.E. P.O. Box 675 Weaverville, NC 28787-0675 (704) 658-0298</p>
<p><b>Consultant</b> Martyn C. Dodd Gabel Dodd Associates 100 Galli Drive, # 1 Novato, CA 94949 (415) 883-5900</p>	<p><b>Consulting Engineer</b> Prem N. Mehrotra General Energy Corporation 230 Madison Street Oak Park, IL 60302 (708) 386-6000</p>
<p><b>Energy Consultant</b> Gene Tsai Acrosoft International, Inc. 3435 S. Yosemite, Suite 220 Denver, CO 80231 (303) 696-6888</p>	<p><b>Consulting Engineers/Computer Simulation Sciences</b> Robert E. Gibeault A-TEC 5515 River Avenue, Suite 301 Newport Beach, CA 92663 (714) 548-6836</p>
<p><b>Consulting Engineer</b> Susan Reilly Enermodal Engineering 1554 Emerson Street Denver, CO 80218 (303) 861-2070</p>	<p><b>Technical Real World Analysis</b> David J. Schwed Romero Management Associates 1805 West Avenue K, # Lancaster, CA 93534 (805) 940-0540</p>
<p><b>Energy Simulation Consultant</b> Joel Neymark, P.E. 2140 Ellis Street Golden, CO 80401 (303) 384-3672</p>	<p><b>Consulting Engineer</b> Gregory Banken, P.E. Q-Metrics, Inc. P.O. Box 3016 Woodinville, WA 98072 (205) 915-8590</p>

**DOE-2 ENERGY CONSULTANTS (continued)**

<p><b>Consulting Engineer</b>                  Chandra Shinde, P.E.                  ENVIRODESIGN GROUP                  385 S. Lemon Ave., E-266                  Walnut, CA 91789 (909) 598-1980</p>	<p><b>Energy Engineering and Analysis</b>                  Leo Rainer                  Davis Energy Group, Inc.                  123 C Street                  Davis, CA 95616 (916) 753-1100</p>
<p><b>Energy Codes DSM</b>                  Doug Mahone                  The Heshong Mahone Group                  4610 Paula Way                  Fair Oaks, CA 95628 (916) 962-7001</p>	<p><b>Consulting Engineer</b>                  Gary H. Michaels, P.E.                  1512 Crain Street                  Evanston, IL 60202 (708) 869-5859</p>
<p><b>Consulting Engineer</b>                  Robert Mowris, P.E.                  606 Pelton Avenue                  Santa Cruz, CA 95060 (408) 454-0606</p>	<p><b>Energy/DSM-Consultants</b>                  Adrian Tuluca                  Steven Winter Associates                  50 Washington Street                  Norwalk, CT 06854 (203) 852-0110</p>
<p><b>Modeling Specialist</b>                  Norm Weaver                  Interweaver Consulting                  P.O. Box 775444                  Steamboat Springs, CO 80477 (970) 870-1710</p>	<p><b>Consultant/Building Systems Engineering</b>                  Ellen Franconi                  1504 Grant Street                  Berkeley, CA 94703 (510) 559-8340</p>
<p><b>Large Facility Modeling</b>                  George Marton                  Consulting Engineer                  1129 Keith Avenue                  Berkeley, CA 94708 (510) 841-8083</p>	<p><b>Consultant/Engineer</b>                  David A. Cohen                  Architectural Energy Corporation                  2540 Frontier Avenue, #201                  Boulder, CO 80301 (303) 444-4149</p>
<p><b>Consultant</b>                  Kurmit Rockwell                  Rocky Mountain Energy Services                  1705 14th Street, Suite 401                  Boulder, CO 80302 (303)499-7907</p>	<p><b>Design Assistance/Model Review</b>                  James Fireovid, P.E. and Khaled Yousef                  SAIC Energy Solutions Division                  1 Marcus Boulevard                  Albany, NY 12205 (518) 458-2249</p>
	<p><b>Research, Education, and Consulting</b>                  Dr. Brian A. Rock, P.E.                  Arch/Engrg Dept                  Marvin Hall                  University of Kansas                  Lawrence, KS 66045-2222 (913) 864-3434</p>

## INTERNATIONAL DOE-2 ENERGY CONSULTANTS

<b>Mainframe DOE-2 for European Users</b> Joerg Tscherry EMPA, Section 175 8600 Dubendorf Switzerland	<b>Energy Consultant</b> Philip Schluchter Institut für Bauphysik Klein Urs Graf-Strasse 1 CH4052 Basel Switzerland
<b>Consultant, Distributor for FTI-DOEv2.1E</b> Andre Dewint rue de Livourne 103/12 B-1050 BRUXELLES Belgium	<b>Consultant</b> Werner Gygli Informatik Energietechnik Weiherweg 19 CH-8604 Volketswil Switzerland
<b>Consultant</b> Curt Hepting, P.Eng. EnerSys Analytics 3990 Lynn Valley Road North Vancouver, B.C. V7K 2S9 Canada	<b>DOE-2 Simulation Specialist</b> René Meldem Meldem Energie SA Ch. de l'Ancienne Pointe 1 CH-1920 Martigny Switzerland
<b>Energy and Environmental Engineering</b> Neil A. Caldwell D. W. Thomson Consultants, Ltd. 1985 West Broadway Vancouver, BC V6J 4Y3 Canada	

### Job Available with the Simulation Research Group at LBNL

**Job Title:** Mechanical Engineer, Energy and Environment Division, Building Technologies Program  
**Job Number:** EED/4462  
**Salary Range:** \$2900-\$5800/mo.

