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A COMPARISON OF DOE-2.1C PREDICTION WITH THERMAL MASS TEST CELL MEASUREMENTS

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ABSTRACT

This report describes a Comparison of DOE-2.1C Prediction with Thermal Mass Test Cell Measurements performed by the Building Energy Simulation Group of the Applied Science Division (ASD) at Lawrence Berkeley Laboratory, Berkeley, California. It is a companion study to one performed by the Passive Solar Group, ASD, at Lawrence Berkeley Laboratory. The purpose of the study was twofold: first, a comparison was made of simulated results with measured data taken by others from test cells of differing wall constructions at Gaithersburg, MD, and Tesuque Pueblo, NM. Second, a comparison was made of two computer simulations of a prototypical residence when using the programs to characterize the effects of wall thermal mass. The results indicate that the DOE-2 Computer Program for Building Energy Analysis and the Building Loads Analysis and System Thermodynamics (BLAST) programs give similar results and that DOE-2 closes within a reasonable tolerance (±20%) to measured data from the test cells.

Key words: thermal mass, wall heat transmission, residential energy consumption, DOE-2/BLAST comparisons.

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A Comparison of DOE-2.1C Prediction with Thermal Mass Test Cell Measurements

Introduction

The purpose of this study was twofold: first, a check of DOE-2[1] against measured data made at two different climate sites; second, based on the assumption that the first checks were satisfactory, a comparison of DOE-2 and BLAST[2] results when using these two programs to characterize the effects of thermal mass type and positioning for differing wall constructions. The sources of measured data for this project were:

> The Oak Ridge National Laboratory's Buildings Envelopes Program provided data gathered by the University of New Mexico's Southwest Thermal Mass Study[3,4] for three test cells built in Tesuque Pueblo, New Mexico. The cells were instrumented in 1981 with data collected between January 1 and June 5, 1982. These test cells are henceforth referred to as the SWTMS test cells in this report.
>
> The ORNL Buildings Envelopes Program also provided data gathered by the National Bureau of Standards for three test cells that were built in Gaithersburg, Maryland. The cells were instrumented in 1981 with data collected between January 4, 1981 and August 5, 1982. These test cells are henceforth referred to as the NBS test cells in this report.

The Passive Solar Group (PSG) of the Applied Science Division at Lawrence Berkeley Laboratory was responsible for preparing a similar study to the one reported here using the BLAST program, and have written a separate report[5].

Discussion of Methodology and Problem Areas

This report describes work performed by the Building Energy Simulation Group (BESG) of the Applied Science Division at Lawrence Berkeley Laboratory. This work followed the course and actions of the PSG but at a reduced scale using the DOE-2 Energy Analysis Program. The PSG used the BLAST program whereas BESG, as authors of the DOE-2 Energy Analysis Program, used DOE-2.1C, the most recent version of that program. The reader is referred to Ref. 5 for a complete description of test cells and of the parametric study of a prototypical residence.

Weather data was collected for both the SWTMS and NBS test cells and this data was processed as input to the DOE-2 as well as BLAST simulations. The preparation of the weather tapes was done independently by PSG and BESG, since the two programs use slightly different formats and weather preprocessors. Naturally, the weather input was of great interest to us and our general reaction regarding the quality of this data was one of skepticism. No attempt was made to examine the weather data in detail; however, in processing the data to create DOE-2 compatible weather files certain problems were uncovered.

The most serious problem involved the NBS test cell solar data and specifically, the total horizontal radiation values. The sunrise and sunset hours vary by as much as 2 hours within a data set for summer days. This might mean that data is missing, that the data is not binned properly, or that all the data is suspect. It is important that the data be binned properly relative to local standard time, since the DOE-2 model used to split the total solar radiation into direct and diffuse components is very sensitive to this binning. The solar data for the SWTMS test cells in New Mexico appeared more consistent. However, the outside temperature values had some fluctuations that were suspicious. The fluctuations although not extreme for the climate, did vary in some instances as much as 20°F in a one hour timestep.

In our view, with the use of DOE-2, we were able to satisfactorily close (±15%) with the measured data from all the test cells except for one. This was NBS Cell 6 Insulated Masonry where the disparity was -20% (DOE-2 was 20% lower than the measured results). These results are discussed in more detail later in this report. The results of the parametric studies to characterize thermal mass effects indicated that a person using DOE-2 would draw the same conclusions that he would when using BLAST.

With due respect to the individuals who did the instrumentation and for their difficult task of collecting data for these two sets of test cells, we caution readers that all measured data must be treated with some element of suspicion. Sensors get out of calibration, whole periods of data are lost, access doors are left open, lights are turned off when they are supposed to be left on, — you name it, it probably happened. The reader should be aware of the fact that in these cells, the electric heating coils were cycling on for periods of only 5 to 10 minutes and therefore more than once in the hour. If three cycles occurred in one hour, and only one in the following hour, spikes show up in the hourly data which are un-representative of the load.

The most important question to ask is, "How accurate could the other temperature and heat flux readings have been under these adverse conditions?" The problems inherent in accurately measuring sensible cooling loads under these same cycling conditions, border on the impossible. A good portion of the run time of the air conditioning compressors could have gone to pulling down the refrigerant to evaporating pressure. Also, the thermocouples on the leaving side of the cooling coil would take a considerable portion of the cycle time to adjust to a 30°F temperature swing within a 10 minute run period.

On the other side of the coin, computer programs leave much to be desired since a simulation with equipment fully modulated and always stable is so far from the "real world". A simulation is, therefore, an idealistic estimate of the situation one is trying to replicate and the human factor evident in the measured data is non-existent. Compounding the problem is the fact that our present computer programs have recognized inadequacies: the most important one in this study is the inability to model conductive edge losses. To put things in perspective, a closure in many cases is just as suspect as a non-closure. Certainly, one should not put any more importance on a closure of ±1% than on one of ±15% when the suspected error margin is ±20%.

It is our opinion that much of the debate over thermal mass effects is due to the fact that computer analyses seldom show the large savings that some individuals feel should inherently be there. Most all of us have experienced living or staying in structures with massive walls and most of us perceive that the structures are cooler during the summer (and therefore should require less energy) than any similar structures of frame construction. Then why don't any of the studies referenced in this report show more than a few percentage points difference? Is it because what we perceive as summer comfort is somewhat independent of air temperature in the space? Certainly, a massive structure with wall surface temperatures lower than a frame structure may be comfortable at higher inside air temperatures. As a result, we may set thermostats higher in one case than another, or turn on air-conditioning for fewer hours in a structure with massive walls. The key to why we aren't showing substantial energy savings for thermal mass may be our inability to simulate the human reactions to a sense of comfort in a massive structure[†].

SWTMS Cell Comparisons

Description of Modeling Variants

DOE-2.1C inputs were prepared for three different constructions:

- Adobe - Cell 1,
- Cement-Masonry Unit (CMU) with furring strips - Cell 6,
- Insulated Wood Frame - Cell 7.

We followed as closely as possible the inputs found on the BLAST runs for these same test cells. However, two exceptions were made. The first involved the material properties which we felt should conform to Table A.1 "Thermal Properties of SWTMS Test Cell Components" (Appendix A of Ref. 4). The initial BLAST inputs used "adjusted" properties for which there seemed to be no justification. The second exception was the simulated heating setpoint used in the DOE-2 inputs. The measured data clearly indicated that the space air temperatures a few feet away from the distribution plenum were 4 to 5°F lower than those inside the plenum. The thermostat was located inside the plenum. The question then was how best to model this effect, and how to do it consistently for all three test cells and all test periods. It was our opinion that the reason for the discrepancy between the measured space temperatures and the thermostat setpoints in all three cells was primarily due to thermostat

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[†] The BLAST program, however, does allow specification of room thermostats that act on mean radiant temperatures for a better measure of comfort than space temperature alone.

"droop" caused by the anticipator heating element inside the thermostat. The droop was identified by Honeywell[6] and conforms conceptually with the ORNL regression equation 4.3 where $T_{AVG} = A + B\ (Q_{HTR})$, with A and B coefficients as found in Table 4.2[3,4]. The A coefficient is the thermostat's base setpoint; the B coefficient is a minus value which, when multiplied by the heating for the hour, establishes the "droop". Most of us instinctively compensate for thermostat droop in our homes when the weather is really cold by setting our thermostats up 3 or 4 degrees. And we do this because we feel uncomfortable since the thermostat is actually holding a lowered setpoint. In modeling this effect with DOE-2, we found that a consistent setpoint of 64°F (the lowest observed space temperature), combined with a throttling range of +5° tracked measured space temperature of a single sensor fairly well, as can be witnessed by Figures 1, 2, and 3.

