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DOE-2: A COMPUTER PROGRAM FOR BUILDING ENERGY SIMULATION

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Simulation Research Group
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Editor: *Kathy Ellington*

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☞ **Dig Deeper!** — Please check out the order form on the inside back page of this newsletter. The National Technical Information Service has raised the price of certain pieces of DOE-2 documentation.

☞ **Back to School!** — Fred Buhl and Jeff Hirsch will present a three-day intensive course on (*what else?*) the DOE-2 program. The course, set for August 26 — 28, is sponsored by the University of California's Engineering Extension office. For registration information, please contact Dick Tsina or Karen Anderson at (415) 642-4151, or write Dick Tsina, Continuing Education in Engineering, Dept. B, 2223 Fulton Street, Berkeley, CA 94720.

If you plan to attend the course and want to pick up a copy of DOE-2.1C while you're in Berkeley, please call Kathy Ellington at (415) 486-5711. Also, please feel free to come to our office before or after the course to meet and talk with us. We are especially interested in getting your ideas on features that you feel should be made a part of the DOE-2 program.

☞ **DOE-2 Utility Programs** — The March 1987 issue of the *ASHRAE Journal* carried an advertisement for utility programs to enhance DOE-2. We contacted Jim Trowbridge (Trowbridge Software Engineering, 4884-D Sunset Terrace, Fair Oaks, CA 95628) to get more information. It's hoped that the next issue of the USER NEWS will feature an article describing the capabilities of the utility programs. If you would like to contact Jim Trowbridge in the meantime, please call him at (916) 962-3001.

☞ **Apply Yourself!** — The American Council for an Energy-Efficient Economy (ACEEE) is holding the First National Conference on Residential Appliance Energy Efficiency, October 26 - 28 in Arlington, VA. The three-day conference will feature leading experts from industry, public utilities, public agencies, and research institutions. For information, please contact:

The American Council for an
Energy-Efficient Economy
Suite 535
1001 Connecticut Avenue N.W.
Washington, DC 20036
Telephone: (202) 429-8873

ACEEE is a non-profit organization that conducts research and analysis on energy efficiency; its goal is stimulating the adoption of energy conserving technologies and practices.

Comments on Modeling Ice Storage Systems

by

Bruce Birdsall
Simulation Research Group

A number of users have inquired about modeling an ice storage system; unfortunately, the current version of DOE-2 has limited capabilities in this regard. The existing DOE-2 PLANT routines do not keep track of energy temperature levels; all calculations of energy use are based on the transfer of BTU's only. [Note: The surface temperature level of the storage tank is calculated to account for losses of the tank to its environment.] Dependencies for part load performance, condensing and evaporating temperatures, and rated COPs are treated by the program as modifiers to the base rated calculations.

With that statement as background, you can see that chilled water storage systems can be modeled fairly well in DOE-2 as the storage tank is considered fully stratified; an example is in the DOE-2.1C Sample Run Book, page 239. Dynamic ice storage systems, where the evaporator temperatures stay within the limited range of 20°F to 26°F, can also be modeled. Static ice-builder systems are, however, an exception in that their evaporator temperatures vary from 26°F down to 0°F depending on the thickness of the ice as it builds on the evaporator tubes; the amount of ice left on the tubes on the next recharge cycle should also be modeled. Because neither the variable evaporator temperature nor the details of the buildup and melting are simulated by DOE-2, the only approach for modeling static ice-building is an approximate one of assuming an average operating temperature for the evaporator of, say, 15°F and derating the compressor accordingly. You should note that ASHRAE has funded research at the University of Texas at Austin to incorporate improved storage models into the DOE-2 Component Based Simulator. The Electric Power Research Institute (EPRI) has been very active in transferring storage technology to the design community and has prepared a "Commercial Cool Storage Design Guide" available upon request from EPRI (Report EM-3981, May 1985).

The procedure for modeling a partial ice-storage system in DOE-2 follows:

- Step 1 -- Model the air system with hourly reports so that you can determine not only the peak cooling rate but the peak integrated daily cooling load. The best procedure for doing this is to request under SYSTEMS-REPORT a REPORT-FREQUENCY=DAILY for the summer months. A typical hourly report that could be used for this purpose is shown in Fig. A which covers the peak day of August 26. Set air and coil capacities high enough to insure that the model is free of hours where space temperatures are not satisfied on the peak days. A storage system has the characteristic of being able to satisfy overloads as, in a sense, the delivery rate is unconstrained and continues to supply 34°F water up until the point of depletion. A conventional system, on the other hand, has a delivery capacity that is constrained by its compressor capacity; as the return water temperature increases so does the supply temperature.