**Essential:** Working with scientific staff in the Simulation Research Group, develop computer models for simulating building heat transfer processes, HVAC equipment and controls. Implement these models in DOE-2 (a widely-used FORTRAN program for building energy simulation) and in SPARK (a new, object-oriented C/C++ program for simulating complex systems), write user and engineering documentation. Assist in linking SPARK to DOE-2 and in combining DOE-2 with the BLAST building energy analysis program. Participate in a collaboration to design and develop next-generation building performance simulation software. Prepare and present technical papers summarizing research and development results.

**Essential:** Experience developing mathematical models for building energy simulation and incorporating the models into computer software. Broad understanding of the principles of building heat transfer processes and HVAC equipment performance. Knowledge of the C and FORTRAN programming languages. Familiarity with building energy simulation methods. Good written communication skills. **Marginal:** Ph.D. in Mechanical Engineering, Physics, Architectural Engineering, Computer Science, or related field. Knowledge of the UNIX operating system.

**To apply:** Send resume to Lawrence Berkeley National Laboratory, Staffing Office, Box NSRG4462, 1 Cyclotron Road, MS 938A, Berkeley, CA, 94720. Be sure to include job number in your cover letter. Lawrence Berkeley National Laboratory is an equal opportunity employer.

## DOE-2 RESOURCE CENTERS

*The people listed here have agreed to be primary contacts for DOE-2 program users in their respective countries. Each resource center has the latest program documentation, all back issues of the User News, and recent LBNL reports pertaining to DOE-2. These resource centers will receive copies of all new reports and documentation. Program users can then make arrangements to get photocopies of the new material for a nominal cost. We hope to establish resource centers in other countries; please contact us if you are interested in establishing a center in your area.*

<b>South America</b> Prof. Roberto Lamberts Universidade Federal de Santa Catarina Campus Universitario--Trindade Cx. Postal 476 88049 Florianopolis SC BRASIL Telephone: (55)482-31-9272 Fax: (55)48-231-9770 email: Lamberts@ecv.ufsc.BR	<b>Australasia</b> Dr. Deo K. Prasad/P. C. Thomas SOLARCH University of New South Wales P.O. Box 1 Kensington, N.S.W. 2033 AUSTRALIA Telephone: (61)-2-697-5783 (P.C. Thomas) Fax: (61) 2-662-4265 or -1378 email: PC.Thomas@unsw.EDU.AU
<b>Portugal, Spain, Italy, and Greece</b> Antonio Rego Teixeira ITIME Unidade de Energia Estrada do Paco do Lumiar 1699 Lisboa PORTUGAL  Telephone: (351) 1-716-4096 Fax: (351) 1-716-4305 email: itime.ue@mail.telpac.pt	<b>Australia</b> Murray Mason ACADS BSG 16 High Street Glen Iris VIC. 3146 AUSTRALIA  Telephone: (61) 885 6586 Fax: (61) 885 5974
<b>Singapore, Malaysia, Indonesia, Thailand, and the Philippines</b> WONG Yew Wah, Raymond Nanyang Technological University School of Mechanical and Production Engineering Nanyang Avenue Singapore 2263 REPUBLIC OF SINGAPORE Telephone: (65)799-5543 Fax: (65)791-1859 email: mywwong@ntuvax.ntu.ac.sg	<b>Germany</b> B. Barath or G. Morgenstern BARATH and WAGNER Rudolf-Diesel-Strasse 2, 40670 Meerbusch GERMANY  Telephone: (49) 2159 528041 Fax: (49) 2159 528043
<b>Hong Kong, China, Taiwan, Japan and Korea</b> Dr. Sam Chun-Man HUI or K.P. Cheung University of Hong Kong Pokfulam Road HONG KONG  Telephone: (852) 2859-2133 (direct to Sam Hui) Fax: (852) 2559-6484 email: CMHUI@HKUCC.HKU.HK	<b>Switzerland</b> René Meldem Meldem Energie SA Ch. de l' Ancienne Pointe 1 CH-1920 Martigny SWITZERLAND Telephone: (41) 26 22 96 96 Fax: (41) 26 22 96 97 email: 106034.630@compuserve.com

