EXAMINATION OF THE CONCEPT OF USING “TYPICAL-WEEK” WEATHER DATA FOR SIMULATION OF ANNUALIZED ENERGY USE IN BUILDINGS

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ABSTRACT

This paper investigates the feasibility of using short segments of weather data to simulate annual energy use in buildings. Use of a “typical week” of weather data is investigated as an alternative to the normal 8760-hour annual simulation process. Statistically-correct weekly weather data were first generated; then trial runs were made on a skin-load-dominated building in four U.S. cities using the DOE-2.1E and ENER-WIN-96.04 simulation software packages. Results from the typical week data correlate well to those derived from full annual energy simulations, but the simulation software models must be modified to accept the short-term data as input.

INTRODUCTION

Fundamental to the building design process is the ability to rapidly iterate design proposals through an energy analysis routine. Short turn-around times are therefore desirable for performing detailed energy simulations during the building design process. This allows designers to investigate more alternatives in less time. Most of the available energy calculation routines are driven by hourly inputs of weather and solar data that cover an entire 8760-hour period for a given location. Much of this is necessary in order to determine the dynamic heat transfer and zone thermal balance characteristics, but the method tends to consume a noticeable amount of computer time and requires access to the appropriate hourly weather data file. This paper examines, through computer software and a case study building, the concept of reducing the monthly simulations to a one-week period through the use of “typical week” weather data. The weather data are still generated on an hourly basis, but the averages and ranges of weather occurrences common to a full month are all contained in a time period of seven days. In other words, the week is generated to be statistically correct. One week was chosen as the practical minimum simulation period since most buildings’ work and occupancy patterns tend to be replicated on a weekly basis.

OBJECTIVE

The objective of this work is to determine what minimum level of resolution in weather data is acceptable while still obtaining reliable results that are useful during the building design process. At one end of the traditional spectrum are simplified methods like variable-base degree-days (ASHRAE 1985) and bin methods, while at the other end are the detailed hourly calculations that use a full year of weather records. While the simplified methods permit rapid turnaround when iterating design proposals, they limit the designer’s ability to examine dynamic load characteristics and to optimize system performance. The detailed hourly calculation procedures give the designer the opportunity to perform system optimization, but are somewhat time-consuming during the early stages of the design process. The purpose of this work is to see whether the superior performance of the detailed hourly methodology can be maintained while making it attractive to use during tentative design stages. A reduced time period for the simulation may answer this objective.

BACKGROUND

Though the bin and variable-base degree-day methodologies are the fastest methods for energy estimation, they lack the ability to accommodate the wide variations in occupancy and system use patterns that are possible in commercial, municipal and institutional buildings. So, the focus of this study is on the hourly calculation procedures. A previous study using DOE-2 simulations (Crawley and Huang 1997) showed that use of the TMY2 or WYEC2 weather data sets produces energy consumption results in U.S. cities that are within about ±1% of the 30-year average consumption values. So, it has been well established that these “typical year” data sets enable very close estimates of energy consumption. The next step is to test whether the weather statistics can be compressed even further.

Prior work by the author (Degelman 1981, 1990) has shown that energy-related weather parameters can be reduced to monthly means and standard deviations and can then be used to regenerate hourly values for energy simulation models. The previous work showed that the generation of weather data for every day will have the identical statistical distribution of the historical weather records and will produce

TABLE 1. Sample Data Base for Weather Generator

COLUMBIA, MISSOURI								WBAN	Lat	Long	STM	Elev
								03945	38.8	92.2	90	886
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Dbave	27.5	32.1	43.1	55.0	64.0	72.8	77.6	75.2	67.5	56.4	43.9	31.8
AveStd	8.0	10.2	9.0	7.4	3.8	4.2	5.7	4.8	5.4	6.9	7.6	8.6
DBMax	36.2	41.1	53.0	65.3	73.9	82.7	88.1	86.1	78.3	67.2	53.3	40.0
MaxStd	9.1	12.2	10.4	8.2	4.3	4.8	4.6	3.3	6.3	7.4	7.9	9.2
DPave	18.8	23.5	33.3	43.0	53.8	62.8	66.4	64.5	57.8	46.0	35.4	24.3
DPStd	8.5	11.2	9.7	7.8	4.0	4.5	5.2	4.0	5.9	7.1	7.7	8.9
SOLAR	711	961	1268	1645	1899	2087	2100	1860	1471	1123	733	595
WIND	11.2	11.2	12.1	11.9	9.6	8.7	8.3	8.1	8.7	9.6	10.7	11.0