Conclusions for SWTMS Cells

Modeling of these three test cells to close within ±12% averaged over 3 days required very little effort. In fact, the first trial runs brought us surprisingly close to the measured data. After finding a way to consistently handle the thermostat setpoint without tweaking up and down for each season and cell construction, we proceeded with a full set of runs. Table 1 shows three daily comparisons for three different periods. DOE-2 also compares favorably over extended test periods as shown in Table 2.

TABLE 1

SWTMS — Energy Use Comparisons

Daily Energy Use

	AVG OA TEMP (^{o}F)	ADOBE — Cell 1			CMU — Cell 6			FRAME — Cell 7		
		MEAS KWH	DOE-2 KWH	Δ%	MEAS KWH	DOE-2 KWH	Δ%	MEAS KWH	DOE-2 KWH	Δ%
HEATING										
Jan 12	30	36.8	41.8	+13%	26.4	30.2	+15%	21.7	17.9	-18%
Jan 14	20	40.6	47.1	+16%	27.6	33.6	+20%	17.5	20.0	+14%
Jan 18	38	33.9	35.6	+05%	24.3	24.9	+02%	17.7	14.9	-16%
			Avg.	+11%		Avg.	+12%		Avg.	-07%
INTERMEDIATE										
Feb 28	39	24.5	26.6	+08%	16.6	19.3	+19%	13.0	12.1	-07%
Mar 02	48	20.3	21.6	+06%	15.1	14.4	-05%	7.3	08.8	+07%
Mar 06	26	37.7	42.4	+12%	29.2	30.3	+01%	22.4	18.1	-19%
			Avg.	+09%		Avg.	+05%		Avg.	-06%
FLOATING										
May 25	59	6.5	5.8	-10%	5.7	5.0	-13%	2.9	3.4	+17%
May 31	64	.8	.3	NS	0	0	NS	.6	1.8	NS
Jun 01	68	0	0	NS	0	0	NS	0	0	NS

$$\Delta\% = \left[\frac{\text{DOE-2.1C}}{\text{Measured}} - 1\right] *100$$

NS = Not Significant as the numbers become too small to compare on a percentage basis.

TABLE 2

DOE-2.1C Predicted and Measured Energy Use for Selected Periods

Heating Period — January 12 through 20

	Total Energy	Kwh	
	Measured	DOE-2.1C	Δ%
<u>SWTMS</u>			
Adobe - Cell 1	335	360	+7
CMU - Cell 6	242	256	+6
Frame - Cell 7	163	154	-6

Intermediate Period — February 28 through March 10

	Total Energy	Kwh	
	Measured	DOE-2.1C	Δ%
Adobe - Cell 1	278	320	+15
CMU - Cell 6	210	230	+10
Frame - Cell 7	137	141	+3

Floating Period — May 25 through June 5

	Total Energy	Kwh	
	Measured	DOE-2.1C	Δ%
Adobe - Cell 1	15	12	NS
CMU - Cell 6	15	26	NS
Frame - Cell 7	14	18	NS

$$\Delta\% = \left[\frac{\text{DOE-2.1C}}{\text{Measured}} - 1\right] * 100$$

NS = Not Significant as the numbers become too small to compare on a percentage basis.

Figure 1

SWTMS CELL 1 — 11-inch Adobe.

Measured versus DOE-2.1C space temperatures.

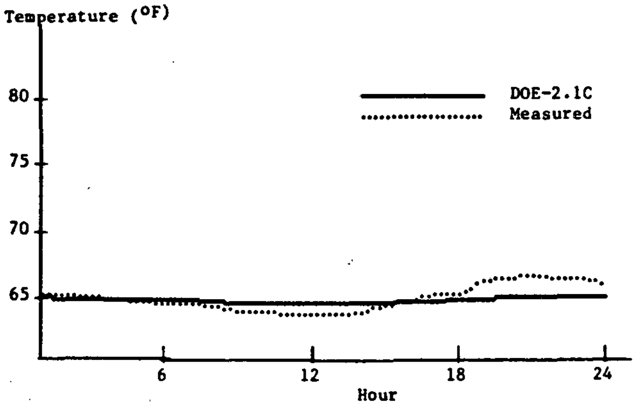

Figure 1a

Heating always on, January 14, 1982, 19.9°F average OA temperature.

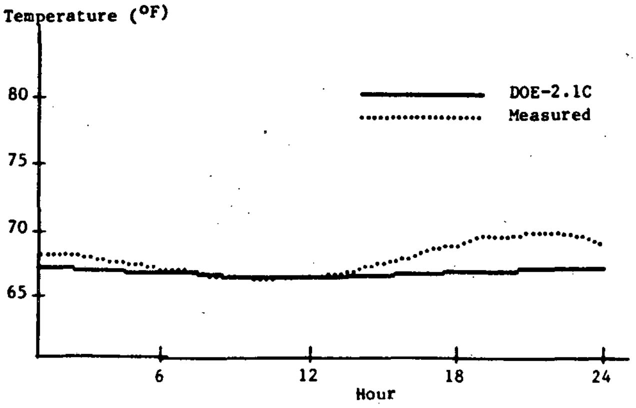

Figure 1b

Intermediate — Modulating heat, February 28, 1982, 38.6°F average OA temperature.

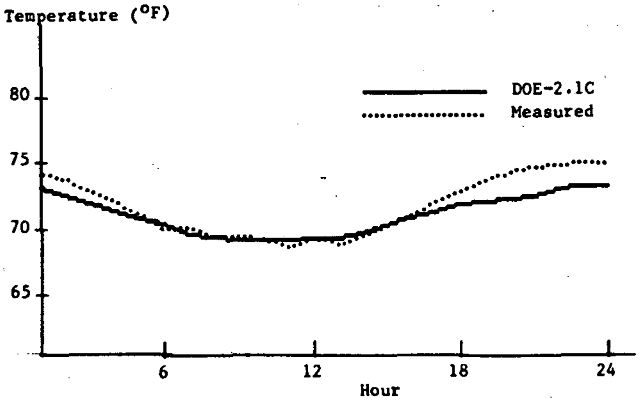

Figure 1c

Summer — Floating, May 31, 1982, 63.7°F average OA temperature.

Figure 2

SWTMS CELL 6 — CMU

Measured versus DOE-2.1C Space Temperatures

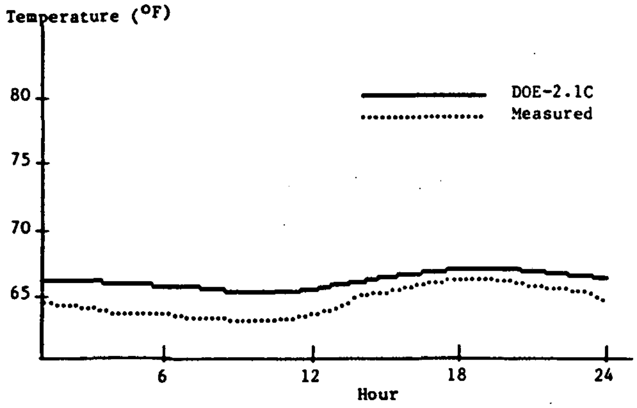

Figure 2a

Heating always on — January 14, 1982, 19.9°F average OA temperature.

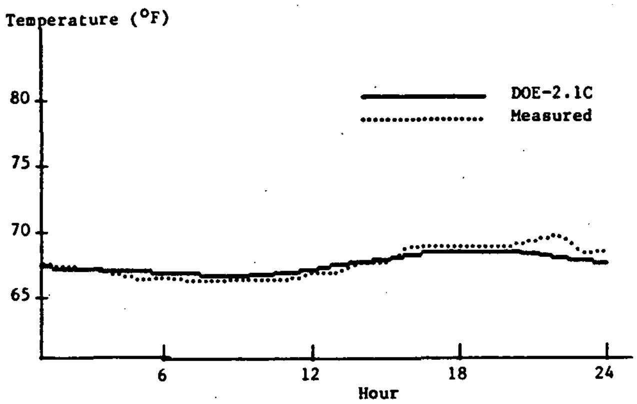

Figure 2b

Intermediate — Modulating heat, February 28, 1982, 38.6°F average OA temperature.

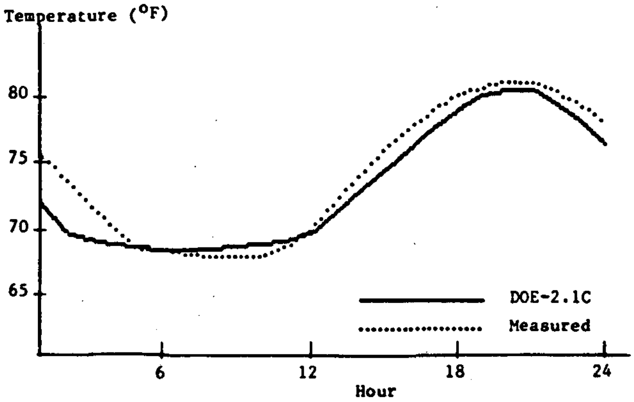

Figure 2c

Summer — Floating, May 31, 1982, 63.7°F average OA temperature.