## World-Wide Web and Internet Sites for Building Energy Efficiency

<a href="http://www.bso.uiuc.edu">http://www.bso.uiuc.edu</a>	<b>BLAST</b> Support Office
(net) <a href="http://sci.engr.heat-vent-ac">sci.engr.heat-vent-ac</a>	<b>HVAC</b> discussion group.
(net) <a href="http://sci.engr.lighting">sci.engr.lighting</a>	<b>Lighting</b> discussion group.
<a href="http://energy.ca.gov/energy/cectext/ETEC.html">http://energy.ca.gov/energy/cectext/ETEC.html</a>	<b>California Energy Commission's Energy Technology and Education Center.</b> See <i>User News</i> , Vol. 16, No. 1, p. 42.
<a href="http://www.hike.te.chiba-u.ac.jp/ikedai/CIE/publ/110-94.html">http://www.hike.te.chiba-u.ac.jp/ikedai/CIE/publ/110-94.html</a>	<b>The International Commission on Illumination - CIE</b> See <i>User News</i> , Vol. 16, No. 1, p. 44.
<a href="http://www.eren.doe.gov/">http://www.eren.doe.gov/</a>	<b>EREN: Energy Efficiency and Renewable Energy Network of the U.S. Department of Energy .</b> See <i>User News</i> , Vol. 16, No. 1, p. 44.
<a href="http://www.doe.gov/">http://www.doe.gov/</a>	<b>U.S. Department of Energy .</b> See <i>User News</i> , Vol. 15, No. 4, p. 1.
<a href="http://www.whitehouse.gov/">http://www.whitehouse.gov/</a>	<b>The White House</b> home page contains an Interactive Citizens Handbook that lists U.S. Government servers by agency. Use this site as a jumping-off point to explore other Federal agencies. See <i>User News</i> , Vol. 15, No. 4, p. 1.
<a href="http://www.fedworld.gov/">http://www.fedworld.gov/</a>	<b>FedWorld</b> is the U.S. Government's Federal Information Network home page. It lists web servers, ftp, gopher, and telnet sites and is organized by subject categories.
<a href="http://www.fedworld.gov/ntis/ntishome.html">http://www.fedworld.gov/ntis/ntishome.html</a>	<b>National Technical Information Service</b> NTIS gathers and markets scientific, technical and business-related information.
<a href="http://www.caddet-ee.org">http://www.caddet-ee.org</a>	<b>Center for the Analysis and Dissemination of Demonstrated Energy Technologies</b> An IEA program for collecting and disseminating information on, energy-efficient and renewable energy technologies. See <i>User News</i> , Vol. 16, No. 2, p. 23.
<a href="http://crest.org/aceee">http://crest.org/aceee</a>	<b>American Council for an Energy-Efficient Economy</b> A non-profit organization for the advancement of energy efficiency. See <i>User News</i> , Vol. 16, No. 2, p. 23.
<a href="http://www.ashrae.org">http://www.ashrae.org</a>	<b>American Society of Heating, Refrigeration and Air-Conditioning</b> An international membership organization for HVAC professionals. <i>User News</i> , Vol. 16, No. 3, p. 31.
<a href="http://www.cisti.nrc.ca/irc/irccontents.html">http://www.cisti.nrc.ca/irc/irccontents.html</a>	<b>[Canadian] Institute for Research in Construction</b> IRC is part of the NRC, Canada's premier science and technology agency. See <i>User News</i> , Vol. 16, No. 3, p. 31.
<a href="http://eicbbs.wseo.wa.gov/">http://eicbbs.wseo.wa.gov/</a>	<b>Washington State Energy Office/Energy Ideas Clearinghouse</b> Information and technical support for increasing energy efficiency in the commercial and industrial sectors.
<a href="http://next1.mae.okstate.edu/ibpsa/">http://next1.mae.okstate.edu/ibpsa/</a>	<b>International Building Performance Simulation Association</b> A not-for-profit international society of building performance simulation professionals.
<a href="http://www.fsec.ucf.edu/">http://www.fsec.ucf.edu/</a>	<b>Florida Solar Energy Center</b> FSEC is the State of Florida's energy institute specializing in energy research and education in partnership with private and public organizations.
<a href="http://beijing.dis.anl.gov/ee-cgi-bin/hem.pl">http://beijing.dis.anl.gov/ee-cgi-bin/hem.pl</a>	<b>Home Energy Magazine</b> An impartial source of analysis to aid the energy practitioner and the public in making informed decisions on energy conservation measures.
<a href="http://eande.lbl.gov/BTP/WDG/RESFEN/resfen.html">http://eande.lbl.gov/BTP/WDG/RESFEN/resfen.html</a> <a href="http://eande.lbl.gov/BTP/WDG/SUPERLITE/superlite2.html">SUPERLITE/superlite2.html</a> <a href="http://eande.lbl.gov/BTP/WDG/WDG.html">WDG.html</a>	<b>Download Free Fenestration software from LBNL</b> See <i>User News</i> , Vol. 17, No. 1, p. 14. <b>RESFEN-2.4</b> - calculates residential fenestration heating and cooling energy use and costs <b>SUPERLITE-2.0</b> - calculates daylight illuminance distributions for room geometries <b>WINDOW-4.1</b> - thermal analysis program to characterize window product performance
<a href="http://www.energy.ca.gov/reports/title24/index.html">http://www.energy.ca.gov/reports/title24/index.html</a>	<b>State of California's Title 24 Building Energy Standards</b>
<a href="http://fcn.state.fl.us/fdi/fdi-home.htm">http://fcn.state.fl.us/fdi/fdi-home.htm</a>	<b>State of Florida's Design Initiative (FDI)</b>
<a href="http://fcn.state.fl.us/fdi/e-design/online/edo.htm">http://fcn.state.fl.us/fdi/e-design/online/edo.htm</a>	<i>e-design</i> , the online newsletter for Florida's Design Initiative



**\*\*\* Featured Sites This Issue \*\*\***

**World-Wide Web and Internet Sites for Building Energy Efficiency**

**STATE OF CALIFORNIA  
BUILDING ENERGY EFFICIENCY STANDARDS**  
<http://www.energy.ca.gov/reports/title24/index.html>

California state building standards mandate energy efficiency measures in new construction. Since being first established in 1977, the building energy standards (along with standards for energy efficiency in appliances) have helped Californians save more than \$11.4 billion in electricity and natural gas costs. The standards are updated every three years to allow new energy efficiency technologies to be considered.