essentially the same results. Regeneration of data may appear to be a redundant task; however, the value of this approach is to generate hourly weather data for locations where data is not collected on an hourly basis. The model can be easily driven by monthly means of daily averages and standard deviations. Methods for how the hourly data are generated can be found in previous publications (Degelman 1980, 1991). This new task will be to generate only one week of weather data for each month and use it to project the energy consumption for an entire month. Statistically speaking, the range and distribution of all possible monthly weather occurrences will happen in one week.

GENERAL APPROACH

The paper first describes the database used to represent monthly weather data and will then describe the test procedure. Two hourly simulation models were used to evaluate the building's energy performance -- DOE-2.1E (LBL 1993) and ENER-WIN-96.04 (Degelman and Soebarto 1995). These simulation models utilize two alternative methods for zone thermal loads. While DOE-2 utilizes the thermal response and weighting factor methodology, ENER-WIN uses the total equivalent temperature differential (TETD) methodology with internal load delay factors. While it is not the purpose of this work to compare one energy simulation model to another, the use of two models affords the opportunity to evaluate whether the two different methods of load determination will affect the degree of sensitivity to use of shortened periods of weather data.

A residence was chosen as the test building, in preference to a commercial building, since a house is a skin-load-dominated structure and would be more likely to show differences in energy consumption that are due to the weather. The building was a 1048-sq.ft. (100 sq.m.) home being constructed in Houston, TX. It has a rather high degree of energy-efficient features in its construction, with an attic radiant barrier, 9 inches (23 cm) of attic insulation, and 4 inches (10 cm) of insulation in a tight-fitting wall cavity. The home's design air conditioning load is around 20,500 Btu/h (6000 watts), which is less than a 2-ton unit.

To study the compressed weather data effects in different climates, four cities were selected from diverse climatic zones in the U.S. These were Houston, TX (hot-humid), Phoenix, AZ (hot-arid), Minneapolis, MN (cold), and Columbia, MO (temperate). These selections represent wide variations in dry bulb temperatures, solar radiation, and humidity -- the three main determinants in residential energy use for HVAC.

PROCEDURES

The procedure was to run annual simulations using weather data from a TMY2 (Typical Meteorological Year, Version 2) (NREL 1995) file, followed by the use of synthetically generated weather data for a full 8760-hour year and a one-week-per-month year. Then, the last two runs were compared to the TMY2 year and the differences noted. This procedure seemed simple at first sight, but it had some practical difficulties that had to be overcome, and the procedures in the two software packages had to be approached differently.

The **ENER-WIN** is integral with and compatible with the statistical weather generator. Sample statistical data input to the ENER-WIN program is shown in Table 1 (above). The weather generator produces hourly weather during the energy simulation process, rather than creating a weather data file to be read later. This makes the program run faster because it minimizes the number of disk reads and writes during processing. Actually, it takes about one-quarter as much time to generate data than it takes to read it from a hard disk file. The ENER-WIN software "believes" it is simulating a full year of contiguous data except that each month only has one week. The days appear to be contiguous, but the dates increment by four to assure the correct sun angles from the beginning to the end of the month. The simulator will transition smoothly from one month to the next, while only changing to a new set of statistics that govern the distribution of days in the next month. The thermal time lag histories are thereby left in tact. The results of each month's simulation (only one week long) are internally multiplied by N/7, where N is the true number of days in the month, before tabulating results to the output file. Processing the three runs in the four cities was a small task and was completed in less than an hour of human time invested.

In the case of **DOE-2**, the weather data had to be prepared in advance. DOE-2 uses a weather data packer that will pack a 1.1-Mbyte TMY file into a 149,000-byte file. The procedure used in this experiment was to generate synthetic hourly weather data in TMY format. This involved first producing one week of statistically-correct data for each month, but DOE-2 does not understand the TMY file if is does not contain 8760 lines of data. Therefore, the remaining 3+ weeks in each month had to be filled in. To complete each month, the first week was simply repeated three more times. In every month except February, this still left two or three days of empty data. Those days were then created from average-day data so the month's statistics would not be altered. This provided the DOE-2 weather packer with a full year's record of 8760 hours of data.