Figure 3

SWTMS CELL 7 — Frame Insulated

Measured versus DOE-2.1C space temperatures

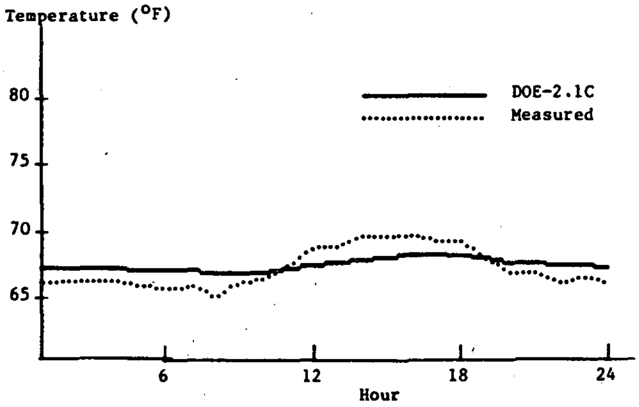

Figure 3a

Heating always on — January 14, 1982, 19.9°F average OA temperature.

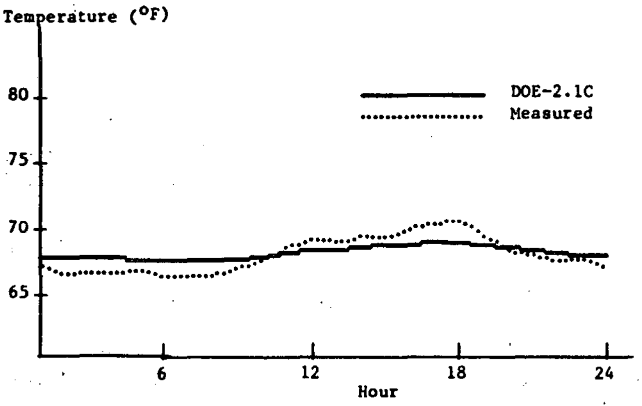

Figure 3b

Intermediate — Modulating heat, February 28, 1982, 38.6°F average OA temperature.

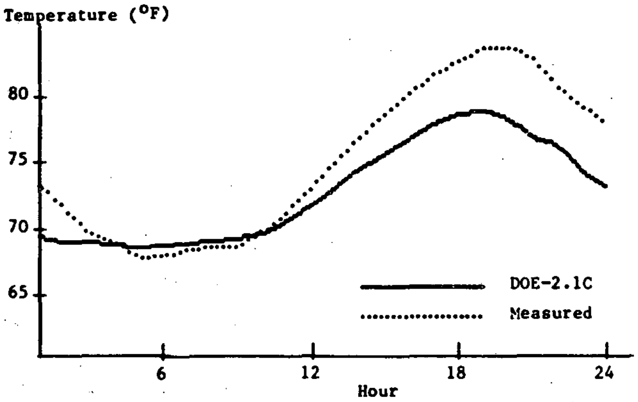

Figure 3c

Summer — Floating, May 31, 1982, 63.7°F average OA temperature.

NBS Cell Comparisons

Description of Modeling Variants

DOE-2.1C inputs were prepared for three different constructions:

- o Insulated Frame — Cell 1,
- o Bare Logs — Cell 5,
- o Insulated Masonry (CMU) — Cell 6.

The DOE-2 inputs followed as closely as possible the inputs prepared for the BLAST runs for these same test cells. However, there were four major variants; some were necessary due to program differences and some were basic differences in modeling techniques. The variants were as follows:

- o modeling edge losses by inputting foundation walls;
- o differing values for ground temperatures;
- o input method for glazing;
- o adjustment of space temperature setpoints.

Modeling edge losses is something that neither DOE-2 nor BLAST are designed to do. Yet, on the first trial runs, it became apparent that the closure of measured versus simulated results was off by a systematic error for all three cells and that an adjustment was necessary. The PSG using BLAST chose to increase wall areas of Cells 1 and 5 by 10%, and Cell 6 by 23% to accommodate edge losses at the corners and at the ceiling. They also increased the base infiltration to account for the foundation wall losses. This adjustment increased the heat losses in winter, but also increased the heat gains in summer which appeared detrimental to the closure. For this reason, we chose to input a 2-ft deep foundation wall instead of increasing the wall areas. From the construction drawings, it appears that 6" to 8" of the foundation walls are above the ground level and, therefore, exposed to ambient air temperatures. This would make the heat losses of these walls actually greater than those predicted by ground temperatures alone, measured in the center of the cells at a depth of 21". It would also make the foundation walls neutral in spring or even a possible source of heat gains in summer due to direct solar radiation. For these reasons, we used the DOE-2 default ground temperatures consistent with recorded temperatures for Washington D.C, and for the summer runs we removed the input for foundation walls.

The DOE-2 method of inputting the glazing also differed from the BLAST input. BLAST used a three-layered construction of two different transmittances; one for the top half of the windows which had a screen attached and a second without screen, for the bottom half. For the DOE-2 inputs, we used a standard three-pane glass using GLASS-TYPE-CODE=3, PANES=3, and a GLASS-CONDUCTANCE=.396 (.36 minus outside air film). The NBS specified overall window solar transmittance of .61 matched perfectly the input of GLASS-TYPE-CODE=3.

For thermostat control setpoints, the BLAST inputs were set to approximately 67°F for heating and 76°F for cooling (matching the observed data). The DOE-2 inputs maintained a 68°F setpoint for heating and a 76°F setpoint for cooling. Our plots for the intermediate season do show a problem created in the simulation due to a misinterpretation of the operation of the heating equipment. The description in the NBS report claimed the heating was "off" during daytime hours, and we took this literally and scheduled the equipment off. This causes the slight dip in space temperatures at 8:00 AM on Figs. 4, 5, and 6.

Conclusions for NBS Cells

Modeling of these three test cells to close within ±20% required a great deal of effort. The first trial runs looked hopelessly disparate, but after much tweaking of inputs we finally brought the results into fair agreement. The most immediate question was why there was such a disparity between the New Mexico SWTMS cells and these NBS cells? What could cause the simulated energy use of the SWTMS cells to be consistently higher than measured, when the simulated energy use of the NBS cells was lower than measured? We have prepared a list of possible causes:

- Thermostat droop in SWTMS cells which lowers energy use. (However, there was almost no evidence of droop in the NBS data.)
- Ground moisture in contact with foundation wall and floor slabs in NBS cells.
- Possible air leakage between the ceiling board and insulation laid on top of ceiling joists in NBS cells.
- The better conductive path of heat flowing from the space into a masonry wall and then into the masonry foundation. This is especially true of NBS Cell 6 and could explain the greater difference of this cell versus the other NBS cells where the exterior walls rest on wood soleplates anchored to the foundation but with a small air gap between.
- Sparse insulation under the windows of NBS Cell 6. We did model this in our runs.

The real cause for the disparity probably lies in a combination of many factors. We used the original collected data of electrical watt-hour meter counts for points 81, 85, and 86 to determine total electrical usage. There seem to be some anomalies in this data in that there are zero counts for periods when the lights at 290w are claimed to have been on. There are other instances when light bulbs must have been burned out or turned off. One must be aware of the significance of 290 watts (1000 Btu/hr) of lighting heat gain, as there were many hours when the energy for heating (and cooling) was of the same magnitude as the lights alone. During the summer cooling season, there were many days when no electric was reported. There were also many night hours where electric meter counts were recorded at levels greater than the lights alone, and yet no sensible cooling was reported. In tabulating the totals of DOE-2 sensible cooling, we restricted the summation of sensible cooling in DOE-2 to the same hours where sensible cooling was reported as data.

Table 3 shows three daily comparisons for three different periods. We did not have raw data for extended periods; however, the DOE-2 runs compare favorably with the NBS report titled "A Field Study of the Effect of Wall Mass on the Heating and Cooling Loads of Residential Buildings"[7].

Figures 4, 5, and 6 show how the DOE-2 simulated space temperatures track the measured space temperature of a single sensor for one day of each period.