**FLORIDA DESIGN INITIATIVE (FDI)**  
<http://fcn.state.fl.us/fdi/fdi-home.htm>  
*e-design*, an online newsletter  
<http://fcn.state-fl.us/fdi/e-design/online/edo.htm>

The Florida Design Initiative (FDI) was started in 1992 as a response to an executive order that mandated a 30 percent reduction in energy use by all state agencies in three years. Originally conceived as a leadership forum, FDI membership now includes academic leadership, representatives from the Public Service Commission, utilities, professional associations, and local government.

One of the goals of the FDI program is to work with the design professions to develop an overall strategy for successfully changing the standards of practice in the building industry to include "best practices" in energy-efficiency.

An unqualified success is *e-design*, FDI's bi-monthly newsletter. *E-design* was envisioned as a guide to other energy-related information sources.

**RLW Analytics, Inc. is conducting a series of nationwide studies involving DOE-2 modeling, end-use metering, and on-site data collection. If you would like to be included as a potential subcontractor, please contact us by mail, fax, or email:**

**Jim McCray (jam@rlw.com)  
RLW Analytics, Inc.  
1055 Broadway, Suite G  
Sonoma, CA 95476  
Phone: (707) 939-8823 / Fax: (707) 939-9218**

## DOE-2 PROGRAM DOCUMENTATION

DOE-2 documentation is available from several sources.

- The National Technical Information Service offers a complete set of DOE-2 manuals, available for purchase separately; prices and ordering information are below.
- Kinko's Copy Center of Berkeley offers the DOE-2.1E updated documentation (BDL Summary, Sample Run Book, and Supplement) as a set; their price includes shipping within the U.S.; see below
- The Energy Science Technology Software Center at Oak Ridge, TN, offers the DOE-2.1E updated documentation free of charge when you purchase the mainframe or workstation version of DOE-2. See the "DOE-2 Directory of Program Related Software and Services" in this issue.
- And finally, many of the PC vendors of DOE-2 offer some or all of the documentation when you buy their program. Names and addresses of all DOE-2 vendors are found in the "DOE-2 Directory of Program Related Software and Services" in this issue.

### To order any or all of the DOE-2 manuals from the National Technical Information Service:

National Technical Information Service  
5285 Port Royal Road  
Springfield, VA 22161  
Phone (703) 487-4650  
FAX (703) 321-8547

Document Name	Order Number	Prices as of 4/1/96
DOE-2 Basics Manual (2.1E)	DE-940-13165	49.00
BDL Summary (2.1E)	DE-940-11217	28.00
Sample Run Book (2.1E)	DE-940-11216	100.00
Reference Manual (2.1A)	LBL-8706, Rev.2	174.00
Supplement (2.1E)	DE-940-11218	100.00
Engineers Manual (2.1A) [algorithm descriptions]	DE-830-04575	57.00

### To order the DOE-2.1E "update" documentation from Kinko's Copy Center in Berkeley, California:

Ms. Dani Aalfs  
Kinko's Copy Center  
901 University Avenue  
Berkeley, CA 94710  
Phone: (510) 204-0781  
Fax: (510) 644-9704

"Update" documentation includes the 2.1E BDL Summary, 2.1E Supplement, and 2.1E Sample Run Book. Cost of the three manuals is \$125 which includes any applicable taxes, shipping, and handling. For foreign orders, please fax Ms. Aalfs to ascertain extra shipping costs. VISA, MasterCard.

*"Building Loads Analysis and System Thermodynamics"*

# blastnews

The **Building Loads Analysis and System Thermodynamics (BLAST)** program is a comprehensive energy analysis tool that allows users from a wide range of experience levels to calculate building heating and cooling loads as well as simulate primary and secondary equipment. The current PC version of BLAST includes several pre- and post-processing auxiliary programs to create BLAST input files and reduce program output data. Documentation in a Windows™ Help format is included in the standard BLAST package; printed documentation is also available. Source code may be obtained from the BLAST Support Office (BSO), allowing BLAST to be ported to other computing environments. The BSO also distributes the WinLCCID96 life cycle cost program [See *User News* Vol. 16, No. 4, p. 5]. Please consult the BSO web page or catalog for the latest information on prices, system requirements and available weather sites.

The **Heat Balance Load Calculator (HBLC)** interface provides a graphical, Windows™-based environment for obtaining BLAST input files and analyzing simulation results. Within HBLC, each story of the building is represented as a floor plan which may contain several separate zones. Numerous other building details may be investigated and accessed through simple mouse operations. On-line help provide valuable on-the-spot assistance that will benefit both new and experienced BLAST users. HBLC makes the process of developing input files more intuitive and efficient; it is available as part of the standard BLAST package. A free demo may be downloaded from the BSO web page or obtained by contacting the BSO.

**BLAST Support Office (BSO)**  
**30 Mechanical Engineering Bldg**  
**University of Illinois**  
**1206 West Green Street**  
**Urbana, IL 61801**  
**Telephone: 333-3977**  
**FAX: (217)244-6534**  
**email: [support@blast.bso.uiuc.edu](mailto:support@blast.bso.uiuc.edu)**  
**www: <http://www.bso.uiuc.edu>**

# Software Engineering in the “Best of” Project

by  
**Graham S. Wright, Ph. D.**  
**BLAST Support Office (BSO)**  
**30 Mechanical Engineering Bldg**  
**University of Illinois**  
**1206 West Green Street**  
**Urbana, IL 61801**

*Note: the “Best of” Project was first mentioned in the User News (Vol. 16, No. 3, Fall 1995). In brief, as funding permits work continues on combining the best features of BLAST and DOE-2 into a single program.*

## Introduction

In response to the challenge posed by the merger of the BLAST and DOE-2 programs, the “Best of” team has recently taken steps toward modernizing its software development process. Key aspects include:

1. Re-engineering to FORTRAN 90
2. Adoption of a configuration management tool
3. Institution of design reviews and code walk-throughs

This article will focus on the re-engineering and language issues of the project. Other software-related topics will be discussed in future issues.