The next step was to see if there was significant time savings if the DOE-2 simulation would run only the first 7 days of each month. This meant that only 84 days out of the year were simulated, so the energy answers were multiplied by the ratio of 365/84, or 4.3452. Peak loads were left unmodified as produced by the program. The answers might be seen as acceptable, but there could be noted some deviations in peak loads and energy consumption that were probably due to the thermal history storage problems from the startup for each month. The results of this simulation along with percent deviation are shown in Table 3 under the column noted as SIMx4.

The simulation runs using TMY data were considered to be the reference runs to which all subsequent runs were compared. TMY2 data were available for all the cities. These data sets were derived from the 1961-1990 National Solar Radiation Data Base (NSRDB 1995). In the case of Houston, an older TMY was also available. It was from the National Climatic Data Center's Tape Deck 9734 (NCDC 1981) and is based on the period from 1950 through 1980. Since this experiment was to determine deviations from adjustments in weather representations, it was of interest to also compare results from simulations using two different sources of nationally used weather data. Both TMY and TMY2 data sets are still being used by simulationists. Results of this comparison are shown for Houston in Table 3.

Results from the full-annual and the one-week-per-month simulations are compared to the reference TMY2 simulations and a percent difference is presented showing accuracy loss in both weather data and the building's energy use for the four locations studied. The program run times are also tabulated to indicate the potential savings in computation time.

TABLE 2. Nomenclature in Tables

Symbol	Description
DBave	Average annual dry bulb temperature (F)
WBave	Average annual wet bulb temperature (F)
HDD65	Heating degree days (base 65F)
HDD55	Heating degree days (base 55F)
CDD75	Cooling degree days (base 75F)
CDD65	Cooling degree days (base 65F)
DBmax	Maximum dry bulb temperature (F)
DBmin	Minimum dry bulb temperature (F)
RHam	Average morning relative humidity (%)
RHpm	Average afternoon relative humidity (%)
DNave	Ave daily direct normal solar (Btu/sq.ft.)
DHave	Ave daily total horizntl solar (Btu/sq.ft.)
Inorth	Ave daily vertical solar North (Btu/sq/ft/)
Ieast	Ave daily vertical solar East (Btu/sq/ft/)
Isouth	Ave daily vertical solar South (Btu/sq/ft/)
Iwest	Ave daily vertical solar West (Btu/sq/ft/)
	ENERGY RESULTS
HGs	Peak sensible heat gain (kBtu/hr)
HGl	Peak latent heat gain (kBtu/hr)
HL	Peak heat loss (kBtu/hr)
TCL	Tot. annual building cooling loads (kBtu)
THL	Tot. annual building heating loads (kBtu)
CE	Tot. annual system cooling loads (kBtu)
HE	Tot. annual system heating loads (kBtu)
Elec	Total annual electric energy (MBtu)
Gas	Total annual gas heating energy (MBtu)
S.L.E.	Total site line energy (MBtu)
	COLUMN HEADINGS
DOE2	DOE-2 simulation results
E-WIN	ENER-WIN results
TMY	Typical Meteorological Year data
TMY2	Typical Meteorological Year, Ver. 2 data
SIM-xx	Simulation for xx=31 or 7 days/mon.
SIMx4	1-week DOE run multiplied by 4.3452

RESULTS

Definitions of terms used in the later tables are shown in Table 2. Tables 3 through 6 at the end of this paper present a summary of all simulation results from 14 DOE-2 runs and 12 ENER-WIN runs. Table 3 indicates the time requirements for the simulations on a 486-DX4/100 MHz computer. In the case of DOE-2 runs, the times shown include processing of the BDL routines but do not include the time used by the weather packer. In the case of ENER-WIN, the time for the TMY2 run includes reading directly from the weather data file, whereas the SIM-31 and SIM-7 runs generated their own weather data.