TABLE 3

NBS — Energy Use Comparisons

Daily Energy Use

	OA TEMP AVG (^{O}F)	FRAME — Cell 1			LOGS — Cell 5			CMU — Cell 6		
HEATING		MEAS KWH	DOE-2 KWH	Δ%	MEAS KWH	DOE-2 KWH	Δ%	MEAS KWH	DOE-2 KWH	Δ%
Feb 23	42	11.1	9.5	-14%	11.1	10.8	-03%	13.9	10.6	-24%
Feb 24	40	9.4	10.5	+11%	9.5	10.5	+10%	12.7	9.8	-23%
Mar 04	35	17.9	18.8	+05%	18.3	19.7	+08%	20.2	17.9	-12%
			Avg.	+01%		Avg.	+05%		Avg.	-20%
FLOATING										
Apr 19	56	4.6	3.9	-15%	1.5	2.5	NS	.5	1.9	NS
Apr 20	58	3.4	3.5	+02%	.9	2.8	NS	.1	2.3	NS
Apr 22	48	8.3	5.9	-28%	4.5	5.0	+11%	2.9	4.4	NS
			Avg.	-14%		Avg.	+11%		Avg.	NS
COOLING*										
Aug 01	72	8.3	8.3	0%	5.8	6.5	+12%	5.4	6.5	+20%
Aug 02	71	7.7	7.7	0%	5.1	5.9	+15%	5.3	5.8	+07%
Aug 03	72	6.7	6.7	0%	4.8	4.9	+02%	3.8	5.1	+34%
			Avg.	0%		Avg.	+10%		Avg.	+20%

$$\Delta\% = \left[\frac{\text{DOE-2.1C}}{\text{Measured}} - 1\right] *100$$

NS = Not Significant as the numbers become too small to compare on a percentage basis.

* Cooling Sensible Loads Btu converted to Kwh.

Figure 4

NBS CELL 1 — Frame with Foundation Wall

Measured versus DOE-2.1C Space Temperatures

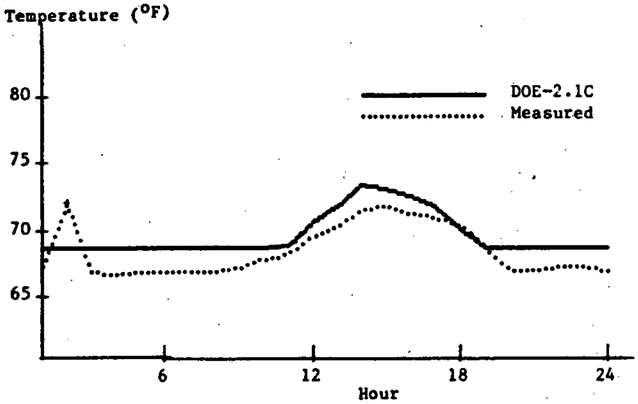

Figure 4a

Heating always on — February 23, 1982, 42.3°F average OA temperature.

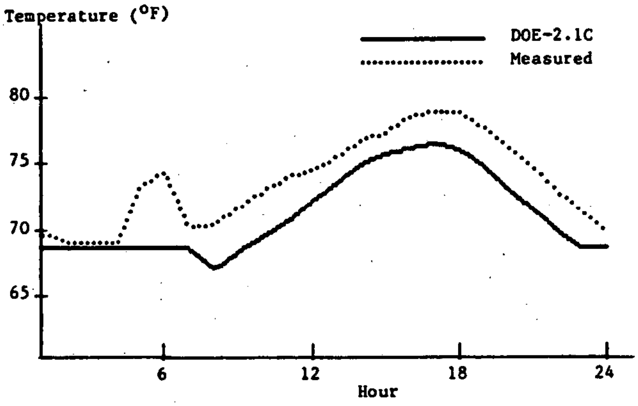

Figure 4b

Floating — April 19, 1982, 56.2°F average OA temperature.

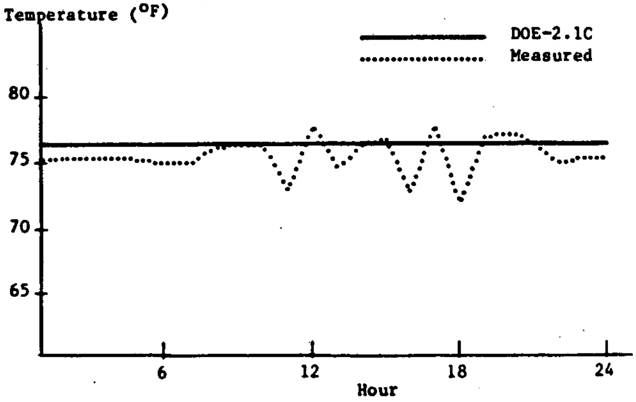

Figure 4c

Cooling always on — August 1, 1982, 72.0°F average OA temperature.

Figure 5

NBS CELL 5 — Logs with Foundation Wall

Measured versus DOE-2.1C Space Temperatures

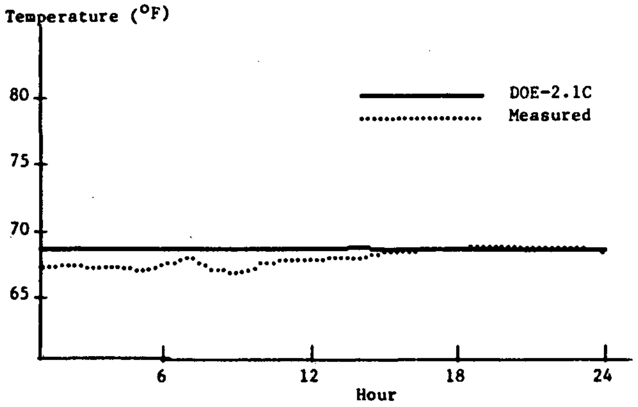

Figure 5a

Heating always on — February 23, 1982, 42.3°F average OA temperature.

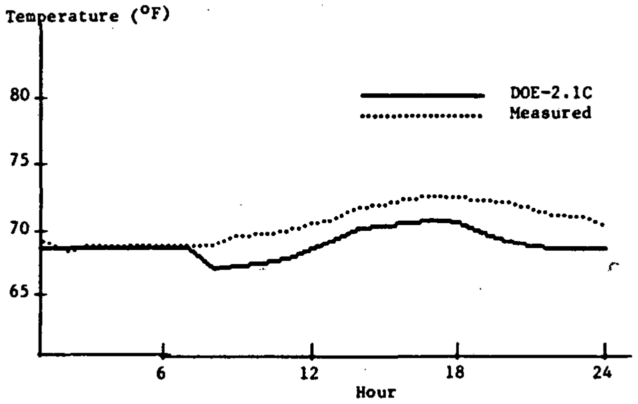

Figure 5b

Floating — April 19, 1982, 56.2°F average OA temperature.

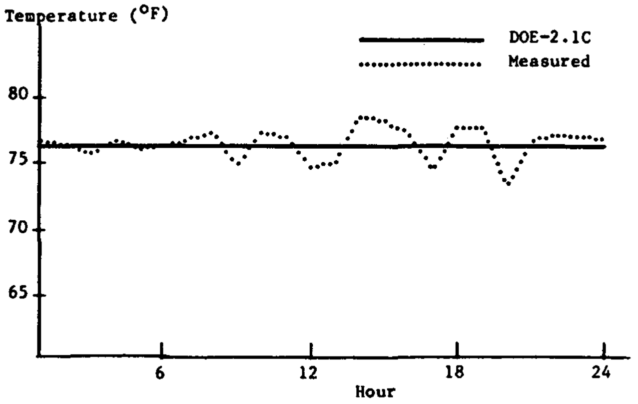

Figure 5c

Cooling always on — August 1, 1982, 72.0°F average OA temperature.

Figure 6

NBS CELL 6 — CMU with Foundation Wall

Measured versus DOE-2.1C Space Temperatures

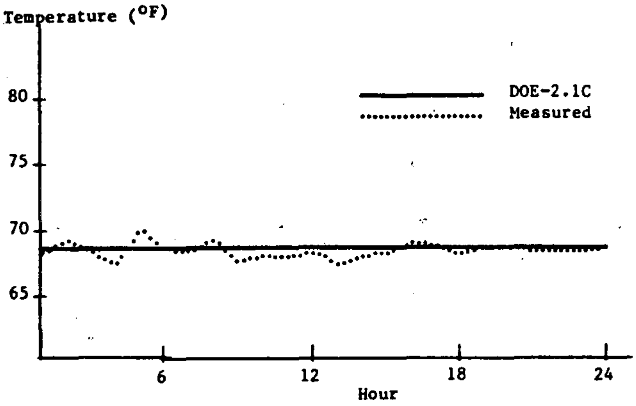

Figure 6a

Heating always on — February 23, 1982, 42.3°F average OA temperature.

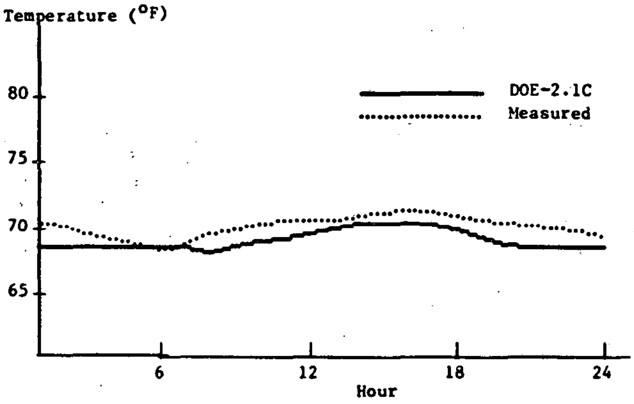

Figure 6b

Floating — April 19, 1982, 56.2°F average OA temperature.