## FORTRAN 90

The predecessor programs of the “Best of” project, BLAST and DOE-2, have been in maintenance mode for some years. New features have been accreted without much modification to the overall structure. Merging their capabilities requires more radical surgery, and the way the programs are written presents obstacles. In looking at a given subroutine, it is often impossible to differentiate the inputs from the outputs or the scope of any variable. The information flow through the program is generally difficult to discern except for those few

people who have extensive experience with the code. This situation must be remedied if the requirements for a more open simulation tool are to be fulfilled. In certain areas, clean and well-documented interfaces must be provided so that third-party developers can participate in extending and enhancing the program.

To a large extent, the current obscurity of the data flow is a consequence of the structure of the FORTRAN language itself. FORTRAN 77 provides only one level of subroutines (“externals” that cannot be hidden inside one another) and one level of global data. This naturally leads to what is called “common-environment coupling” in which one subroutine stores results into part of the global data store, and other routines retrieve them. It is not possible to look at a list of common blocks and know which variables are used only for communication between two closely-related routines, which ones are used only within a larger subsystem of calculations, and which ones are used throughout the code. Partitioning into named common blocks helps some, but this initial structuring tends to fray over time as unrelated variables are tacked on and common blocks are included where they are not really needed.

FORTRAN 90 on the other hand, provides facilities for packaging subroutines and data structures together in modules, for hiding subroutines inside one another, and for declaring subroutine arguments as input or output. These features all provide a key service: they allow the scope and usage of identifiers (variable and

subroutine names) to be limited. The programs already have a structure; some routines are called only in one place, some are called in more than one place but only within, say, shadowing calculations, and some are called in many places. Similarly for the data; there is structure but it is not obvious. By using the information-hiding features of FORTRAN 90, the current de facto scope of the names can be revealed and made explicit. When the scope of identifiers is made clearer, the scope of any proposed change to the program is thereby also made clearer. It becomes easier to understand what will and will not be affected. This would be helpful even if the existing data and associated subroutines could only be swept into a few large piles. The complexity that a new developer faces would be reduced significantly.

The process is referred to as *re-engineering* and consists of first reverse-engineering, or analyzing and tracing the existing data flow, followed by repackaging into FORTRAN 90 modules and internal routines, as well as some local “de-spaghettifying” using automated restructuring tools. This re-engineering process is intended to be *algorithmically neutral* so that it can be easily validated. Any changes to the computation are to be dealt with in a separate step. This re-engineering will benefit the “Best of” team in the short term as we piece together the new program, and future developers in the longer term who will inherit a more easily modifiable program.

Because FORTRAN 90 is backward-compatible with FORTRAN 77, the re-engineering process can proceed incrementally and concentrate on areas of greatest interest and importance.

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# Combining the BLAST Loads and Systems Simulations Through the Zone Heat Balance Equation

by

**Russell D. Taylor and Curtis O. Pedersen**  
**BLAST Support Office (BSO)**  
**30 Mechanical Engineering Bldg**  
**University of Illinois**  
**1206 West Green Street**  
**Urbana, IL 61801**

## Nomenclature

### Variables

A - area of zone surface  
h - surface convection coefficient  
Q - rate of heat flux  
T - temperature

$DT_c$  - difference between cooling setpoint temperatures  
 $DT_h$  - difference between heating setpoint temperatures  
 $h_c$  - reheat fraction  
 $h_h$  - reheat fraction  
r - air density

### Subscripts

z - zone related variable  
sys - system related variable  
h/c - heating coil  
inf - infiltration  
mix - interzone mixing

## **1. Motivation**

The primary motivation for developing a simulation which combines loads, systems, and central plant simulations is to improve the understanding of feedback effects between these building elements. In BLAST, the building, its air handling systems, and its equipment are simulated sequentially with no feedback. The building conditions are fed to the air handling system to determine its response, but that response is not allowed to affect the building conditions. This simulation technique works well when the system response is a well-defined function of the air temperature of the conditioned space. But in situations where the system is dependent on outside conditions and/or other parameters of the conditioned space, the lack of feedback from the system to the building can lead to unphysical results. For example, if the system provides too much cooling to a conditioned space the excess cooling is reported by BLAST as "overcooling". To the

system designer, it would be far more useful to see how much below the desired temperature the zone actually went. This article describes how the basic equations of the BLAST zone heat balance were used to develop a method for combining the zone and system simulations. This method has been implemented and substantially tested in the IBLAST (Integrated BLAST) program. IBLAST is an experimental version of BLAST which is not currently in release. However, major components of its integrated heat balance engine will be used in the “Best of” project to combine the best features of IBLAST and DOE-2.