- Step 2 -- Size the storage and compressor capacity based on the results of Step 1. This is primarily a trial-and-error solution, requiring multiple runs, and Fig. B shows an input that satisfies this requirement. (However, I wouldn't advise sizing the storage without any safety factor as I have done as a means of illustrating DOE-2's capabilities.) Note that we have input two compressors: a hermetic-reciprocating unit operating in the morning at normal evaporator temperatures, and an open-reciprocating unit operating at 26°F to make ice on nights and weekends. The idea, of course, is to simulate a single machine operating at these two mutually exclusive conditions for a partial storage system. By increasing the tank size and cutting the operation of the compressor during the day, you could simulate a full storage system. (EPRI is also co-funding investigations into better sizing methods.)

- Step 3 -- Inspect the hourly reports from PLANT to see if the operation and storage is satisfactory; if not, revise the input in Step 2. Fig. C is our example from this sample run.

1-STORY OFFICE BLDG, ATLANTA,GA — RUN 1 VARIABLE AIR VOLUME SYSTEM THERMOSTATIC BASEBOARDS WITH WARM-UP CYC — DOE-2.1C

REPORT4 = HOURLY-REPORT

	GLOBAL WET BULB TEMP F	GLOBAL DRY BULB TEMP F	GLOBAL STD. AIR ENTHALPY BTU/LB	RZ1 ZONE TEMP F	RZ5 ZONE TEMP F	BLDG-SYS RETURN AIR TEMP F	BLDG-SYS TOT CLG COIL PWR BTU/HR	BLDG-SYS TOT ZONE HTG PWR BTU/HR	BLDG-SYS LATENT COOLING BTU/HR
	----(7)	----(8)	----(12)	----(6)	----(6)	----(4)	----(6)	----(7)	----(48)
826 1	72.0	75.0	36.50	92.6	96.3	.0	0.	0.	0.
826 2	72.0	75.0	36.50	92.6	95.8	.0	0.	0.	0.
826 3	72.0	73.0	36.50	92.5	95.3	.0	0.	0.	0.
826 4	71.0	72.0	35.50	92.4	94.5	.0	0.	0.	0.
826 5	71.0	73.0	35.50	92.3	94.2	.0	0.	0.	0.
826 6	71.0	73.0	35.50	92.3	93.7	.0	0.	0.	0.
826 7	71.0	74.0	35.50	79.7	76.9	87.9	944959.	0.	11285.
826 8	72.0	77.0	36.50	78.4	77.7	80.6	840652.	0.	62851.
826 9	73.0	82.0	37.00	77.9	77.2	80.3	817569.	0.	60485.
82610	75.0	85.0	39.00	77.2	77.4	80.0	805728.	0.	60239.
82611	77.0	87.0	41.00	76.9	77.6	79.7	768571.	0.	56626.
82612	78.0	89.0	42.00	76.7	78.3	79.3	745294.	0.	67759.
82613	75.0	85.0	39.00	76.6	77.8	79.1	716978.	0.	67380.
82614	67.0	70.0	32.00	76.6	76.8	79.0	632982.	0.	50412.
82615	70.0	76.0	34.50	76.4	76.8	78.8	617858.	0.	54933.
82616	71.0	76.0	35.50	76.3	76.7	78.7	578770.	0.	42430.
82617	73.0	76.0	37.00	76.1	76.5	78.4	540873.	0.	42869.
82618	73.0	76.0	37.00	81.8	85.6	.0	0.	0.	0.
82619	73.0	76.0	37.00	83.6	86.8	.0	0.	0.	0.
82620	72.0	75.0	36.50	83.8	86.7	.0	0.	0.	0.
82621	72.0	76.0	36.00	83.9	86.5	.0	0.	0.	0.
82622	72.0	73.0	36.50	83.8	86.0	.0	0.	0.	0.
82623	71.0	72.0	35.50	83.8	85.7	.0	0.	0.	0.
82624	71.0	73.0	35.50	83.6	85.3	.0	0.	0.	0.
DAILY SUMMARY (AUG 26)									
MN	67.0	70.0	32.00	76.1	76.5	.0	0.	0.	0.
MX	78.0	89.0	42.00	92.6	96.3	87.9	944959.	0.	67759.
SM	1735.0	1839.0	879.00	1988.1	2022.2	881.9	8010234.	0.	577268.
AV	72.3	76.6	36.63	82.8	84.3	36.7	333760.	0.	24053.