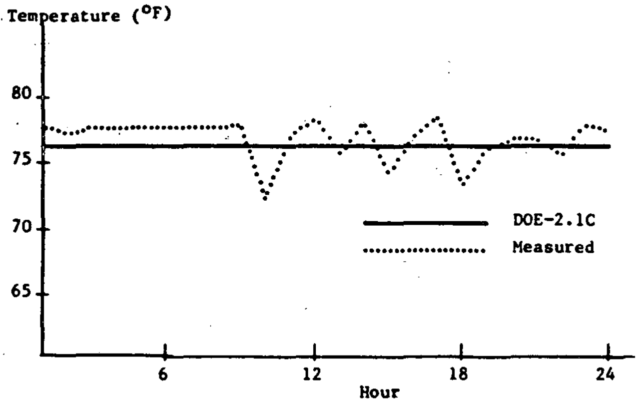

Figure 6c

Cooling always on — August 1, 1982, 72.0°F average OA temperature.

Parametric Study to Characterize Thermal Mass

Description of Modeling Variants

DOE-2.1C parametric run inputs were prepared for a prototypical residence varying wall materials and location of insulation, i.e. whether inside or outside of the wall itself. We followed as closely as possible the inputs found on the BLAST runs for this same structure. The parameter of wall thickness was limited to less than 11" because DOE-2 periodically failed to calculate response factors for walls of greater thicknesses with densities of 150 lb/cuft and conductances of .07 Btu/HR/^{O}F-FT). The possibility of such wall constructions occurring in the real world are of little concern. We also added a metal siding with zero resistance and building paper with a resistance equal to .06. The DOE-2 program seems to handle a multi-layered wall of extreme densities better than a single layer when it tries to calculate response factors. Two sets of parametrics were run for locations of Phoenix and Minneapolis (in lieu of six sets as was done by PSG).

There were some major differences in the two programs which appear to produce systematic differences in the results (see Tables 4 and 5). The first is the calculation of reradiation of wall and roof surfaces to the sky. BLAST accepts a special weather tape which allows the program to calculate reradiation in a more realistic way, accounting for moisture in the atmosphere. Conversely, DOE-2 calculates a correction for reradiation from roof surfaces using a linear relationship of 20 Btu/hr with 0 cloud cover and 0 Btu/hr at a cloud cover of 10. For vertical wall surfaces, a constant loss of 7 Btu/hr is assumed.

The BLAST program also calculates the sensible cooling and heating rates within its thermal balance loads subroutines. In DOE-2 the sensible cooling and heating loads are calculated at a fixed temperature in the LOADS program using custom weighting factors, but the actual coil sensible loads are then calculated in SYSTEMS allowing for a "real" air temperature correction due to thermostat throttling range and night setback temperatures.

The natural ventilation routines which simulate outside air cooling by opening windows is suspected to be a likely cause of systematic differences between the two programs. We were not able to pin down the specifics of how natural ventilation is calculated in BLAST. The routines used in DOE-2 are described in the <u>DOE-2 Engineers Manual,</u> page IV.128-129.

Another possible cause of systematic differences between the two programs was the PSG split of the residence into three individually controlled thermal zones. The DOE-2 input maintained the split of the residence into three zones using the living space as the primary control zone. This should provide a more realistic simulation than the PSG method, but at the same time it introduces a modeling difference, and thus a discrepancy, in the results. As a check we tried an input of a single zone residence, but this had the detrimental effect of masking the non-coincident solar gains apparent in the three zone model. This also made the closure with BLAST runs more disparate.

The PSG made a number of sensitivity runs to check the effects of infiltration values and of natural ventilation (opening windows to decrease cooling loads). We also made a series of runs to see if DOE-2 produced similar results. It appeared that the infiltration levels input into the BLAST runs were excessively high in comparison to the value of 0.6 air change per hour used in another LBL study[11]. The nominal values used in the DOE-2 inputs, thus conforming to the BLAST inputs, were 1.0 air change for summer (based on 98°F outside temperature and 7.5mph wind speed) and 1.88 air changes for winter (based on 0°F outside temperature and 15mph windspeed). The infiltration runs indicated that although this one component certainly dominated the heating load (81% of total heating in Phoenix, 72% in Minneapolis), the effect of changing wall construction was not masked and stayed relatively constant independent of infiltration levels.

The check of removing natural ventilation in the simulation again produced similar results to the BLAST runs. The heating was unaffected, but the cooling increased by 1.0 Mbtu in Phoenix and 3.0 Mbtu in Minneapolis with natural ventilation removed. Even though there is a questionable correspondence between the DOE-2 and BLAST natural ventilation algorithms, any errors introduced should be of minor significance.

DOE-2 Results

As a means of reducing the hundreds of runs to manageable terms for this report, we tabulated the results in Table 4 (Cooling) and Table 5 (Heating) for three imaginary wall types, labelling them as follows:

Wood – 30 lb/ft^3 Density with .07 units Conductivity
Concrete – 90 lb/ft^3 Density with .5 units Conductivity, and
Stone – 150 lb/ft^3 Density with 1.0 units Conductivity.

The full set of results is tabulated in Appendix A.

We are satisfied that a person using DOE-2 would draw the same conclusions regarding thermal mass effects as he would using BLAST. In Minneapolis with R-5 insulation on the outside the increased mass reduces the cooling by approximately 26% but increases the heating by 10%. In Phoenix, with R-5 insulation on the outside, the increased mass reduces both the cooling (by 2%) and the heating (by 6%). Moving the insulation from outside to inside the wall surface for an R-5 insulated wall increases the cooling by 6% in Minneapolis, but only 3% in Phoenix. The heating in both climates changes very little with a change in location of insulation. Insulating to an R-20 level completely masks the effects of mass when the insulation is on the inside. On the other hand, with R-20 on the outside of the wall, the mass effects are more pronounced than with an R-5 insulated wall (i.e., a 6% and 7% reduction in cooling and heating in Phoenix, and a 21% and 5% reduction in cooling and heating in Minneapolis).

TABLE 4

DOE-2.1C Results for Cooling — Millions Btu/Year

Location	Wall Description			Insulation — Resistance and Location				
	Material Density	Thickness Inches	Conductance Btu/Hr/^{O}F-Ft	R-0 None	R-5 Outside--Inside		R-20 Outside--Inside	
Minneapolis	Wood 30 lb/cuft	3.6"	.07	7.5(-3.9)	6.9(-3.0)	7.3(-2.9)	6.8(-2.4)	7.3(-2.7)
	Concrete 90 lb/cuft	7.2"	0.5	6.1(-4.3)	5.6(-2.5)	6.8(-2.8)	5.7(-2.0)	7.2(-2.7)
	Stone 150 lb/cuft	10.8"	1.0	5.2(-4.1)	5.1(-2.3)	6.7(-2.7)	5.4(-1.7)	7.1(-2.7)
Phoenix	Wood 30 lb/cuft	3.6"	.07	43.9(-5.0)	37.8(-5.3)	38.8(-4.1)	34.9(-5.0)	35.9(-4.9)
	Concrete 90 lb/cuft	7.2"	0.5	50.6(-6.0)	37.3(-5.2)	39.4(-4.1)	33.5(-4.8)	35.7(-5.2)
	Stone 150 lb/cuft	10.8"	1.0	51.6(-6.7)	37.1(-5.1)	39.5(-4.2)	33.2(-4.6)	36.0(-4.9)

Numbers in parenthesis show actual numeric differences of DOE-2 values (±) to BLAST results.

TABLE 5

DOE-2.1C Results for Heating — Millions Btu/Year

Location	Wall Description			Insulation — Resistance and Location				
	Material Density	Thickness Inches	Conductance Btu/Hr/°F-Ft	R-0 None	R-5 Outside	R-5 Inside	R-20 Outside	R-20 Inside
Minneapolis	Wood 30 lb/cuft	3.6"	.07	89.1(-1.1)	73.3(-2.3)	73.2(-3.7)	67.3(-2.9)	63.2(-4.0)
	Concrete 90 lb/cuft	7.2"	0.5	129.4(+4.1)	79.9(-.4)	79.8(-2.5)	64.0(-2.0)	64.0(-3.9)
	Stone 150 lb/cuft	10.8"	1.0	138.6(+5.2)	80.6(-0)	80.4(-2.5)	64.0(-1.7)	63.9(-4.0)
Phoenix	Wood 30 lb/cuft	3.6"	.07	9.2(-.8)	6.2(-.5)	6.4(-1.0)	4.7(-.5)	5.1(-1.0)
	Concrete 90 lb/cuft	7.2"	0.5	12.8(+1.5)	6.0(+.2)	6.4(-1.0)	4.0(-.4)	5.0(-1.0)
	Stone 150 lb/cuft	10.8"	1.0	13.0(+1.9)	5.8(+.3)	6.2(-1.1)	3.9(-.2)	4.9(-1.0)

Numbers in Parentheses show actual numeric differences of DOE-2 values (±) to BLAST results

References

1. DOE-2, a computer program for building energy analysis written by the Building Energy Simulation Group, Lawrence Berkeley Laboratory (LBL), and supported by the U. S. Department of Energy.