## 2. Development of the Combined Loads/Systems Simulation

In the current structure of BLAST the zone energy balance is represented by Equation (1):

$$\sum Q_{\text{int}} + \sum_{i=1}^{N_{\text{surfaces}}} h_i A_i (T_i - T_z) + \sum_{i=1}^{N_{\text{zones}}} \dot{m}_{\text{mix},i} C_p (T_i - T_z) + \dot{m}_{\text{inf}} C_p (T_{\infty} - T_z) + Q_{\text{sys}} = 0 \quad (1)$$

The first term represents the sum of internal heat gains, the second term is the heat flux convected from the zone surfaces, the third term is the heat gain due to air mixing between zones, the fourth term is the heat gain due to infiltration of outside air and the final term represents the system output. Equation (1) can be generalized so that instead of the difference of loads and system output being set to zero to provide an exact balance, the zone air capacitance is introduced so that the difference represents the rate of change in the enthalpy of the zone air. This rate is given by the product of the zone air capacitance and the first derivative of the zone air temperature  $T_z$ :

$$C_z \frac{dT_z}{dt} = \sum Q_{\text{int}} + \sum_{i=1}^{N_{\text{surfaces}}} h_i A_i (T_i - T_z) + \sum_{i=1}^{N_{\text{zones}}} \dot{m}_{\text{mix},i} C_p (T_i - T_z) + \dot{m}_{\text{inf}} C_p (T_{\infty} - T_z) + \dot{m}_{\text{sys}} C_p (T_{\text{sys}} - T_z) \quad (2)$$

In this equation, the general term for the system output has been replaced by a term specifically representing convective systems. Additionally, it may be appropriate to define  $C_z$ , the zone total heat capacitance, to include contributions from thermally fast responding elements within the zone, as well as the zone air. A numerical solution to equation (2) can be obtained by replacing the derivative term with a finite difference approximation, such as:

$$\left. \frac{dT_z}{dt} \right|_t \approx (\delta t)^{-1} (T_z^t - T_z^{t-\delta t}) + O(\delta t) \quad (3)$$

Substituting equation (3) into (2) yields a method for updating the zone air temperature in terms of quantities which been lagged by one time step and, hence, are known. These terms are indicated in Equation (4) by the superscript  $t-\delta t$ :

$$C_z \frac{T_z^t - T_z^{t-\delta t}}{\delta t} = \left( \sum Q_{\text{int}} + \sum_{i=1}^{N_{\text{surfaces}}} h_i A_i (T_i - T_z) + \sum_{i=1}^{N_{\text{zones}}} \dot{m}_{\text{mix},i} C_p (T_i - T_z) + \dot{m}_{\text{inf}} C_p (T_{\infty} - T_z) + \dot{m}_{\text{sys}} C_p (T_{\text{sys}} - T_z) \right)^{t-\delta t} \quad (4)$$

This equation may be further refined by grouping all the terms containing the zone air temperature on the left side of the equation, as shown in (5):

$$C_z \frac{T_z^t - T_z^{t-d}}{d} + \sum_{i=1}^{N_{\text{surfaces}}} h_i A_i T_z^t + \sum_{i=1}^{N_{\text{zones}}} \dot{m}_{\text{mix},i} C_p T_z^t + \dot{m}_{\text{inf}} C_p T_z^t + \dot{m}_{\text{sys}} C_p T_z^t = \left( \sum Q_{\text{int}} + \sum_{i=1}^{N_{\text{surfaces}}} h_i A_i T_i + \sum_{i=1}^{N_{\text{zones}}} \dot{m}_{\text{mix},i} C_p T_i + \dot{m}_{\text{inf}} C_p T_{\infty} + \dot{m}_{\text{sys}} C_p T_{\text{sys}} \right)^{t-d} \quad (5)$$

Then the lagged zone temperature term is moved to the right side of Equation (5) and  $T_z$  is factored out of each term remaining on the left side so that both sides of the equation can be divided by the resulting coefficient of  $T_z$ . This yields an explicit solution for the zone temperature, formulated entirely in terms of lagged quantities, which is called *lagging with zone capacitance*.

$$T_z^t = \left\{ \frac{\frac{C_z}{d} T_z + \sum Q_{\text{int}} + \sum_{i=1}^{N_{\text{surfaces}}} h_i A_i T_i + \sum_{i=1}^{N_{\text{zones}}} \dot{m}_{\text{mix},i} C_p T_i + \dot{m}_{\text{inf}} C_p T_{\infty} + \dot{m}_{\text{sys}} C_p T_{\text{sys}}}{\frac{C_z}{d} + \sum_{i=1}^{N_{\text{surfaces}}} h_i A_i + \sum_{i=1}^{N_{\text{zones}}} \dot{m}_{\text{mix},i} C_p + \dot{m}_{\text{inf}} C_p + \dot{m}_{\text{sys}} C_p} \right\}^{t-d} \quad (6)$$

Using Taylor series expansion methods, higher order expressions (with correspondingly higher order truncation errors for the first derivative of the zone air temperature) may be developed to replace equation (3). Two example expressions, Equations (7) and (8), are, respectively, the second- and third-order finite difference approximations of the first derivative of the zone air temperature with respect to time.

$$\left. \frac{dT_z}{dt} \right|_t \approx (\delta t)^{-1} \left( \frac{3}{2} T_z^t - 2T_z^{t-\delta t} + \frac{1}{2} T_z^{t-2\delta t} \right) + O(\delta t^2) \quad (7)$$

$$\left. \frac{dT_z}{dt} \right|_t \approx (\delta t)^{-1} \left( \frac{11}{6} T_z^t - 3T_z^{t-\delta t} + \frac{3}{2} T_z^{t-2\delta t} - \frac{1}{3} T_z^{t-3\delta t} \right) + O(\delta t^3) \quad (8)$$

As the order of the approximation increases, the number of previous temperatures required increases and the dependence on the most recent temperature decreases. The higher order derivative approximations allow the use of larger time steps by smoothing transitions through sudden changes in zone conditions.