Not the warmest day of summer

Space temperatures are slightly above the setpoint of 76°F

Peak Hourly Load

Peak integrated daily load usually occurs on a day following a weekend or holiday

```
INPUT PLANT  ..

          PLANT-REPORT        SUMMARY=(PS-A,PS-B,PS-D,PS-G,BEPS) ..

          $ EQUIPMENT DESCRIPTION

$ THIS PLANT IS AN ICE STORAGE PLANT WITH A SINGLE 60 TON RECIPROCATING
$ COMPRESSOR WHICH CAN MAKE ICE AT NIGHT BUT OPERATE DURING THE DAY
$ AT NORMAL EVAPORATOR TEMPERATURES.  ITS DERATED CAPACITY WHEN
$ MAKING ICE IS 36 TONS.

CMPC    =PLANT-EQUIPMENT   TYPE=HERM-REC-CHLR  SIZE=.72  I-N=1  ..
ICEM    =PLANT-EQUIPMENT   TYPE=OPEN-REC-CHLR  SIZE=.43  I-N=1  ..

DHWH    =PLANT-EQUIPMENT    TYPE=ELEC-DHW-HEATER  SIZE=-999  ..
PLANT-PARAMETERS  HERM-REC-COND-TYPE = AIR  CHILL-WTR-T = 40
                  OPEN-REC-COND-TYPE = AIR  ..

PART-LOAD-RATIO   TYPE=OPEN-REC-CHLR  E-I-R=.39  ..
PART-LOAD-RATIO   TYPE=HERM-REC-CHLR  MIN-RATIO=.7  ..

CTANK   =PLANT-EQUIPMENT  TYPE=CTANK-STORAGE  SIZE=6.0   I-N=1  ..

ENERGY-STORAGE  COOL-STORE-RATE=.43  COOL-SUPPLY-RATE=.80
                COOL-STORE-SCH=TANK-CHG  CTANK-LOSS-COEF=100
                CTANK-BASE-T=44  CTANK-T-RANGE=10   ..

TANK-CHG=SCHEDULE THRU MAY 1 (ALL) (1,24) (0)
                  THRU OCT 1 (ALL) (1,7) (1) (8,18) (0) (19,24)(1)
                  THRU DEC 31 (ALL) (1,24) (0)  ..

TANK-CHARGE=L-A  TYPE=COOLING L-R=1  P-E=ICEM   N=1  ..
RELEASE-CHG=L-A  TYPE=COOLING O-M=RUN-NEEDED
                 LOAD-RANGE=1.2
                 P-E=CTANK  N=1  ..

MORNING-OP =L-A  TYPE=COOLING L-R=1  P-E=CMPC  N=1
                                     P-E=CTANK  N=1  ..

CONVENTIONAL-OP=L-A TYPE=COOLING L-R=1 P-E=CMPC  N=1  ..

WINTER-OP = DAY-ASSIGN-SCH (1,24) (CONVENTIONAL-OP)  ..

CHW-CTRL =DAY-ASSIGN-SCH (1,7) (TANK-CHARGE)  (8,12) (MORNING-OP)
                         (13,18) (RELEASE-CHG) (19,24) (TANK-CHARGE) ..

WEH-CTRL =DAY-ASSIGN-SCH (1,24) (TANK-CHARGE)  ..

CHILLER-CTRL=SCHEDULE THRU MAR 15 (ALL) WINTER-OP
                      THRU NOV 15 (WD) CHW-CTRL (WEH) WEH-CTRL
                      THRU DEC 31 (ALL) WINTER-OP  ..

LOAD-MANAGEMENT  PRED-LOAD-RANGE=999
                 ASSIGN-SCHEDULE=(DEFAULT,CHILLER-CTRL,DEFAULT)  ..

$                          HOURLY-REPORT INPUT
$
R-SCHED =SCH       THRU JUN 16  (ALL) (1,24)(0)
                   THRU JUN 19  (ALL) (1,24)(1)
                   THRU JUL 6  (ALL) (1,24)(0)
                   THRU JUL 9  (ALL) (1,24)(1)
                   THRU AUG 25 (ALL) (1,24)(0)
                   THRU AUG 28  (ALL) (1,24)(1)
                   THRU SEP 1  (ALL) (1,24)(0)
                   THRU SEP 4  (ALL) (1,24)(1)
                   THRU DEC 31 (ALL) (1,24)(0)  ..
$
  RB5     = REPORT-BLOCK V-T=OPEN-REC-CHLR    VARIABLE-LIST=(1)  ..
  RB6     = REPORT-BLOCK V-T=HERM-REC-CHLR    VARIABLE-LIST=(1)  ..
  RB7     = REPORT-BLOCK V-T=CTANK-STORAGE   VARIABLE-LIST=(1,4,8,14)  ..
  REPORT1 = HOURLY-REPORT REPORT-SCHEDULE=R-SCHED R-B=(RB5,RB6,RB7) ..

END  ..
COMPUTE PLANT  ..
```