Several of the weather and energy values have been extracted and plotted in Figures 1 through 9. This gives a quick glance across the different simulation periods for both software packages. The horizontal axis of each plot has a code which are to be interpreted as follows:

1. DOE-2 with TMY2 weather file
2. DOE-2 with 31-day/mo. simulation
3. DOE-2 with 7-day/mo. simulation
4. ENER-WIN with TMY2 weather file
5. ENER-WIN with 31-day/mo. simulation
6. ENER-WIN with 7-day/mo. simulation

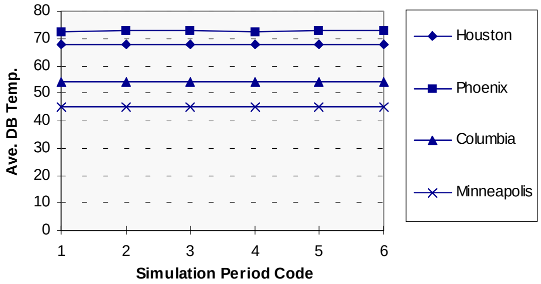

Fig. 1 Ave. Annual Dry Bulb Temperatures vs. Simulation Period

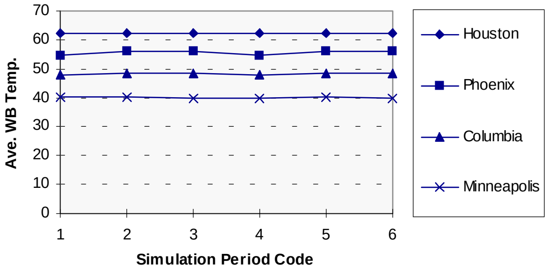

Fig. 2 Ave. Annual Wet Bulb Temperatures vs. Simulation Period

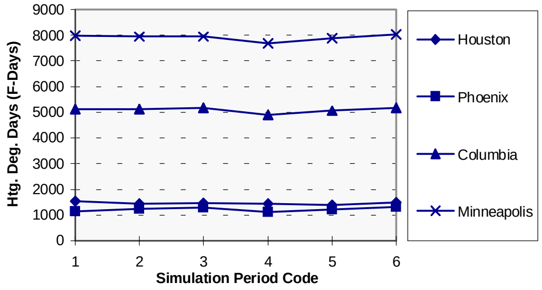

Fig. 3 Heating Degree Days vs. Simulation Period

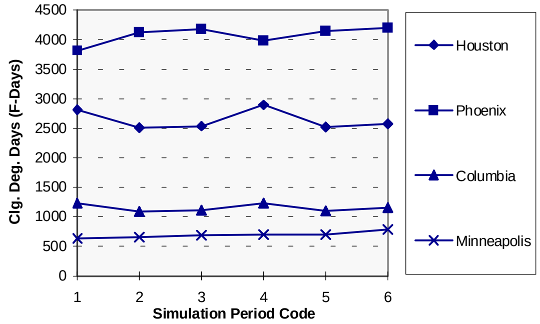

Fig. 4 Cooling Degree Days vs. Simulation Period

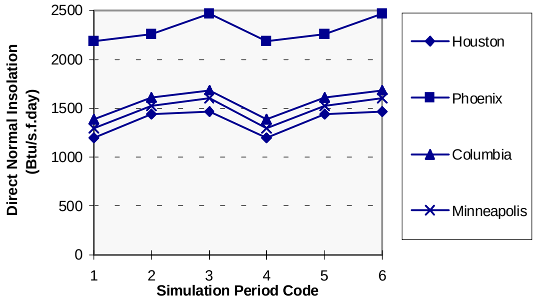

Fig. 5 Direct Normal Insolation vs. Simulation Period

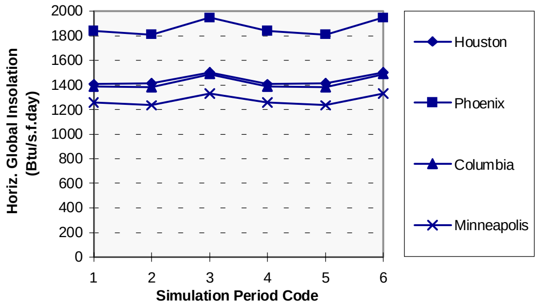

Fig. 6 Horizontal Global Insolation vs. Simulation Period

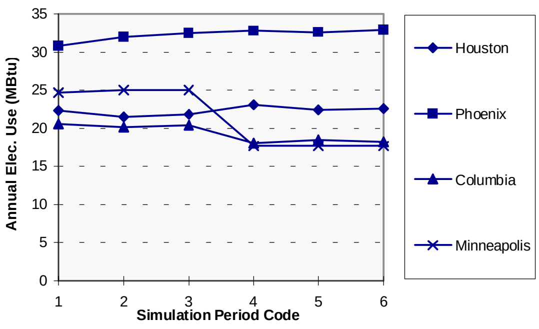

Fig. 7 Annual Electric Use vs. Simulation Period

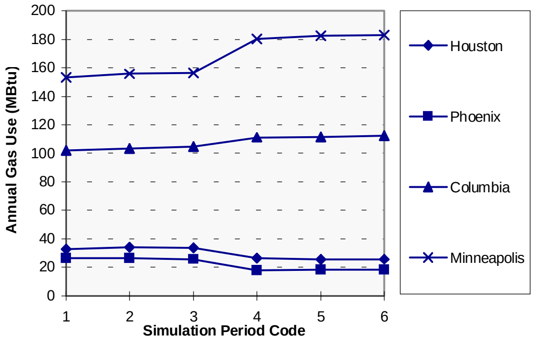

Fig. 8 Annual Gas Use vs. Simulation Period

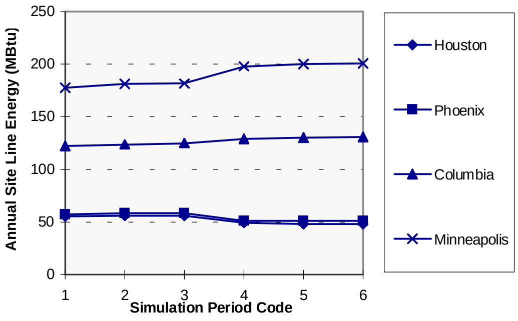

Fig. 9 Annual Site Line Energy vs. Simulation Period

CONCLUSIONS

The objective of this study was not to compare simulation packages. It is obvious that the ENER-WIN software runs in much less time than DOE-2 software, but this is expected because ENER-WIN uses a simplified systems simulation method that employs overall system EER's (Energy Efficiency Ratios) and DOE-2 uses detailed system simulation routines. The objective, rather, was to determine if acceptable accuracy and significant savings could be incurred by analyzing with a shorter simulation period -- i.e., one week per month instead of four weeks per month. The DOE-2 simulations took 225 seconds for the full run and 110 seconds for the reduced runs. Though this ratio (1-to-2) is not as impressive as was expected, the actual savings were around 2 minutes per run (125 seconds). It should be recognized that this is the simplest of buildings -- being a residence with only one zone and using a packaged air conditioner -- and that the differences in a larger commercial building with many zones may be much more impressive. In a design setting, the time savings could be important, but the designer must be willing to accept errors on the order of ±10% to 18% in comparison to the reference run using 8760 hours of standardized TMY data.