### 3. System Control

In the previous section, we discussed the formulation of the zone heat balance equation in which the zone temperature was calculated entirely in terms of time-lagged quantities. However, the right hand side of the heat balance still contained implicit dependencies on the zone temperature through the system term. This implicit dependence is a result of the system control scheme which



samples the zone temperature to determine the proper mode of system operation needed to maintain the desired zone conditions. In real buildings the sampling device may be a wall thermostat which can continuously sample zone conditions. Thus, when the system is properly sized, updates to the system output occur on a time scale much shorter than any characteristic time of the system or zone. The feedback between zone and system, in this case, generally results in stable zone conditions and system operation. Conversely, the numerical model is only able to sample zone conditions for every time step which, in order to minimize computation time, is as large as possible. As a result, sampling of zone conditions generally occurs on a time scale of the order of, or longer than, the characteristic times of the system or zones. This has the potential for unstable feedback between the zone and system simulations and requires special consideration in the solution procedure.

The method implemented in IBLAST takes advantage of the fact that, unlike the real controller, the computational model *knows* the net heat flux entering or leaving the zone as a function of zone temperature, which can be expressed as:

$$Q_{load} = \sum Q_{int} + \sum_{i=1}^{N_{surfaces}} h_i A_i (T_{surf,i} - T_z) + \sum_{i=1}^{N_{zones}} \dot{m}_{mix,i} C_p (T_{zone,i} - T_z) + \dot{m}_{inf} C_p (T_{\infty} - T_z) \quad (9)$$

This is equation (1) minus the system term and where  $T_z$  is the *desired* zone temperature, i.e., one of the control system setpoints specified by the user. If capacity is available, the system is assumed to meet the zone conditioning requirements (i.e.,  $Q_{sys} = Q_{load}$ ) and maintain the desired zone temperature. Otherwise, the zone temperature adjusts itself according to the system capacity. Equation (9) is used solely to determine the system output and once this is accomplished the zone temperature is updated using equation (6). This method is called *predictive system energy balance*. It is, in some sense, a predictor-corrector method because first the system response is calculated, and then its effects on the zone temperature.

Use of the predictive system energy balance method is simplified when the system output can be explicitly formulated as a function of the zone temperature. For example, consider a simplified variable air volume (VAV) system, where the supply air temperature and the supply air volume vary continuously over a specified range of zone temperatures, as shown in

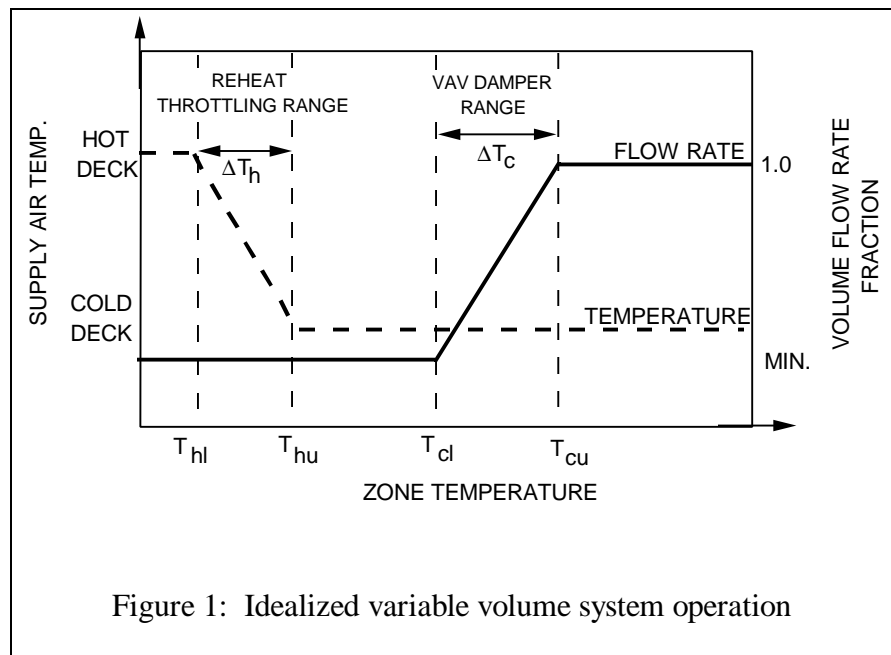


Figure 1: Idealized variable volume system operation

figure 1. The figure illustrates the relationship of reheat coil operation to the upper and lower heating setpoints respectively, and the operation of the VAV air damper when the zone air temperature is between the upper and lower cooling setpoints  $T_{cu}$  and  $T_{cl}$ . As a result, the zone temperature can be expected to vary within the damper range or reheat throttling range depending upon whether the system is cooling or heating. This means that the desired zone temperature is also a variable and must be calculated in order to determine the system output.