2 BLAST, the acronym for "Buildings Loads Analysis and System Thermodynamics", a computer program written by the Construction Engineering Research Laboratory (CERL), U. S. Department of the Army, Champaign, Illinois.

3. *Simulation of SWTMS Test Cells Using the DOE-2.1A Model*. McLain, Christian, Chi, Bledsoe. Oak Ridge National Laboratory.

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5. *Thermal Mass: A Comprehensive Residential Analysis*, Carroll, Mertol, Sullivan. Lawrence Berkeley Laboratory Report No. LBL-18020

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7. *A Field Study of Effect of Wall Mass on Heating and Cooling Loads of Residential Buildings*. Burch, Remmert, Krintz, Barnes. National Bureau of Standards.

8. *How Accurate is a Computer Simulation of the Thermal Performance of a Building?* Francisco Arumi-Noe, Consultant to Oak Ridge National Laboratory.

9. *Validation Project of the Performance Evaluation Program*. Sorrell, North Carolina State University.

10. *Dynamic Thermal Performance of an Experimental Masonry Building*, Peary, Powell, Burch, National Bureau of Standards, BSS-45, 1973.

11. *Thermal Mass in Exterior Walls of Residential Buildings*, Byrne, Ritschard, Foley, Hsui, Lawrence Berkeley Laboratory, LBL-19041.

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APPENDIX A

Original Data Sheets for Parametric Runs of Prototypical Residences

APPENDIX A

Original Data Sheets for Parametric Runs of Prototypical Residences

TABLE A.1

	BLAST RESULTS								DOE-2.1C RESULTS	
City	Heat	Cool	TK	Cond	DENS	SPHT	RINS	Outside RINO	Heat	Cool
Phoenix	10.0	48.9	.3	.07	30	.3	-	0	9.2	43.9
	6.3	42.4	.6	.07	30	.3	-	0	5.9	37.2
	5.6	41.0	.9	.07	30	.3	-	0	5.0	36.0
	21.8	73.4	.3	.5	30	.3	-	0	20.1	65.5
	15.7	61.9	.6	.5	30	.3	-	0	15.6	55.7
	11.6	54.5	.9	.5	30	.3	-	0	12.1	48.6
	25.1	80.5	.7	1.0	30	.3	-	0	23.1	70.9
	20.0	70.9	.6	1.0	30	.3	-	0	19.6	63.6
	15.8	63.5	.9	1.0	30	.3	-	0	16.4	57.3
	7.4	45.7	.3	.07	90	.3	-	0	7.6	40.8
	5.7	41.9	.6	.07	90	.3	-	0	5.4	36.8
	5.2	40.6	.9	.07	90	.3	-	0	4.8	35.6
	18.2	68.6	.3	.5	90	.3	-	0	18.8	61.7
	11.3	56.6	.6	.5	90	.3	-	0	12.8	50.6
	8.9	51.5	.9	.5	90	.3	-	0	10.2	45.8
	21.5	75.7	.3	1.0	90	.3	-	0	21.8	67.7
	14.8	64.6	.6	1.0	90	.3	-	0	16.6	57.9
	11.7	58.7	.9	1.0	90	.3	-	0	13.6	52.2
	6.8	44.9	.3	.07	150	.3	-	0	7.1	40.1
	5.5	41.7	.6	.07	150	.3	-	0	5.3	36.6
	5.0	40.2	.9	.07	150	.3	-	0	4.7	35.2
	15.6	65.6	.3	.5	150	.3	-	0	17.2	58.7
	10.3	55.4	.6	.5	150	.3	-	0	12.0	49.4
	8.7	51.5	.9	.5	150	.3	-	0	9.9	45.8
	18.7	72.4	.3	1.0	150	.3	-	0	20.3	65.1
	13.2	62.7	.6	1.0	150	.3	-	0	15.3	55.9
	11.1	58.0	.9	1.0	150	.3	-	0	13.0	51.6

TABLE A.2

	BLAST RESULTS								DOE-2.1C RESULTS	
City	Heat	Cool	TK	Cond	DENS	SPHT	RINS	Outside RINO	Heat	Cool
Phoenix	6.7	43.1	.3	.07	30	.3	-	5	6.2	37.8
	5.5	41.0	.6	.07	30	.3	-	5	5.0	35.9
	5.3	40.4	.9	.07	30	.3	-	5	4.7	35.3
	8.3	46.4	.3	.5	30	.3	-	5	8.0	41.4
	6.6	43.9	.6	.5	30	.3	-	5	6.8	38.9
	6.0	42.8	.9	.5	30	.3	-	5	6.1	37.8
	8.4	46.8	.3	1.0	30	.3	-	5	8.3	41.4
	6.9	44.5	.6	1.0	30	.3	-	5	7.2	39.4
	6.3	43.5	.9	1.0	30	.3	-	5	6.5	38.3
	5.6	41.7	.3	.07	90	.3	-	5	5.4	36.5
	5.2	40.5	.6	.07	90	.3	-	5	4.7	35.5
	4.9	39.8	.9	.07	90	.3	-	5	4.5	34.4
	6.4	43.7	.3	.5	90	.3	-	5	6.7	38.8
	5.8	42.5	.6	.5	90	.3	-	5	6.0	37.3
	5.6	42.0	.9	.5	90	.3	-	5	5.6	37.2
	6.5	44.0	.3	1.0	90	.3	-	5	6.9	39.0
	5.9	42.9	.6	1.0	90	.3	-	5	6.2	38.0
	5.7	42.4	.9	1.0	90	.3	-	5	5.9	37.6
	5.4	41.4	.3	.07	150	.3	-	5	5.2	36.6
	5.0	40.2	.6	.07	150	.3	-	5	4.7	35.1
	4.7	39.4	.9	.07	150	.3	-	5	*	*
	6.0	43.1	.3	.5	150	.3	-	5	6.3	38.0
	5.6	42.2	.6	.5	150	.3	-	5	5.8	37.1
	5.4	41.7	.9	.5	150	.3	-	5	5.5	36.7
	6.1	43.3	.3	1.0	150	.3	-	5	6.5	38.5
	5.7	42.6	.6	1.0	150	.3	-	5	6.0	37.4
	5.5	42.2	.9	1.0	150	.3	-	5	5.8	37.1

* Fails to calculate response factors

TABLE A.3

	BLAST RESULTS								DOE-2.1C RESULTS	
City	Heat	Cool	TK	Cond	DENS	SPHT	RINS	Outside RINO	Heat	Cool
Phoenix	7.4	42.9	.3	.07	30	.3	5	-	6.4	38.8
	6.2	41.1	.6	.07	30	.3	5	-	5.1	36.2
	5.9	40.6	.9	.07	30	.3	5	-	4.8	35.6
	9.7	46.4	.3	.5	30	.3	5	-	8.3	42.8
	8.3	44.6	.6	.5	30	.3	5	-	7.4	40.8
	7.5	43.4	.9	.5	30	.3	5	-	6.6	39.2
	10.0	46.9	.3	1.0	30	.3	5	-	8.5	43.2
	8.9	45.6	.6	1.0	30	.3	5	-	8.0	42.0
	8.1	44.5	.9	1.0	30	.3	5	-	7.3	40.8
	6.6	42.0	.3	.07	90	.3	5	-	5.6	37.5
	6.1	41.2	.6	.07	90	.3	5	-	5.0	36.4
	5.8	40.6	.9	.07	90	.3	5	-	4.7	35.4
	8.4	45.0	.3	.5	90	.3	5	-	7.6	41.0
	7.4	43.5	.6	.5	90	.3	5	-	6.4	39.4
	7.0	43.1	.9	.5	90	.3	5	-	6.0	38.9
	8.8	45.6	.3	1.0	90	.3	5	-	8.0	42.2
	7.8	44.3	.6	1.0	90	.3	5	-	7.0	40.4
	7.4	43.7	.9	1.0	90	.3	5	-	6.4	39.6
	6.6	42.0	.3	.07	150	.3	5	-	5.5	37.4
	6.1	41.2	.6	.07	150	.3	5	-	4.9	36.4
	5.6	40.6	.9	.07	150	.3	5	-	*	*
	7.9	44.4	.3	1.0	150	.3	5	-	7.1	40.6
	7.2	43.5	.6	1.0	150	.3	5	-	6.2	39.3
	7.0	43.1	.9	1.0	150	.3	5	-	5.9	38.9
	8.2	45.0	.3	1.0	150	.3	5	-	7.5	41.1
	7.5	44.0	.6	1.0	150	.3	5	-	6.6	40.0
	7.3	43.7	.9	1.0	150	.3	5	-	6.2	39.5