Figure B

1-STORY OFFICE BLDG, ATLANTA,GA — RUN 1 VARIABLE AIR VOLUME SYSTEM THERMOSTATIC BASEBOARDS WITH WARM-UP CYC

REPORT1 = HOURLY-REPORT

	OPEN-REC -CHLR LOAD BTU/HR	HERM-REC -CHLR LOAD BTU/HR	CTANK-ST ORAGE ENERGY RELEASED BTU/HR	CTANK-ST ORAGE ENERGY STORED BTU/HR	CTANK-ST ORAGE ENERGY AVAILABL BTU/HR	CTANK-ST ORAGE TOTAL IN STORAGE BTU/HR
	----(1)	----(1)	----(1)	----(4)	----(8)	----(14)
826 1	0.	0.	0.	0.	800000.	5778538.
826 2	0.	0.	0.	0.	800000.	5774474.
826 3	0.	0.	0.	0.	800000.	5770612.
826 4	0.	0.	0.	0.	800000.	5766850.
826 5	0.	0.	0.	0.	800000.	5762988.
826 6	0.	0.	0.	0.	800000.	5759128.
826 7	0.	483098.	480772.	0.	800000.	5755168.
826 8	0.	470958.	388605.	0.	800000.	5270216.
826 9	0.	456558.	379922.	0.	800000.	4876996.
82610	0.	447555.	377084.	0.	800000.	4492224.
82611	0.	439731.	347752.	0.	800000.	4110154.
82612	0.	0.	764206.	0.	800000.	3757274.
82613	0.	0.	735090.	0.	800000.	2968470.
82614	0.	0.	651893.	0.	800000.	2249604.
82615	0.	0.	636769.	0.	800000.	1594244.
82616	0.	0.	597681.	0.	800000.	954116.
82617	0.	0.	353176.	0.	353176.	353176.
82618	393003.	0.	0.	186394.	0.	0.
82619	382346.	0.	0.	382346.	179964.	179964.
82620	384405.	0.	0.	384405.	559116.	559116.
82621	382346.	0.	0.	382346.	800000.	940162.
82622	388419.	0.	0.	388419.	800000.	1319388.
82623	390374.	0.	0.	390374.	800000.	1704722.
82624	388419.	0.	0.	388419.	800000.	2091846.
DAILY SUMMARY (AUG 26)						
MN	0.	0.	0.	0.	0.	0.
MX	393003.	483098.	764206.	390374.	800000.	5778538.
SM	2709311.	2297900.	5713749.	2502702.	17092256.	77809432.
AV	112888.	95746.	238073.	104279.	712177.	3242060.

Both compressors OFF during peak time-of-use rate period

Btu's left over in the tank on the Peak Day

Figure C

EPRI and the Department of Energy are co-funding a project to develop improved methods for sizing chilled water and ice storage systems. The study will be carried out using DOE-2. The improved sizing methods will be available to designers in the Fall of 1988. They will be incorporated into DOE-2.

BUGS DISCOVERED IN DOE-2.1C, INTERIM SOLUTIONS AND BUG FIXES

Following are recent bugs discovered in the 2.1C version of the program. Users are urged to document suspected bugs, and report them to us. We first give a description of each bug, along with its temporary (no code change) solution, and the date the permanent correction was moved to our 2.1C release files. If you received a tape sent by us after the date given in the bug description, then the bug fix is already on your tape in one of the "mod" files. In any case, before you fix a bug, make sure it has not already been corrected on your DOE-2.1C tape.

Following the bug descriptions are the bug corrections in the form of UPDATE modification directives. The corrections are independent of each other (they do not interact). Therefore, you can fix only those bugs you consider important. All the bugs for one program element are together; that is, all the corrections to BDL are under the heading "FILE BDL.BUG", then all the corrections to the keyword file, etc. Lines beginning with */ are UPDATE comment lines and can be left out.

All users who have received 2.1C versions released before April 4, 1986, should read the descriptions of bugs D-29 and D-30, and fix these bugs or avoid them.

Questions or comments should be directed (in writing) to Fred Buhl, Simulation Research Group, 90-3147, Lawrence Berkeley Laboratory, Berkeley, Ca 94720.

Bug D-45

The (in)famous hourly report bug.

Date moved to release file : 02-27-87

Bug fix mods in file HRP.MOD

```
----+----1----+----2----+----3----+----4----+----5----+----6----+
*/ --- THIS FIXES BUG D-45. 870227. HOURLY REPORTS DID
*/ --- NOT WORK WHEN TOO LONG REPORTS ARE REQUESTED.
*D USERPR.65
----+----1----+----2----+----3----+----4----+----5----+----6----+
```

Bug D-46

```
----+----1----+----2----+----3----+----4----+----5----+----6----+

*/ --- BUG D-46. 870430. LOADS aborts with 0./0.
*/ --- error in subroutine DCOF
*/ ---
*D DCOF.585
      RHOFW = (ARHP(2)*ETA+ARHP(1))/(AP(2)*ETA+AP(1)+1.E-9)

----+----1----+----2----+----3----+----4----+----5----+----6----+
```