In the case of ENER-WIN, changing the simulation from reading of the TMY2 data to a full 8760-hour simulation reduced the run time from 82 seconds to just 17 seconds, a ratio of almost 1-to-5. This comes with a small sacrifice of 3 to 4% error in accuracy in the annual fuel estimates. (Higher errors are noticed in some of the intermediate statistics.) The next step of reducing the simulation to one week per month reduced the run time from 17 seconds to 12 seconds, with no noticeable increase in error. This time savings is barely noticeable and probably would have negligible impact on a designer's work progress or his/her attitude toward simulation. This does not suggest much advantage of using a shorter simulation unless the project would be of a much larger size. On projects with a large number of zones, the simulation ratio will be closer to 1-to-4. The reason the example ratio is just 12-to-17 is that the project input time is occupying the first several seconds of the run and the 1-to-4 ratio of actual simulation savings is not evident.

RECOMMENDATIONS

This experiment imposed a large burden on the DOE-2 processing of runs since the weather data had to be generated and then transferred through several formats before the data were compatible with the DOE-2 weather packer. After the one-week-per-month simulations were completed the results had to be further revised by the multiplication factor mentioned earlier. The open question here is whether DOE-2 might show better time savings if its code is modified to allow for a 7-day month. This would require some reprogramming to permit the simulation process to progress through successive months without losing its temperature histories. If this could be undertaken, it may still be beneficial -- time wise -- to apply the multiplication technique internally in much the same way that ENER-WIN does currently. In large projects, the time savings could be rather significant and could be an important factor in the long-term of evolution of using simulation tools in the design process.