When cooling, the VAV system is designed to operate with constant supply air temperature and variable supply air volume. The volume air fraction normalized to the maximum flow rate is given by:

$$h_c = h_{c,\min} + (1 - h_{c,\min}) \left( \frac{T_z - T_{cl}}{\Delta T_c} \right); \quad h_{c,\min} \leq h_c \leq 1.0 \quad (10)$$

Conversely, when heating is required the VAV becomes a constant volume flow rate system with a variable supply air temperature which can be related directly to the energy output of the reheat coil. The energy output of the reheater normalized to the maximum coil output gives the reheat fraction:

$$h_h = \left( \frac{T_{hu} - T_z}{\Delta T_h} \right); \quad 0.0 \leq h_h \leq 1.0 \quad (11)$$

The VAV system output to the zone can now be written in terms of  $h_c$  and  $h_h$  depending on whether the system is heating or cooling. Equation (12) represents the heating output of the system  $Q_{\text{sys,heat}}$  in terms of the reheat fraction, the capacity of the heating coil, and the system minimum volume flow rate:

$$Q_{\text{sys, heat}} = \eta_h Q_{h/c, \max} + C_p \rho \dot{V}_{\min} (T_{\text{cold deck}} - T_z) \quad (12)$$

Equation (13) is the corresponding expression for a system in cooling mode:

$$Q_{\text{sys, cool}} = C_p \rho \eta_c \dot{V} (T_{\text{cold deck}} - T_z) \quad (13)$$

where the cooling output of the system is given in terms of the system volume flow rate and the cold deck temperature. Equating the system output given by equation (12) or (13) to the zone load, as given by equation (9), and using the definitions of  $h_c$  and  $h_h$ , two expressions can be derived for the predicted zone temperature corresponding to the system heating and cooling modes. Solution of these expressions for the predicted zone temperature then allows the damper or reheat fractions to be calculated, as appropriate. When the system is in the cooling mode the system supply air temperature is constant and the volume flow rate is given by equation (14):

$$\dot{V}_{\text{supply}} = \eta_c \dot{V}_{\text{max}} \quad (14)$$

When heating is selected the system provides air at the minimum volume flow rate and at a temperature given by:

$$T_{\text{supply}} = T_{\text{cold deck}} + \frac{\eta_h Q_{h/c, \text{max}}}{C_p \rho \dot{V}_{\text{min}}} \quad (15)$$

With the supply air flow rate and temperature known, the updated zone temperature can now be calculated by substitution of these quantities into equation (6). Similar sets of equations may be developed to solve for the heating and cooling response of systems types other than the VAV. For example, IBLAST has simulation models for single zone draw through, dual duct and three duct multizone, packaged DX, unit heater and unit ventilator systems. Other system types may also be amenable to this solution method, although, in the case of very complicated system control schemes, an iterative procedure using a Newton-Raphson or similar solver may be appropriate.

This concludes the discussion of the methods used to integrate the BLAST zone heat balance with the air handling system simulation. Essentially, this covers the modeling of air side processes between the zones and systems in IBLAST. In a subsequent article, the methods used to simulate the system water side processes that link the system to the central plant will be covered.

#### 4. References

- Taylor, R. D., C. O. Pedersen, L. Lawrie, "Simultaneous Simulation of Buildings and Mechanical Systems in Heat Balance Based Energy Analysis Programs," Proceedings of the 3rd International Conference on System Simulation in Buildings, Liege, Belgium, December 3-5, 1990, pp. 87-106.
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- Witte, M.J., C.O. Pedersen, and J. D. Spitler, "Techniques for Simultaneous Simulation of buildings and Mechanical Systems in Heat Balance Based Energy Analysis Programs", Building Simulation '89, IBPSA, Vancouver, B.C., June 1989.



## **Call for SPARK Beta Testers**

Beta testing of SPARK will begin soon. As you may know, SPARK will let you quickly build models of complex physical processes by connecting calculation modules from a library. It is aimed at simulation of innovative and/or complex building systems that are beyond the scope of programs like DOE-2 and BLAST.

The main elements of SPARK are an interactive *graphical editor*, an *object library* containing calculation modules for building components and processes, and a *solver* for solving the set of simultaneous algebraic and differential equations that correspond to the physical problem being simulated. With the graphical editor you graphically link the objects into networks that represent a building's envelope, lighting or HVAC system. With the support of DOE, SPARK is being developed by the LBNL Simulation Research Group, California State University Fullerton and Chapman University.

SPARK differs from DOE-2 in several important respects: (1) its time step can be as small or large as you want; (2) it uses an iterative solution and so can handle non-linear systems; (3) it is equation based and so can simulate arbitrarily complex systems that can be described by sets of algebraic and differential equations; and (4) its algorithms are not hard wired, which means you can easily customize it to particular simulation problems. SPARK will be initially be made available as a stand-alone program. The first release will include a library of basic HVAC components like fans, mixing boxes, heat exchangers, coils, chillers, cooling towers, and controls that you can immediately begin to assemble into complete HVAC systems. Later, SPARK will be integrated into DOE-2.2 and the combined BLAST/DOE-2 program, allowing you to analyze the performance of innovative HVAC systems using loads calculated by these programs. We will also add a library of envelope component objects, at which point you will be able to use SPARK to add innovative heat transfer models. You will be able to run the beta version under UNIX, DOS or Microsoft Windows. However, to use the graphical editor you will need a machine that can run the X-Window operating system. Otherwise, you can use the SPARK command-line interface to define and link objects.

If you would like to be a beta tester please contact Kathy Ellington at [kathy@gundog.lbl.gov](mailto:kathy@gundog.lbl.gov) or fax this page to 510-486-4089. We will contact you with more information prior to beta release.

**LAWRENCE BERKELEY NATIONAL LABORATORY**  
**Simulation Research Group MS: Bldg 90, Room 3147**  
**University of California**  
**Berkeley, CA 94720 U.S.A.**

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