* Fails to calculate response factors

TABLE A.4

	BLAST RESULTS								DOE-2.1C RESULTS	
City	Heat	Cool	TK	Cond	DENS	SPHT	RINS	Outside RINO	Heat	Cool
Phoenix	5.2	39.9	.3	.07	30	.3	-	20	4.7	34.9
	5.0	39.5	.6	.07	30	.3	-	20	4.4	34.3
	4.9	39.4	.9	.07	30	.3	-	20	4.3	34.2
	5.4	40.0	.3	.5	30	.3	-	20	5.2	35.1
	4.8	39.0	.6	.5	30	.3	-	20	4.5	34.1
	4.7	38.8	.9	.5	30	.3	-	20	4.3	34.0
	5.5	40.0	.3	1.0	30	.3	-	20	5.2	35.2
	4.8	38.9	.6	1.0	30	.3	-	20	4.6	34.1
	4.6	38.6	.9	1.0	30	.3	-	20	4.3	34.1
	4.8	39.1	.3	.07	90	.3	-	20	4.3	34.1
	4.7	38.9	.6	.07	90	.3	-	20	4.1	33.9
	4.6	38.7	.9	.07	90	.3	-	20	4.2	33.8
	4.5	38.5	.3	.5	90	.3	-	20	4.3	33.7
	4.4	38.3	.6	.5	90	.3	-	20	4.0	33.5
	4.4	38.2	.9	.5	90	.3	-	20	4.0	33.5
	4.5	38.3	.3	.5	90	.3	-	20	4.4	33.6
	4.3	38.0	.6	.5	90	.3	-	20	4.0	33.4
	4.3	38.0	.9	.5	90	.3	-	20	4.0	33.4
	4.7	38.8	.3	.07	150	.3	-	20	4.2	37.9
	4.5	38.6	.6	.07	150	.3	-	20	4.1	33.7
	4.3	38.3	.9	.07	150	.3	-	20	*	*
	4.4	38.1	.3	.5	150	.3	-	20	4.1	33.4
	4.3	38.1	.6	.5	150	.3	-	20	4.0	33.4
	4.2	38.0	.9	.5	150	.3	-	20	3.9	33.3
	4.3	38.0	.3	1.0	150	.3	-	20	4.1	33.3
	4.2	37.9	.6	1.0	150	.3	-	20	3.9	33.2
	4.1	37.8	.9	1.0	150	.3	-	20	3.9	33.2

* Fails to calculate response factors

TABLE A.5

	BLAST RESULTS								DOE-2.1C RESULTS	
City	Heat	Cool	TK	Cond	DENS	SPHT	RINS	Outside RINO	Heat	Cool
Phoenix	6.1	40.8	.3	.07	30	.3	20	-	5.1	35.9
	5.8	40.4	.6	.07	30	.3	20	-	4.7	35.2
	5.7	40.3	.9	.07	30	.3	20	-	4.6	35.1
	6.6	41.6	.3	.5	30	.3	20	-	5.5	36.6
	6.2	41.1	.6	.5	30	.3	20	-	5.2	35.9
	6.0	40.9	.9	.5	30	.3	20	-	5.0	35.7
	6.6	41.7	.3	1.0	30	.3	20	-	5.6	36.7
	6.3	41.3	.6	1.0	30	.3	20	-	5.4	36.4
	6.2	41.1	.9	1.0	30	.3	20	-	5.2	36.2
	5.9	40.6	.3	.07	90	.3	20	-	4.8	35.7
	5.8	40.5	.6	.07	90	.3	20	-	4.7	35.3
	5.6	40.4	.9	.07	90	.3	20	-	4.6	35.0
	6.2	41.2	.3	.5	90	.3	20	-	5.2	36.0
	6.0	40.9	.6	.5	90	.3	20	-	5.0	35.7
	5.9	40.8	.9	.5	90	.3	20	-	4.9	35.9
	6.3	41.3	.3	1.0	90	.3	20	-	5.3	36.4
	6.1	41.0	.6	1.0	90	.3	20	-	5.1	36.1
	6.0	40.9	.9	1.0	30	.3	20	-	4.9	35.7
	5.9	40.7	.3	.07	150	.3	20	-	4.9	36.1
	5.7	40.5	.6	.07	150	.3	20	-	4.7	35.2
	5.6	40.3	.9	.07	150	.3	20	-	*	*
	6.1	41.1	.3	.5	150	.3	20	-	5.1	36.2
	6.0	40.9	.6	.5	150	.3	20	-	4.9	35.7
	5.9	40.9	.9	.5	150	.3	20	-	4.8	36.0
	6.2	41.1	.3	1.0	150	.3	20	-	5.2	36.3
	6.0	41.0	.6	1.0	150	.3	20	-	5.0	35.8
	5.9	40.9	.9	1.0	150	.3	20	-	4.9	36.0

* Fails to calculate response factors

TABLE A.6

	BLAST RESULTS								DOE-2.1C RESULTS	
City	Heat	Cool	TK	Cond	DENS	SPHT	RINS	Outside RINO	Heat	Cool
M'polis	90.2	11.4	.3	.07	30	.3	R-0	-	89.1	7.5
	76.4	9.3	.6	.07	30	.3	R-0	-	74.3	6.6
	71.2	9.1	.9	.07	30	.3	R-0	-	68.6	6.5
	150.7	16.8	.3	.5	30	.3	R-0	-	154.2	9.3
	127.5	13.7	.6	.5	30	.3	R-0	-	130.4	8.0
	113.1	11.3	.9	.5	30	.3	R-0	-	115.5	6.9
	168.6	18.3	.3	1.0	30	.3	R-0	-	172.3	9.8
	149.9	15.7	.6	1.0	30	.3	R-0	-	154.1	8.7
	136.3	13.4	.9	1.0	30	.3	R-0	-	140.4	7.8
	88.8	9.4	.3	.07	90	.3	R-0	-	88.6	6.3
	75.5	8.7	.6	.07	90	.3	R-0	-	73.9	6.1
	70.4	8.6	.9	.07	90	.3	R-0	-	68.2	6.2
	149.1	14.6	.3	.5	90	.3	R-0	-	153.8	8.2
	125.3	10.4	.6	.5	90	.3	R-0	-	129.4	6.1
	111.5	9.0	.9	.5	90	.3	R-0	-	114.5	5.4
	166.9	16.2	.3	1.0	90	.3	R-0	-	172.1	8.9
	147.4	12.1	.6	1.0	90	.3	R-0	-	153.1	6.9
	134.1	10.1	.9	1.0	90	.3	R-0	-	139.2	5.8
	88.2	8.8	.3	.07	150	.3	R-0	-	88.2	5.8
	75.1	8.5	.6	.07	150	.3	R-0	-	73.6	6.0
	69.9	8.3	.9	.07	150	.3	R-0	-	68.0	5.9
	147.8	12.8	.3	.5	150	.3	R-0	-	153.3	7.2
	124.5	9.4	.6	.5	150	.3	R-0	-	128.9	5.5
	111.0	8.6	.9	.5	150	.3	R-0	-	114.0	5.2
	165.6	14.3	.3	1.0	150	.3	R-0	-	171.6	8.0
	146.5	10.6	.6	1.0	150	.3	R-0	-	152.4	5.9
	133.4	9.3	.9	1.0	150	.3	R-0	-	138.6	5.2