The experiment has at least pointed out the feasibility of using abbreviated weather resolution for simulation projects, while not causing significant damage to the accuracy of the results. In further work on this topic, it may be worth examining other weather compression techniques that would improve the accuracy of the weather results. At least the concept is appears to be viable.

Lastly, it should be pointed out that the reduced weather simulation technique will probably be the favored approach for sites that do not collect hourly weather data. At those sites, simulated data is all that is available.

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TABLE 3. Results for Houston, TX

Vari- able	DOE2 TMY- 1981	DOE2 TMY2 225 *	DOE2 SIM-31 225 *	% Diff.	DOE2 SIM-7 225 *	% Diff.	DOE2 SIMx4 110 *	% Diff.	E-WIN TMY2 82 *	E-WIN SIM-31 17 *	% Diff.	E-WIN SIM-7 12 *	% Diff.
DBave	68.6	68.1	68	--	68	--	68	--	67.9	67.9	--	67.9	--
WBave	62.3	62.4	62.2	--	62.1	--	62.1	--	62.4	62.4	--	62.4	--
HDD65	1363	1552	1436	-7.5	1479	-4.7	1479	-4.7	1445	1402	-3.0	1486	2.8
HDD55	426	614	386	-37.1	434	-29.3	434	-29.3	563	368	-34.6	435	-22.7
CDD75	946	811	695	-14.3	707	-12.8	707	-12.8	817	697	-14.7	727	-11.0
CDD65	2878	2810	2510	-10.7	2532	-9.9	2532	-9.9	2890	2519	-12.8	2569	-11.1
DBmax	99	97	97	--	97	--	97	--	96	97	--	97	--
DBmin	26	14	27	--	27	--	27	--	14	27	--	27	--
RHam	85	89	95	6.7	94	5.6	94	5.6	89	95	6.7	94	5.6
RHpm	56	58	56	-3.4	55	-5.2	55	-5.2	58	56	-3.4	55	-5.2
DNave	1124	1200	1442	20.2	1466	22.2	1466	22.2	1200	1442	20.2	1466	22.2
DHave	1366	1406	1414	0.6	1503	6.9	1503	6.9	1406	1414	0.6	1503	6.9
Inorth	451	479	397	-17.1	433	-9.6	433	-9.6	479	397	-17.1	433	-9.6
Ieast	822	825	914	10.8	959	16.2	959	16.2	825	914	10.8	959	16.2
Isouth	963	1014	970	-4.3	1041	2.7	1041	2.7	1014	970	-4.3	1041	2.7
Iwest	823	946	723	-23.6	762	-19.5	762	-19.5	946	723	-23.6	762	-19.5
HGs	16.7	16	15.8	-1.3	16.8	5.0	15	-6.3	16.5	17	3.0	16.6	0.6
HGl	4.8	4.7	4.6	-2.1	3	-36.2	3.6	-23.4	3.1	2.8	-9.7	2.4	-22.6
HL	16.2	19.8	17.9	-9.6	17	-14.1	16.6	-16.2	23.4	19.9	-15.0	20.6	-12.0
TCL	31.8	31.6	28.7	-9.2	29.9	-5.4	34	7.6	n.a.	n.a.		n.a.	
THL	18.2	19	20.2	6.3	20.3	6.8	17.8	-6.3	n.a.	n.a.		n.a.	
CE	15.5	14.9	13.5	-9.4	14.1	-5.4	17.6	18.1	22.1	19.7	-10.9	20	-9.5
HE	13.4	13.9	14.8	6.5	14.6	5.0	12.4	-10.8	9.2	8.8	-4.3	8.9	-3.3
Elec	22.8	22.3	21.5	-3.6	21.8	-2.2	23.5	5.4	23.1	22.4	-3.0	22.6	-2.2
Gas	32.4	32.9	34.2	4.0	33.9	3.0	30.9	-6.1	26.3	25.5	-3.0	25.7	-2.3
S.L.E.	55.2	55.3	55.7	0.7	55.8	0.9	54.6	-1.3	49	48	-2.0	48	-2.0

* indicates the run times on a 486-DX4/100 MHz microcomputer

TABLE 4. Results for Phoenix

Variable	DOE2 TMY2	DOE2 SIM-31	% Diff.	DOE2 SIM-7	% Diff.	E-WIN TMY2	E-WIN SIM-31	% Diff.	E-WIN SIM-7	% Diff.
DBave	72.5	72.9	--	73	--	72.5	72.9	--	73	--
WBave	54.8	56.2	--	56	--	54.8	56.2	--	56	--
HDD65	1154	1253	8.6	1300	12.7	1111	1221	9.9	1322	19.0
HDD55	280	309	10.4	347	23.9	277	297	7.2	363	31.0
CDD75	1802	2111	17.1	2134	18.4	1879	2119	12.8	2154	14.6
CDD65	3815	4121	8.0	4179	9.5	3987	4138	3.8	4200	5.3
DBmax	115	114	--	114	--	114	114	--	114	--
DBmin	27	26	--	26	--	27	26	--	26	--
RHam	50	54	8.0	52	4.0	50	54	8.0	52	4.0
RHpm	22	26	18.2	25	13.6	22	26	18.2	25	13.6
DNave	2188	2262	3.4	2469	12.8	2188	2262	3.4	2469	12.8
DHave	1839	1810	-1.6	1945	5.8	1839	1810	-1.6	1945	5.8
Inorth	466	416	-10.7	435	-6.7	466	416	-10.7	435	-6.7
Ieast	989	1187	20.0	1263	27.7	989	1187	20.0	1263	27.7
Isouth	1334	1303	-2.3	1405	5.3	1334	1303	-2.3	1405	5.3
Iwest	1207	896	-25.8	957	-20.7	1207	896	-25.8	957	-20.7
HGs	25.6	24.5	-4.3	24.4	-4.7	25.5	24.9	-2.4	24.7	-3.1
HGl	0.6	1.8	200.0	1.5	150.0	0.8	1	25.0	1	25.0
HL	12.7	13.6	7.1	12.3	-3.1	15.5	17.6	13.5	18.1	16.8
TCL	53.8	53.5	-0.6	55.1	2.4	n.a.	n.a.		n.a.	
THL	13.6	13.9	2.2	13.8	1.5	n.a.	n.a.		n.a.	
CE	31.9	32.4	1.6	33.3	4.4	38.7	38.6	-0.3	39	0.8
HE	8.7	8.9	2.3	8.3	-4.6	5.1	5.3	3.9	5.3	3.9
Elec	30.8	32	3.9	32.5	5.5	32.8	32.6	-0.6	32.9	0.3
Gas	26.2	26.4	0.8	25.6	-2.3	18.1	18.4	1.7	18.4	1.7
S.L.E.	57	58.4	2.5	58.1	1.9	51	51	0.0	51	0.0