TABLE A.7

BLAST RESULTS									DOE-2.1C RESULTS	
City	Heat	Cool	TK	Cond	DENS	SPHT	RINS	Outside RINO	Heat	Cool
M'polis	75.6	9.9	.3	.07	30	.3	-	R-5	73.3	6.9
	70.6	9.2	.6	.07	30	.3	-	R-5	68.1	6.6
	68.1	9.1	.9	.07	30	.3	-	R-5	65.3	6.6
	83.8	10.6	.3	.5	30	.3	-	R-5	82.8	7.0
	81.1	9.3	.6	.5	30	.3	-	R-5	80.4	6.3
	79.2	8.8	.9	.5	30	.3	-	R-5	78.4	6.0
	84.9	10.6	.3	1.0	30	.3	-	R-5	84.1	7.0
	83.1	9.4	.6	1.0	30	.3	-	R-5	82.6	6.3
	81.7	8.8	.9	1.0	30	.3	-	R-5	81.2	6.0
	74.6	8.8	.3	.07	90	.3	-	R-5	73.0	6.2
	69.9	8.6	.6	.07	90	.3	-	R-5	67.8	6.2
	67.3	8.5	.9	.07	90	.3	-	R-5	65.0	6.2
	82.7	8.8	.3	.5	90	.3	-	R-5	82.4	5.9
	80.3	8.1	.6	.5	90	.3	-	R-5	79.9	5.6
	78.5	7.9	.9	.5	90	.3	-	R-5	77.9	5.5
	83.9	8.8	.3	1.0	90	.3	-	R-5	83.7	6.0
	82.2	8.1	.6	1.0	90	.3	-	R-5	82.1	5.4
	81.0	7.8	.9	1.0	90	.3	-	R-5	80.8	5.3
	74.2	8.5	.3	.07	150	.3	-	R-5	72.8	6.0
	69.5	8.3	.6	.07	150	.3	-	R-5	67.6	5.9
	67.0	8.2	.9	.07	150	.3	-	R-5	*	*
	82.3	8.2	.3	.5	150	.3	-	R-5	82.2	5.6
	80.0	7.8	.6	.5	150	.3	-	R-5	79.7	5.4
	78.1	7.6	.9	.5	150	.3	-	R-5	77.7	5.3
	83.4	8.2	.3	1.0	150	.3	-	R-5	83.4	5.5
	81.9	7.7	.6	1.0	150	.3	-	R-5	81.9	5.2
	80.6	7.4	.9	1.0	150	.3	-	R-5	80.6	5.1

* Fails to calculate response factors

TABLE A.8

	BLAST RESULTS								DOE-2.1C RESULTS	
City	Heat	Cool	TK	Cond	DENS	SPHT	RINS	Outside RINO	Heat	Cool
M'polis	76.5	10.2	.3	.5	30	.3	R-5	-	73.2	7.3
	71.6	9.2	.6	.5	30	.3	R-5	-	68.0	7.0
	69.0	9.5	.9	.5	30	.3	R-5	-	65.2	6.9
	85.5	11.2	.3	.07	30	.3	R-5	-	82.6	7.9
	83.0	10.4	.6	.07	30	.3	R-5	-	80.3	7.4
	80.9	9.8	.9	.07	30	.3	R-5	-	78.2	7.0
	86.7	11.3	.3	1.0	30	.3	R-5	-	83.8	7.9
	85.1	10.7	.6	1.0	30	.3	R-5	-	82.5	7.6
	83.7	10.2	.9	1.0	30	.3	R-5	-	81.2	7.3
	76.0	9.5	.3	.07	90	.3	R-5	-	72.8	6.8
	71.3	9.4	.6	.07	90	.3	R-5	-	67.6	6.8
	68.7	9.4	.9	.07	90	.3	R-5	-	64.8	6.8
	84.8	10.4	.3	.5	90	.3	R-5	-	82.4	7.5
	82.3	9.6	.6	.5	90	.3	R-5	-	79.8	6.8
	80.4	9.4	.9	.5	90	.3	R-5	-	77.7	6.7
	86.0	10.6	.3	1.0	90	.3	R-5	-	83.6	7.6
	84.4	9.9	.6	1.0	90	.3	R-5	-	82.0	7.1
	83.1	9.6	.9	1.0	90	.3	R-5	-	80.7	6.8
	75.8	9.4	.3	.07	150	.3	R-5	-	72.6	6.7
	71.1	9.4	.6	.07	150	.3	R-5	-	67.5	6.8
	68.3	9.3	.9	.07	150	.3	R-5	-	*	*
	84.5	10.0	.3	.5	150	.3	R-5	-	82.1	7.1
	82.1	9.5	.6	.5	150	.3	R-5	-	79.6	6.7
	80.2	9.4	.9	.5	150	.3	R-5	-	77.5	6.7
	85.7	10.2	.3	1.0	150	.3	R-5	-	83.4	7.4
	84.1	9.6	.6	1.0	150	.3	R-5	-	81.8	6.8
	82.9	9.4	.9	1.0	150	.3	R-5	-	80.4	6.7

* Fails to calculate response factors

TABLE A.9

BLAST RESULTS									DOE-2.1C RESULTS	
City	Heat	Cool	TK	Cond	DENS	SPHT	RINS	Outside RINO	Heat	Cool
M'polis	66.2	9.2	.3	.07	30	.3	-	R-20	63.3	6.8
	65.1	9.1	.6	.07	30	.3	-	R-20	62.1	6.6
	64.3	9.0	.9	.07	30	.3	-	R-20	61.3	6.7
	67.2	9.1	.3	.5	30	.3	-	R-20	64.7	6.6
	66.4	8.3	.6	.5	30	.3	-	R-20	64.3	6.2
	66.1	8.3	.9	.5	30	.3	-	R-20	63.9	6.1
	67.3	9.1	.3	1.0	30	.3	-	R-20	64.9	6.6
	66.7	8.3	.6	1.0	30	.3	-	R-20	64.6	6.1
	66.4	8.0	.9	1.0	30	.3	-	R-20	64.3	6.0
	65.5	8.6	.3	.07	90	.3	-	R-20	63.1	6.3
	64.4	8.5	.6	.07	90	.3	-	R-20	62.0	6.3
	63.5	8.5	.9	.07	90	.3	-	R-20	61.2	6.2
	66.6	7.9	.3	.5	90	.3	-	R-20	64.4	5.9
	66.2	7.7	.6	.5	90	.3	-	R-20	64.0	5.7
	65.9	7.6	.9	.5	90	.3	-	R-20	63.7	5.7
	65.5	7.9	.3	1.0	90	.3	-	R-20	64.6	5.8
	65.5	7.5	.6	1.0	90	.3	-	R-20	64.2	5.6
	65.5	7.4	.9	1.0	90	.3	-	R-20	64.1	5.5
	65.3	8.3	.3	.07	150	.3	-	R-20	63.0	6.2
	64.2	8.2	.6	.07	150	.3	-	R-20	61.9	6.1
	63.1	8.2	.9	.07	150	.3	-	R-20	*	*
	66.3	7.6	.3	.5	150	.3	-	R-20	64.3	5.7
	65.8	7.4	.6	.5	150	.3	-	R-20	63.9	5.6
	65.5	7.3	.9	.5	150	.3	-	R-20	63.6	5.5
	66.4	7.5	.3	1.0	150	.3	-	R-20	64.4	5.6
	66.0	7.2	.6	1.0	150	.3	-	R-20	64.2	5.4
	65.7	7.1	.9	1.0	150	.3	-	R-20	64.0	5.4

* Fails to calculate response factors

TABLE A.10

BLAST RESULTS									DOE-2.1C RESULTS	
City	Heat	Cool	TK	Cond	DENS	SPHT	RINS	Outside RINO	Heat	Cool
M'polis	67.2	10.0	.3	.07	30	.3	20	-	63.2	7.3
	66.2	9.8	.6	.07	30	.3	20	-	62.0	7.2
	65.4	9.8	.9	.07	30	.3	20	-	61.2	7.3
	68.6	10.3	.3	.5	30	.3	20	-	64.5	7.6
	68.1	10.1	.6	.5	30	.3	20	-	64.2	7.4
	67.8	9.9	.9	.5	30	.3	20	-	63.8	7.2
	68.7	10.4	.3	1.0	30	.3	20	-	64.6	7.6
	68.4	10.2	.6	1.0	30	.3	20	-	64.4	7.6
	68.2	10.0	.9	1.0	30	.3	20	-	64.2	7.4
	67.1	9.8	.3	.07	90	.3	20	-	63.0	7.2
	66.0	9.8	.6	.07	90	.3	20	-	61.9	7.2
	65.2	9.8	.9	.07	90	.3	20	-	61.1	7.2
	68.3	10.1	.3	.5	90	.3	20	-	64.4	7.4
	67.9	9.9	.6	.5	90	.3	20	-	64.0	7.2
	67.4	9.8	.9	.5	90	.3	20	-	63.7	7.1
	68.5	10.1	.3	1.0	90	.3	20	-	64.5	7.6
	68.2	9.9	.6	1.0	90	.3	20	-	64.3	7.3
	68.0	9.8	.9	1.0	90	.3	20	-	64.0	7.2
	67.0	9.8	.3	.07	150	.3	20	-	64.0	7.2
	65.9	9.8	.6	.07	150	.3	20	-	61.8	7.2
	64.9	9.8	.9	.07	150	.3	20	-	*	*
	68.2	9.9	.3	.5	150	.3	20	-	64.3	7.3
	67.8	9.8	.6	.5	150	.3	20	-	63.9	7.2
	67.6	9.8	.9	.5	150	.3	20	-	63.6	7.2
	68.4	10.0	.3	1.0	150	.3	20	-	64.4	7.4
	68.1	9.9	.6	1.0	150	.3	20	-	64.2	7.2
	67.9	9.8	.9	1.0	150	.3	20	-	63.9	7.1

* Fails to calculate response factors

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