TABLE 5. Results for Columbia

Variable	DOE2 TMY2	DOE2 SIM-31	% Diff.	DOE2 SIM-7	% Diff.	E-WIN TMY2	E-WIN SIM-31	% Diff.	E-WIN SIM-7	% Diff.
DBave	54	54	--	54	--	54	54	--	54	--
WBave	48.1	48.5	--	48.3	--	48.1	48.5	--	48.3	--
HDD65	5129	5142	0.3	5180	1.0	4907	5074	3.4	5186	5.7
HDD55	3170	3115	-1.7	3162	-0.3	2995	3053	1.9	3164	5.6
CDD75	271	203	-25.1	208	-23.2	263	208	-20.9	243	-7.6
CDD65	1228	1089	-11.3	1112	-9.4	1235	1100	-10.9	1149	-7.0
DBmax	100	98	--	98	--	100	98	--	98	--
DBmin	0	0	--	0	--	1	-1	--	-1	--
RHam	80	92	15.0	91	13.8	80	92	15.0	91	13.8
RHpm	54	51	-5.6	51	-5.6	54	51	-5.6	51	-5.6
DNave	1387	1608	15.9	1687	21.6	1387	1608	15.9	1687	21.6
DHave	1389	1382	-0.5	1488	7.1	1389	1382	-0.5	1488	7.1
Inorth	436	363	-16.7	391	-10.3	436	363	-16.7	391	-10.3
Ieast	864	928	7.4	974	12.7	864	928	7.4	974	12.7
Isouth	1159	1140	-1.6	1223	5.5	1159	1140	-1.6	1223	5.5
Iwest	930	737	-20.8	793	-14.7	930	737	-20.8	793	-14.7
HGs	14	12.8	-8.6	12.6	-10.0	14.4	13	-9.7	11.7	-18.8
HGl	3.5	3.4	-2.9	2.2	-37.1	3.1	2.1	-32.3	1.5	-51.6
HL	36.6	39.9	9.0	37.4	2.2	39.7	46.2	16.4	42.6	7.3
TCL	9	7.5	-16.7	8.2	-8.9	n.a.	n.a.		n.a.	
THL	83.5	85.1	1.9	85.2	2.0	n.a.	n.a.		n.a.	
CE	1.5	0.7	-53.3	0.9	-40.0	4.2	3.5	-16.7	3.6	-14.3
HE	67.8	69	1.8	69.8	2.9	54.4	54.7	0.6	55.2	1.5
Elec	20.6	20.2	-1.9	20.4	-1.0	18.1	18.5	2.2	18.2	0.6
Gas	101.9	103.5	1.6	104.5	2.6	111.1	111.6	0.5	112.4	1.2
S.L.E.	122.5	123.7	1.0	124.9	2.0	129	130	0.8	131	1.6

TABLE 6. Results for Minneapolis

Variable	DOE2 TMY2	DOE2 SIM-31	% Diff.	DOE2 SIM-7	% Diff.	E-WIN TMY2	E-WIN SIM-31	% Diff.	E-WIN SIM-7	% Diff.
DBave	45.2	45.2	--	45.3	--	45.1	45.2	--	45.3	--
WBave	40.3	40.2	--	40	--	40	40.2	--	40	--
HDD65	7986	7945	-0.5	7951	-0.4	7702	7876	2.3	8030	4.3
HDD55	5570	5475	-1.7	5488	-1.5	5347	5415	1.3	5560	4.0
CDD75	73	112	53.4	118	61.6	97	145	49.5	182	87.6
CDD65	634	661	4.3	686	8.2	692	700	1.2	786	13.6
DBmax	95	98	--	98	--	95	98	--	98	--
DBmin	-20	-18	--	-18	--	-20	-19	--	-19	--
RHam	80	87	8.8	85	6.3	80	87	8.8	85	6.3
RHpm	58	52	-10.3	52	-10.3	58	52	-10.3	52	-10.3
DNave	1299	1523	17.2	1607	23.7	1299	1523	17.2	1607	23.7
DHave	1257	1236	-1.7	1332	6.0	1257	1236	-1.7	1332	6.0
Inorth	409	329	-19.6	358	-12.5	409	329	-19.6	358	-12.5
Ieast	810	856	5.7	917	13.2	810	856	5.7	917	13.2
Isouth	1156	1164	0.7	1264	9.3	1156	1164	0.7	1264	9.3
Iwest	870	686	-21.1	741	-14.8	870	686	-21.1	741	-14.8
HGs	8.1	10.8	33.3	10.8	33.3	9.7	10.6	9.3	11.7	20.6
HGl	3.7	2.4	-35.1	1.5	-59.5	3.4	1	-70.6	1	-70.6
HL	45.6	46.9	2.9	45	-1.3	49.3	53.8	9.1	53.2	7.9
TCL	2.3	2.4	4.3	3.1	34.8	n.a.	n.a.		n.a.	
THL	130.6	133.8	2.5	134.1	2.7	n.a.	n.a.		n.a.	
CE	0	0.03	-	0.01	-	4.1	1.1	-73.2	1.2	-70.7
HE	109.6	111.8	2.0	112.4	2.6	91.5	92.6	1.2	93.1	1.7
Elec	24.7	25	1.2	25	1.2	17.7	17.7	0.0	17.7	0.0
Gas	153.3	155.8	1.6	156.5	2.1	180.2	182.2	1.1	183.1	1.6
S.L.E.	178	181	1.7	181.5	2.0	198	200	1.0	201	1.5